REPUBLIC OF TURKEY

YILDIZ TECHNICAL UNIVERSITY

GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

DESIGNING A MULTIMODAL PEDAGOGICAL MODEL IN GIFTED EDUCATION: IMPACTS ON REPRESENTATIONAL COMPETENCE OF TEACHERS OF GIFTED

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DOCTOR OF PHILOSOPHY THESIS

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Science Education Program

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July, 2021

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A thesis submitted by Muhammet Davut GÜL 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.

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Muhammet Davut GÜL

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Dedicated to my parents

and my wife

ACKNOWLEDGEMENTS

This dissertation would never have been completed without the support of many people, and I would like to take a moment to offer them my thanks and appreciation. First, I would like to thank my supervisor, Bayram Coştu, for providing valuable feedback and support throughout my graduate school career.

I would also like to thank my dissertation committee members, Emine Adadan and Hakan Akçay, for all of their incredibly helpful advice and feedback.

I‘d also like to thank my family, who was absolutely crucial in helping me to see my way through this process. To my wife, Merve: you are the most loving and supportive partner anyone could ask for. It is an indisputable fact that this dissertation couldn‘t have been completed without your support, encouragement, and patience.

I‘d like to thank especially my researchmate Zekai Ayık, this dissertation couldn‘t have been completed without your support, encouragement, and patience.

I present my great thanks to the participant teachers who agreed to participate in this research.

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

Muhammet Davut GÜL

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LIST OF ABBREVIATIONS

ARDE	Awareness-Recognize-Design-Evaluation
CF	Critical Framing
CHC	Cattle-Horn-Carroll
CIA	Contemporary Intellectual Assessment
CLT	Cognitive Load Theory
D	Domain
DCT	Dual Coding Theory
DeFT	Design-Function-Task
DMGT	Differentiated Model of Giftedness and Talent
DP	Design Principles
DPE	Designing Pedagogic Environment
E	Environmental
EDR	Educational Design Research
G	Giftedness
Ga	Auditory Processing
Gc	Crystalized Intelligence
Gf	Fluid Intelligence
Gh	Tactile Abilities
Gk	Kinesthetic Abilities
Gkn	Domain Specific Knowledge
Glr	Long Term Storage
Go	Olfactory Abilities
Gp	Psychomotor Abilities
Gps	Psychomotor Speed
Grw	Reading Writing Knowledge
Gs	Cognitive Process Speed
Gq	Quantitative Knowledge

Gt	Reaction Decision Speed
Gv	Visual Processing
I	Intrapersonal
IF-SO	Identify-Function-Sequence-Ongoing Task
LwR	Learning with Representations
MpM	Multimodal Pedagogical Model
PA	Peer Assessment
RC	Representational Competence
RCA	Representational Construction Affordances
SA	Student Assessment
SACs	Science and Art Centers
SC	Student Conception
SF-MDA	Systemic Functional Multimodal Discourse Analysis
SFL	Systemic Functional Linguistics
SFT	Systemic Functional Theory
SR	Student Representation
T	Talent
T1	Teacher 1
T2	Teacher 2
T3	Teacher 3
T4	Teacher 4
TA	Teacher Assessment
TC	Teacher Conception
TM	Teaching Metalanguage
ToG	Teacher of Gifted
TP	Transformed Practice
TR	Teacher Representation

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ABSTRACT

Designing a Multimodal Pedagogical Model in Gifted Education: Impacts on Representational Competence of Teachers of Gifted

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Doctor of Philosophy Thesis

Supervisor: Prof. Dr. Bayram COŞTU

The current study is an educational design research on the design, implementation and evaluation a differentiated pedagogy (called Multimodal Pedagogical Model) which is aimed at improving representational competence skills of teachers of gifted (ToG). It was aimed to describe design process of the model and developmental process of ToG during and after the intervention.

Participants were chosen by convenience sampling. The six teachers voluntarily accepted to participate. Two of them are male, four of them are female. Data were collected through multimodal representations designed by the teachers, the interpretations made by them to their representations, the discussions made on designs and model during classrooms, and the interviews realized with participants and experts. Data obtained from artefacts were analyzed according to the analytical frameworks improved by the researcher. Interviews and discussions were analyzed qualitatively through content analysis.

At the end of the micro cycle 1 and 2, findings showed that teachers gained abilities of identifying, but they were not qualified at selecting/designing and evaluating multimodal representations. At the end of the micro cycle 3 and 4, findings revealed that teachers were able to design different types of multimodal representations, but also they were able to identify different types of intermodal mechanisms, and for what purposes they designed. At the end of the micro cycle 5, results indicated that teachers were able to identify and analyze adequacy of multimodal representations, they were also able to criticize to what extent the representation reflects the intermodal relations pointed. Briefly, these parameters showed that teachers can be called as representational competent.

At the end of the educational design research, the MpM and its design principles revealed as a result of all these iterations in a solid structure/a desirable design. Findings revealed that applying the MpM and its principles improve representational competence skills of ToG.

Keywords: Gifted education, multimodality, teacher training, representational competence, educational design research

ÖZET

Özel Yetenekliler Eğitiminde Çokmodlu Pedagojik Model Tasarlama: Özel Yeteneklilerin Öğretmenlerinin Temsil Yetkinlikleri Üzerine Etkileri

Muhammet Davut GÜL

Matematik ve Fen Bilimleri Eğitimi Bölümü

Doktora Tezi

Danışman: Prof. Dr. Bayram COŞTU

Mevcut çalışma, özel yeteneklilerin öğretmenlerinin temsili yetkinlik becerilerini geliştirmeyi amaçlayan farklılaştırılmış bir pedagojinin (Multimodal Pedagojik Model olarak adlandırılan) tasarımı, uygulanması ve değerlendirilmesi üzerine bir eğitim tasarımı araştırmasıdır. Bu çalışmada, modelin tasarım süreci ve müdahale sırasında ve sonrasında özel yeteneklilerin öğretmenlerinin becerilerinin gelişim süreci detaylı bir şekilde betimlenerek ortaya konmaya çalışılmıştır.

Katılımcılar uygun örneklem yoluyla seçilmiştir. Altı öğretmen gönüllü olarak bu araştırmaya katılmayı kabul etmiştir. Bunlardan ikisi erkek, diğerleri kadındır. Veriler, her döngüde öğretmenler tarafından tasarlanan temsiller, temsillerine yaptıkları açıklama ve yorumlar, tasarım ve model üzerine yapılan tartışmalar, katılımcılar ve uzmanlarla gerçekleştirilen görüşmeler yoluyla toplanmıştır. Katılımcılar tarafından tasarlanan çokmodlu metinlerden elde edilen veriler, araştırmacı tarafından geliştirilmiş olan analitik çerçevelere göre analiz edilmiştir. Görüşmeler ve tartışmalar içerik analizi yoluyla nitel olarak analiz edilmiştir.

İlk yinelemenin sonunda, bulgular öğretmenlerin tanımlama becerileri kazandıklarını, ancak çokmodlu temsilleri tasarlama/seçme ve değerlendirme konusunda yeterli olmadıklarını göstermiştir. İkinci yinelemenin sonunda, bulgular öğretmenlerin yalnızca farklı türlerde çokmodlu temsiller tasarlama becerilerine sahip olmadıklarını, aynı zamanda tasarladıkları intermodal mekanizma türlerini ve hangi amaçlarla tasarladıklarını da belirlediklerini ortaya koymuştur. Üçüncü yinelemenin sonunda elde edilen sonuçlar, öğretmenlerin sadece çokmodlu temsillerin yeterliliğini tespit edip analiz etmekle kalmayıp, aynı zamanda temsilin işaret edilen intermodal ilişkileri ne ölçüde yansıttığını eleştirdiklerini göstermiştir. Ayrıca ne tür ilişkiler ve metin tutarlılığı nitelikleri kullanmaları gerektiği konusunda akranlarına tavsiyelerde bulunabildiklerini ortaya koymuştur. Kısaca bu parametreler öğretmenlerin temsili yetkin olarak adlandırılabileceğini göstermiştir.

Eğitim tasarımı araştırmasının sonunda, tüm bu mikro döngüler sonucunda MpM ve tasarım ilkelerinin son hali ortaya konmuştur. Bulgular, MpM ve ilkelerinin uygulanmasının öğretmenlerin temsili yetkinlik becerilerini geliştirdiğini göstermiştir.

Anahtar Kelimeler: Özel yetenekliler eğitimi, çokmodluluk, öğretmen eğitimi, temsili yetkinlik, eğitim tasarım araştırması

1
INTRODUCTION

1.1 Literature Review

1.1.1 Characteristics of Gifted

Gifted individuals differ from peers due to their high level cognitive improvement (Renzulli, 1978). They have abilities of encoding complex information fast in a comprehension process (Clark, 2008), recognizing and constructing causal and correlational relationships between concepts (Sayı & Demir, 2016), experiencing deep learning –self motivated to learn- and acting independently (Sayı & Yurtseven, 2021). They are committed to a task in high motivation by paying attention and internal control (Renzulli, 2003). They have exceptional memory, rich and extraordinary imagination, and extensive vocabulary (Miedijensky, 2018). Gifted students have a high curiosity and enjoy a high level and challenging learning process (Syafril, Yaumas, Ishak, Yusof, Jaafar, Yunus, & Sugiharta, 2020). They are active and creative in problem solving and able to transfer their learnings into new situations (Altintas & Ozdemir, 2012; Betts & Neihart, 2017; Vogelaar & Resing, 2018).

VanTassel-Baska (2011) claims that there are three basic characteristics of gifted learners. These are: (1) precocity, (2) intensity-refers to being able to focus on or concentrate on longlasting duties that fascinates them, (3) complexity-refers to being able to engage in higher order thinking, handle with complex ideas, and enjoy challenging activities.

Apart from these, their characteristics can be coded as followings: prominent in various fields of any subject, high self-perception and attitude, high self-concept, high self-esteem, and advanced moral judgment and sensitivity (Davis, Rimm, & Siegle, 2014; Demir, 2021; Renzulli, Siegle, Reis, Gavin, & Sytsma-Reed, 2009; Renzulli et al., 2013; Sak, 2010; Tortop, 2018).

Unlike his colleagues, Francoys Gagne (2004, 2010) differentiates giftedness and talent in identifying gifted individuals. Giftedness (G), on the one hand, refers to having untrained outstanding natural abilities in at least one ability domain such as in mental realms (intellectual, creative, social, and perceptual skills) and the physical realms (muscular and motor skills). On the other hand, talent (T) refers to transforming the natural abilities into the systematically developed competencies in any particular field of human activity. He states that giftedness is evolved to talent through developmental process (D) (like a structured program which leads to improvement in any skills of giftedness) facilitated by the action of two types of catalysts intrapersonal (I) (such as self-awareness, motivation, and volition) and environmental (E) (such as social and cultural factors, parent, peers, and talent development programs) (Gagne, 2015).

The present study adopts Gagne's perspective on defining giftedness and talent in designing a talent development model which called as a Multimodal Pedagogical Model (MpM).

1.1.2 Gifted Students' Learning Needs

Gifted children are sitting in their classrooms without their abilities being noticed and their needs met. Most of them get bored easily, and they are waiting for non-gifted peers to learn concepts that they learned one year earlier because of their precocity (Davis et al., 2014). They find the classroom environment intolerable so they do not want to attend classroom activities. They enjoy and look for challenging teaching materials and process, and problem solving during the teaching process (Phillips & Lindsay 2006; Sayi & Yurtseven, 2021; Subotnik, Olszewski-Kubilius, & Worrell 2011; Taber, 2007). Over repetition of basic ideas, over generalized explanations, inadequate details, and lack of challenges result in boredom which leads to decrease in motivation (Taber, 2014). Gagne (2010) also indicates that a learning environment which lacks of proper challenging activities and content bring about ennui in gifted students. Furthermore, he states that their intrinsic motivation for learning is decreased when they are exposed to an unchallenging instructional process.

The other problem faced by gifted students in school is teacher ineffectiveness while meeting the instructional needs of them (Mammodow, 2019). Students' views in his study indicated that their teachers lack pedagogical knowledge about appropriate instructional accommodations that propose a learner sufficient challenge.

Briefly, the problems encountered by students can be classified into three categories: boredom, lack of challenge, and teacher ineffectiveness. The last one brings about ill designed learning activities, and then since these activities do not provide sufficient challenge, they cause boredom, disengagement and decrease in motivation. All problems trigger each other. Thus, many scholars have a consensus that there are strong needs about designing differentiated pedagogy, differentiated teaching and learning activities with opportunities for advanced levels, activities and materials which propose challenges and engage students attention, curiosity, and creativity (Hobden, Hobden, Douglas, & Hardman, 2012; Housond, 2016; Mammadov, 2019; Stott & Hobden, 2016; Tabber, 2014; Ulger & Irving, 2019; VanTassel-Baska, 2011).

At this point, firstly, researchers provided some curriculum models in a broad framework, such as School-Wide Enrichment Model (Reis & Renzulli, 2009), Autonomous Learner Model (Betts & Kercher, 2009), Purdue Three-Stage Enrichment Model (Moon Kolloff, Robinson, Dixon, & Feldhusen, 2009), Integrated Curriculum Model (VanTassel-Baska, 2009), and The Grid: A Model to Construct Differentiated Curriculum for the Gifted (Kaplan, 1986, 2009).

Secondly, similar to the curriculum recommendations above, but with a narrower scope, some researchers proposed talent development models, such as Renzulli's Enrichment Triad model (Renzulli, 1977), Tannenbaum's Star model (Tannenbaum, 1983), Piirto's Pyramid model (Piirto, 2000), Gagne's Differentiated Model of Giftedness and Talent (DMGT) (1985, 2004, 2010), and Subotnik and Jarvin's SP/A model (Subotnik & Jarvin, 2005).

All these models indicate that two main elements should be emphasized in order to meet the needs of the gifted students while differentiating their teaching and learning process. The former is about differentiating by acceleration which refers to moving faster through academic content via compacting curriculum. The process results in advanced placement by getting credit from higher grade classes. The latter is about differentiating by enrichment which refers to providing students with greater depth and breadth in specific subjects via more diverse educational experiences (Davis et al., 2014).

Enrichment is a strategy that in instructional process is realized through adapting the component of content, process/product, and learning environment regarding the readiness, interest and learning profile of students (Tomlinson, 2005; VanTassel-Baska & Stambaugh, 2006). Enrichment can be diversified in four distinct ways (Gagne, 2007). The former is enrichment density that refers to compacting the curriculum content, simlar to Renzulli's model (Renzulli, 1979) and Rogers's curriculum condensation (Rogers, 2001). The latter is enrichment in difficulty which means presenting more challenging and complex questions and activities in the content of compact curriculum. The third is enrichment in depth which enable students to learn detail of given topic, like Renzulli's Type III research projects (Renzulli, 1979). The last one is enrichment in diversity that pertains to the introduction of short topics not found in regular curriculum.

Enrichment in content stratum should be designed to appeal to interests of gifted; should include advanced and deep content (theories and generalizations) beyond the prescribed curriculum; should be exposed students to a variety of fields and topics of study in depth; should provide students with engaging in conceptual exploration; should direct students to think on more complex ideas (Reis & Renzulli, 2003, 2009; Taber, 2007, 2014; VanTassel-Baska & Wood, 2010).

Process/product stratum emphasizes on integrating teaching methods and embedded activities in order to improve gifted students' higher order thinking skills such as creative thinking and problem solving (Reis & Renzulli, 2009). In this step, students should be encouraged to criticize their thinking and learning. Teachers should also present intellectually challenged activities with differentiated teaching methods which center students' learning experiences around major complex issues (VanTassel-Baska & Stambaugh, 2006; VanTassel-Baska & Wood, 2010). In this process, students should experience an appropriate level of challenge by being permitted to work at their own rapid pace (Tomlinson & Jarvis, 2009). Such a challenge like an inquiry approach should direct students to be in charge of their learning, to independent and self-directed learning with proper scaffolding provided by the teacher (Taber, 2007). In this way, students can play the role of active investigators who use the skills of analyzing, synthesizing, and evaluation, and also explore new ways of thinking. As stated by Taber (2014), enrichment in teaching methods and processes enable students to encounter stimulating problems which lead them to be involved in in-depth discussions.

The last issue is about the learning environment. It should be arranged in a way that students feel safe and supported while learning (Tomlinson & Jarvis, 2009). Properties of learning environments can be stated as follows: be flexible and open to new ideas; encourage investigations, questioning and discussion; prompt Bloom's high level cognitive skills (analyze, synthesise, and evaluate); encourage student independence (Van-Tassel-Baska & Hubbard, 2016). The learning environment should be goal oriented and make gifted students self-regulated (de Corte, 2013).

Depending on the nature of a lesson, enrichment can be realized in a broad range -from concrete to abstract, simpler to more complex, less independece to greater independence, more structured to more open, and slower pace to faster pace- (Tomlinson, 2001). Teachers should have capabilities of adjusting these different dimensions with respect to students' need and readiness.

In the context of this study, within the terms of Gagne's DGMT, the researcher proposes a pedagogical model as an environmental catalyst in order to improve a specific talent called representational competence.

Based on the perspective adopted, participants experience a developmental process (D) in which they attend systematically planned a sequence of teaching and learning sequences as environmental catalysts in order to gain competence or expertise. While the researcher conduct this process, he identifies target population, then determines specific learning goals, and content and activities of the developmental intervention (Moon & Rosselli, 2000). The researcher starts process providing participants with access to a systematic program which includes proper teaching and learning activities in a specific learning format. Then, he pursues development progress of participants' competence by analyzing their learning products with analytical tools during the developmental process.

1.1.3 Characteristics and Needs of Teachers of Gifted

The key to the success of any instructional program is about the teacher, so effectiveness of a teacher in gifted education has become a pertinent consideration for scholars (Miedijensky, 2018). In gifted education, teachers are expected to be aware of emotional and cognitive needs of the gifted student (VanTassel-Baska & Stambaugh, 2006). Teachers in gifted programs are demanded to be epistemically more advanced than teachers in general education programs (Coleman, 2014a). Renzulli (2011) and Miedijensky (2018) stated that ToG should have an ability to employ differentiated teaching methods that improve higher order thinking skills of gifteds. Those teachers who should have a high level proficiency in the subject they taught, and they are qualified to enrich the subject and teaching process. They should have skills of organizing teaching activities according to their students' learning styles, and then providing appropriate methods to meet the needs of them (Altun & Serin, 2019). Some researchers also indicated that ToG are demanded to be skilled in teaching higher order level thinking, providing students to gain autonomy in their learning process, and designing challenging teaching materials that encourages these skills (Chan, 2011; Davis et al., 2014; Yuen & Westwood, 2004). They should be inclined to encourage students to make independent research.

Studies showed that teachers have awareness about preparing a teaching and learning environment which demands students to use higher order cognitive skills including analysis, synthesis, and evaluation (Taber, 2007, 2014). However, they have no qualifications about realizing these requirements (Reis, 2009), and a few of them had advanced certification about these issues (Chan, 2011). They have not been enabling challenging teaching process and materials to the gifted students, since they are stuck to teacher-centered, textbook based, and examination oriented teaching (Yuen, 2004). Thus, a differentiated pedagogy is required to design in order for teachers to gain these above mentioned skills. These needs are also emphasized by different researchers. For example, Coleman (2014 a, b), Hong, Green and Hartzell (2011), and Dilekli (2017) indicated that special learning environments including enrichment and differentiation should be prepared. This type of environment should enable them to comprehend both the theoretical and practical aspects of being a teacher of gifted. Moreover, VanTassel-Baska and Hubbard (2016) stated that ToG should be instructed regarding content, content pedagogy, and teaching strategies in order to provide instruction which challenges students, and improves creative, artistic, and scientific thinking skills of them.

Yet, few efforts were found in literature regarding these concerns (Chan, 2011). Hence, there is a requirement for ToG to attend a different pedagogical approach which aims to improve their skills mentioned above. In this way, teacher effectiveness would be realized, and then the problem of boredom and lack of challenge would be overcome. Teacher educators should embed proper pedagogical approach into in-service or pre-service programs. These approaches should provide teachers to experience different teaching approaches.

In this context, the researcher aims to design a pedagogical model for ToGs considering the elements of enrichment in order to improve their representational competence skills. Before designing the model, needs analysis was realized through literature reviews, interviews, and examining participants' teaching materials. After problems and needs were defined, the researcher looked for possible solutions, and then determined theoretical and practical principles of the model, its learning and teaching process, and its activity types. The investigations revealed that multimodality and multimodal approach to teaching and learning offer lots of opportunities to enable a differentiated pedagogy for gifted education. These are explained in the following titles.

1.1.4 A Differentiation Approach: Multimodality

The study proposes multimodality as a differentiation approach for gifted education because of the following reasons. The ways of how knowledge is constructed by orchestration of different and complementary modes (image, written and spoken text, gesture and etc.), represented and disseminated have become inseparable parts of meaning making, learning and teaching in the last decades. It is due to the claim that new educational technologies changed dispositions towards access to information, knowledge construction, and their representations (Mayer & Moreno, 2003). These tools provided greater facilities for designing, disseminating and accessing to different forms of texts which include more detailed definitions and representations of knowledge (Kress & Selander, 2012; Tang, 2016). Advanced educational technologies enabled various mediums in which different modes can be integrated in order to design representations in specific ways. Approach to knowledge construction and their representations changed from paper-based pedagogical texts towards a greater use of multimodal representations via the digital media (Bezemer & Kress, 2008). Texts are now presented and constructed multimodally, expanding from linguistic texts to include different images and image types, such as diagrams, infographics, simulations and etc (Kress, Jewitt, Ogborn, & Tsatsarelis, 2001; Qiuping, 2019). These texts are coherent and meaningful combinations of modes, hence they are called as multimodal representations (Airey & Linder, 2009). Representations, in here, refer to tools that used for organizing complex information, and help readers to comprehend complex subjects by presenting knowledge in a meaningful coordination between modes (Tang, Won, & Treagust, 2019).

In this respect, multimodality examines how meaning is constructed and represented by combining various modes in multimodal representations. It guides us to comprehend how teachers and students make meanings through orchestration of various modes within and across representations during teaching and learning process (Airey & Linder, 2009; Kress et al., 2001). It investigates and answers the main premise of multimodality is that the ways in which the concepts in teaching materials represented by designers (teachers) determine, shape and impact what is to be learned, how it is to be learned, and the teaching process (Jewitt, 2008).

Apart from the basic opportunities offered by multimodality to the instructional process, multimodal studies guide us in designing challenging teaching materials from simple (that is, texts that appeal to low-level cognitive processes) to advanced (appeal to high-level cognitive processes) by bringing together different modes for gifted students who are bored and do not care when information is presented in a uniform way. Moreover, these studies provide guidance on how to design pedagogical texts for different instructional purposes (paying attention, providing participation, increasing motivation, preparing a discussion environment, putting students in an inquiry process, enabling interactivity, promoting higher order thinking levels of designing, analysing, and evaluating) in the classroom. These studies also enlighten us how to construct and present knowledge creatively and constructively in various ways. Since multimodal texts that convey information appear with animation, simulation, diagram, infographic, virtual laboratories and similar tools, multimodality sheds light on how the modes in these teaching tools should be integrated for serving different instructional purposes.

The above-mentioned claims have been drawn from many studies on multimodality (Forey & Polias, 2017; Gebre & Polman, 2016; He & Forey, 2018; Jaipal, 2010; Kress et al., 2001; Lemke, 1998; Qiuping, 2019; Tang, 2016; Tang, Delgado, & Moje, 2014; Tytler, Prain, Hubber, & Waldrip, 2013; Xu, Ferguson, & Tytler, 2020; Yeo, Lim, Tan, & Ong, 2021). These studies can be classified into following categories: analysis of teaching materials (mentioned in analytical framework part), impacts on learning-meaning making-understanding, knowledge construction, realization of classroom discourse and communication, and representational competence. In the following sections, these issues will be addressed.

1.1.4.1 Learning-meaning making-understanding

In this study, learning, meaning making and understanding are considered as parallel terms in terms of meaning because learning a new concept refers to understanding what the concept means (Novak, 2010).

In this context, many researchers investigated the impacts of multimodal representations on learning (Aagaard & Lund, 2013; Airey & Linder, 2009; Andersen & Munksby, 2018; Atilla, Gunel, & Büyükkasap, 2010; Buccholz & Pyles, 2018; Gunel, Kingir, & Aydemir, 2016; Hoban & Nielsen, 2010; Hubber & Tytler, 2017; Jewitt, 2008; Kay, 2011; Keles, 2016; Leijon & Lindstrand, 2012; McDermott & Hand, 2015; Sivle & Uppstad, 2018; Unsworth, 2006; Xu, et al., 2020; Yeo, et al, 2021). Findings of these studies revealed that there is a consensus between researchers. That is, multimodal representations had positive impacts on learning concepts. For instance, Atilla et al. (2010) indicated that applying multimodal writing to learn activities, which encourage students to use more than one mode develop a deeper understanding of scientific concepts.

Kay (2011) stated that using multimodal web based learning tools which include computer based simulations have positive impacts on students' ability to learn key concepts in science classrooms. McDermott & Hand (2015) reported that using multimodal writing tasks encourages students to integrate different modes, and this effective integration made by students improved their conceptual understanding. Gunel et al. (2016) found that scaffolding students' awareness and understanding about multimodal representations by giving homework such as writing tasks, and realizing classroom discussions about the form and function of the modal representations affected the learning process and the perceptions of students. Keles (2016) also stated that students understand scientific information deeply, since multimodal representations involve a more detailed level of explanations and descriptions with visuals modes in the text.

In another study, Andersen and Munksby (2018) stated that organizing activities among the students about affordances of different modes, making practical experiments by using representations to show data, and designing digital multimodal representations strengthened concept learning. Buccholz and Pyles (2018) found that multimodal representations enabled students to make meaning in multiple ways. Xu et al. (2020) indicated that learning the lever principle is provided effectively when students are engaged with orchestration between a variety of representational modes. The processes of translation and transduction across/between modes and their integration enabled students to interpret and predict patterns of balance. Moreover, Yeo et al. (2021) pointed out that using activities of multimodal representations like image to writing approach improved conceptual understanding of the students on the subject of temperature and heat. At the end of their study, they hypothesized that semantic and semiotic work done together advances conceptual understanding.

1.1.4.2 Knowledge Construction

Recent studies on multimodality also revealed that the approach had positive impacts on the process of knowledge construction (Hubber, Tytler, & Haslam, 2010; Jewitt, 2008; McDermott & Hand, 2013; Oz & Memis, 2018; Prain & Tytler, 2012; Sivle & Uppstad, 2018; Taber & Akpan, 2017; Tang, Tan, & Yeo, 2011; Waldrip, Prain, & Carolan, 2010)

Jewitt (2008) found that different modes of representation encourage students to construct knowledge in different ways. The epistemological shaping of knowledge is ultimately impacted by choice of mode. In another study, Tang et al (2011) analyzed how students construct knowledge when they are exposed to multimodal elements that constitute the concept of work-energy. They examined in detail three parts of discussions among a group of students. They concluded that students constructed knowledge through the orchestration of four distinct modes: language, diagrams, mathematical symbolism, and gestures, since each mode has different affordances. McDermott and Hand (2013) advocated that exposing to and engaging in multiple modes encourage students to be more creative and constructive in the process of developing and creating scientific ideas.

In the study of Wilson and Bradbury (2016), they pointed out that multimodal representations provide opportunities to readers to construct knowledge in a way of analysis and evaluation of various sources and then finally synthesise their understandings. Taber and Akpan (2017) stated that orchestration of modes to transfer multiple meanings encourages readers to reject a single interpretation of the concept in knowledge construction. Oz and Memis (2018) stated that using multiple modes provided students to describe and construct the same concepts in different demonstrations representationally, figuratively, experimentally, and mathematically. Sivle and Uppstad (2018) indicated that, since each mode has different affordances in expressing meaning, synergistic impact of modes' integration in knowledge construction lead to a complex whole that can represent more aspects of a phenomenon than each mode can reveal.

1.1.4.3 Discourse

In parallel with knowledge construction, lots of studies have conducted on examining discourse in the classroom (Acher & Arcà 2009; Airey, & Linder, 2012; Fernandez-Fontecha, O'Halloran, Tan, & Wignell, 2019; Fredlund, Oliveira, Rivera, Glass, Mastroianni, Wizner, & Amodeo, 2014; Marquez, Izquierdo, & Espinet 2006; Pozzer-Ardenghi & Roth, 2007; Tang, 2016)

Marquez et al (2006) analyzed how classroom discourse is realized in teaching of the water cycle. They claimed that representations are critical components of the description of a teacher's discourse. They also stated that four modes –speech, visual, gesture, and written text- work in co-operative ways to construct meaningful discourse. During teaching water cycle, while speech presents the temporal and sequential characteristics of phenomenon, visuals contribute to the establishment of functional mechanisms and spatial characteristics through diagrams and arrows. In the same way, while gesture revives the system by pointing, speech helps identifying and describing. They said that organizing all modes in a coherent way performed by the teacher enables fluency in classroom discourse. Oliveira et al (2014) investigated how teachers perform reading alouds in science. They simply pointed out that read aloud does not only include text delivery. In order for conveying meaning in text, teachers use different types of gestures and visual representations while realizing discourse. The discourse can be classified in two categories: multimodal description and multimodal explanation. The former refers to deploy descriptive symbolism with indexical gesturing (spatial aspect of multimodal representations-like locating the position of objects). The latter refers to use explanatory symbolism and iconic gesturing (imagery for the unimaginable-like making shapes with hands and fingers to visualize light captured by human retina).

In another study, Tang (2016) examined a series of nanoscience lessons on the particular nature of state of matter; he concluded that classroom discourse is realized through the co-deployment of verbal, visual, and gestural mode. Fontecha et al (2019) indicated that by means of multimodal representations like sketchnotes transform abstract meanings in the scientific article into concrete forms and unpack condensed ones. In this way, the complicated form of specialized discourse reduces.

1.1.4.4 Representational Competence (RC) Skills

RC skills are about (1) selecting the best suited representations for teaching a concept, (2) being able to criticizing, comparing, and justifying the adequacy of representations for various task, (3) the ability to transform one representation to another flexibly, (4) being able to design new representations by constructing intermodal relations between modes, (5) the ability to identify and analyze features of representations, (6) being able to understand form and functions of different representations and the conventions and traditions presented in multiple modes, (7) the ability to use multiple modes to conceptualise and communicate about concepts, (8) being able to overcome problems designing and using representations, and using representations to advocate claims, make inferences, and make predictions (diSessa, 2004; Gilbert, 2008; Halverson & Friedrichsen 2013; Kozma & Russell, 2005; Nitz, et al., 2014; Stieff, 2011). These skills are necessary for teachers of gifted students to select, design and evaluate challenging teaching materials.

There have been many studies in the literature about RC and how students or teachers can improve RC through multimodality (Botzer & Reiner, 2007;

Chandrasegaran, Treagust, & Mocerino, 2008; Danish & Phelps, 2011; diSessa, 2004; Kohl & Finkelstein, 2006; Kozma & Russell, 2005; Linebarger & Meier, 2016; Mishra, Clase, Bucklin, & Daniel, 2018; Nitz, Ainsworth, Nerdel, & Prechtl, 2014; Patwardhan & Murphy, 2017; Stieff, 2011; Stieff, & Desutter, 2021; Waldrip, Prain, & Hand, 2010; Wilson & Bradbury, 2021). For instance in the study of Kohl and Finkelstein (2006) found that focusing on using diverse multimodal representations in physics teaching improves RC of students. Botzer and Reiner (2007) indicated that encouraging learner generated representations about magnetic fields resulted in growth in RC. The study of Danish and Phelps (2011) revealed that exposing students to a set of inquiry and representational activities during two one-hour-long sessions per week, for a total of 19 sessions, led students to develop new representational practices including an understanding of the content, how to represent it, and how to assess representations of it. In parallel with Danish and Phelps, the study of Stieff (2011) showed that using multimodal representations like simulations and animations in the subject of matter, supported the development of RC. Patwardhan and Murphy (2017) stated that using method of Reciprocative Dynamic Linking which enables students to apply switch over among types of multiple representations (verbal-textual, symbolic-mathematical, visual-graphical, and actional-operational) led to improvement in RC in the subject of Signals and Systems from Electrical Engineering program.

On the contrary, Nitz et al (2014) stated that although teaching photosynthesis including potentially rich opportunities for participants to integrate representational aspects improved content knowledge, a slight development (5%) in RC was realized. In the same way, Chandrasegaran, Treagust, and Mocerino (2008) indicated that although explicit instruction was made on the use of macroscopic, submicroscopic, and symbolic representations, Grade 9 students had experienced challenges in designing appropriate representations and converting representations between each of them. In parallel with previous research, Waldrip et al. (2010) reported that during multimodal units of force and matter, students faced challenges about how best to represent concepts. Stieff and Desutter (2021) clearly showed in their study that, applying drawing activities by emphasizing on novel representations and their use of representations (novel or provided in the curriculum), the students did not demonstrate improvement on the selected representational competence measures.

Apart from the titles mentioned above, studies on multimodality revealed that, it improved students' engagement with materials presented, science concepts and ideas (Fernandez-Fontecha et al., 2019; Kay, 2011), provided students meta-reflect on their representations (Andersen & Munksby, 2018), developed the readers' interest and attention (Keles, 2016), enabled a more active student participation (Kim, 2017), enhanced their ability to solve problems and high-level cognitive activities (Cromley, Snyder- Hogan, & Luciw-Dubas, 2010; Donnelly, 2010).

1.1.4.5 Problem Statement Regarding Multimodality

The problems encountered when embedding multimodality into the instructional process are presented in the following titles.

- **Teaching Method**

The current digital world is enabling teachers to design new representations in new ways; however, teachers have problems in comprehending how students learn in the digital world and how they teach them in the multimodally rich environment (Andersen & Munksby, 2018). Teaching in a traditional perspective is not effective to embed multimodal representations into classroom settings (Reiser, 2013). Gilbert and Justi (2016) found that even if teachers have opportunities to engage students in representational design, they insist on using traditional ways of teaching. Moreover, Tomlinson (2013) indicated that although teachers are aware of the need for multimodality in classrooms, they tend to sticking what they know.

Researchers (e.g. Kalantzis & Cope, 2020) indicate that one of the deepest problems encountered in the digital environment is that teachers have difficulty in adopting new teaching approaches to the new settings by using its opportunities such as a semiotically rich environment (Lim, 2020). The other point is that teachers do not adequately address how the various modalities students encounter are related to the semantic bonds between related concepts, and they do not know how to deal with this (Yeo et al., 2021).

- **Poorly designed texts**

Failure to implement multimodality causes significant problems in the classroom environment like designing noncoherent texts which means there are no or few referential connections between the components of text leads to misunderstandings and misconceptions in teaching process (Catley, Novick, & Shade, 2010; Ge, Unsworth, & Wang, 2017). These types of texts result in misleading meaning that correctly prevents understanding (Eilam, 2013; Tang & Moje, 2010). For instance, Ainsworth (2006) indicated that if the image cannot associate with the written text regarding meaning, readers would experience to form coherent meaning. Freitas and Castanheira (2008) found that contradictions between the modes of teachers' speech and visual image in the textbook bring about misconceptions in biology classrooms. Ge, Unsworth, Wan, and Chang (2018) claimed that designing poor intermodal relations between image and text leads to noncoherent mental representations, since meaning making or knowledge construction is realized through structuring mapping between representations.

- **Designing multimodal representations**

Although there have been lots of studies on exposing individuals to design multimodal representations, many scholars found that participants had experienced difficulties in using and combining modes (Danielsson, 2013; Daniellsson & Selander, 2016; Kuo, Won, Zadnik, Siddiqui, & Treagust, 2017; Rappoport & Ashkenazi, 2008; Stieff, 2011; Tang & Moje, 2010; Tang et al., 2014). Prain and Waldrip (2006) examined Grades 4 to 6 students' use of representations and found that many students needed more scaffolding in designing different representations. The study of Stieff (2011) showed that from middle school through university in physical science courses, students encountered the challenges while establishing coordination between their conceptual understandings and external representations of those phenomena. In the topic of optics, Kuo et al. (2017) indicated even if students are taught about explicit knowledge about multimodal representations, many students did not answer the questions by using representations regarding ray diagrams.

Research also pointed out that teachers' choice of modes is often implicit and unintentional. Studies indicated that teachers were not aware of the appropriate orchestration of multimodal representations (Keles, 2016; Tang, 2016; Tippett, 2011; Tytler, 2007; Unsworth, 2006). Moreover, research has shown that teachers have difficulties in combining visual and verbal modes in a meaningful way (McDermott & Hand, 2010; Waldrip & Prain, 2012). Zangori, Forbes, and Biggers (2013) stated that constructing multimodal scientific explanations is challenging for teachers. While teachers have a conscious knowledge about properties of written language modes, they have no conscious knowledge about affordances of other modes, and how these integrate (Myhill, Lines, & Watson, 2012).

- **Digital tools**

The digital environment has rapidly changed our perspective in designing representations, the screen has taken over the role of textbook, and visuals and other modes other than written text have been started to use predominantly while constructing knowledge through representations (Bezemer & Kress, 2008; Kress & Selander, 2012; Lim, 2018). The facilities of new digital media have emerged some questions like how should teachers or students combine modes on screen to convey knowledge about the concepts taught or learned (Jewitt, 2008), since orchestration of modes and media of dissemination have critical impacts on meaning making and learning (Kress, 2003). These new text types–called as multimodal representations- and new environments demand teachers and students to be aware of, identify, select, design, and evaluate multimodal representations in order to understand representational and communicative potential of different modes and how they interact in digital media. These concerns also impact directly how teaching and learning resources should be designed and distributed (Chan & Unsworth, 2011; Daniellsson & Selander, 2016;

Selander, 2007). Hence, Lim (2011) indicated that new skills should be improved in this increasingly interactive digital media enabled multimodally rich environment.

- **Instruction - analytical framework**

The problem is how to guide students and teachers to design coherent-orchestrated-embedded multimodal representations and how to evaluate these types of representations whether they are integrated. The former should be dealt with designing a pedagogical model (Ainsworth, 2008). The latter should be handled with improving an analytical framework. Studies showed that more research is required to design a comprehensive analytical framework that could be applicable in a variety of educational context in order to reach an agreed-upon measure of RC (de Vries & Lowe, 2010; Prain & Hand, 2016; Prain & Tytler, 2012; Tippett, 2016).

Apart from the titles mentioned above, two problems have also been investigated in literature. The former, in order to improve RC of teachers or students, and applying multimodal representations in teaching and learning process, meta-textual discussions are required. However, studies show that these types of discussions are scarce in classroom settings (Daniellsson & Selander, 2016). The latter is that, whether studies indicate the importance of applying multimodality due to all of those reasons, multimodality is not part of education programs or of science curricula around the globe except Sweden where they integrate multimodal applications to science literacy in primary school. Recent research points out this shortcoming (Berry, Friedrichsen & Loughran 2015; Jaipal 2010; Patron, Wikman, Edfors, Johansson, & Linder, 2017; Prain 2009).

In order to cope with these problems and using gains provided by multimodality, it is clear that students at all levels need to learn the metalanguage (grammar) of the multimodal representations rather than knowing only types of modes (e.g. image, text) (Kress & van Leeuwen, 1996). These needs are also explicated by numerous scholars (Ainsworth, 2008; Andersen & Munksby, 2018; Hubber, Tytler, & Haslam, 2010; Keles, 2016; Lim, 2018; Lim & Hung, 2016; McDermott

& Hand, 2016; Qiuping, 2019; Tippett, 2011). As stated by McDermott and Hand (2016), realizing cohesive piece of communication and a full understanding of any concept require students to be able to use an assortment of modes. In parallel with the previous statement, Lim (2018) indicated that students must have awareness about affordances of modes and know how these work together in coherent ways to realize effective communication and the process of meaning making. Hubber et al. (2010) claimed that a strong understanding of how to represent and use concepts are accompanied with comprehending and combining different representational modalities. Andersen and Munksby (2018) advocated that thinking and behaving scientifically requires students to have the ability to explain concepts in possible forms and to transform representations flexibly between them, so they have to understand the forms, functions and conventions of modes.

Before being able to equip students with those qualifications, there is one premise that should be accomplished. It is to enable teachers to have these qualities. That is, teachers (pre or in services) must understand the nature of multimodal representations (Shannon, 2014). They must know how to select, design and assess multimodal representations in order to equip their students with the skills necessary, so there is a strong corresponding need to build these skills in teachers (Lim, 2018). As indicated by Patron et al. (2017), teachers need (1) a semiotic awareness, (2) representational competence for design, and (3) use of meaning making affordances. Teachers should be aware of how to construct multimodal representations between modes and how to combine various types of images with texts (Xu et al., 2020). It is apparent that first teachers should be equipped with the abilities of being aware of, identifying, and selecting best suited multimodal representations regarding the subject in focus. Finally, they should have qualifications in abilities of designing and assessing multimodal representations. Briefly, they should have representational competence skills. RC can be described as: "…the full range of capabilities that students (and others) have concerning the construction and use of external representations.…[It] includes the ability to select, produce and productively use representations but also the abilities to critique and modify representations and even to design completely new representations. (diSessa & Sherin, 2000, p. 387)."

All in all, studies revealed that teachers have problems in comprehending how students learn science in the digital world and how they teach them in a multimodally rich environment (Andersen & Munksby, 2018; Gilbert & Justi, 2016). Research also pointed out that teachers' choice of modes are often implicit and unintentional. Studies indicated that teachers did not aware of the appropriate orchestration of multimodal representations and intermodal relations (Keles, 2016; Prain & Waldrip, 2006; Tytler, 2007; Tippett, 2011; Tang, 2016; Unsworth, 2006). Moreover, research has shown that teachers have difficulties in combining visual and verbal modes in a meaningful way (McDermott & Hand, 2010; Waldrip & Prain, 2012). Zangori et al. (2013) stated that constructing multimodal scientific explanations is challenging for teachers. While teachers have a conscious knowledge about properties of written language modes, they have no conscious knowledge about affordances of other modes, and how these integrate (Myhill et al., 2012).

At this point, in order to investigate possible methods to embed multimodality into instructional process, and to examine their impacts on RC, the researcher first reviewed the literature comprehensively. He found that scholars reached a consensus that multimodality requires somewhat different pedagogy, but there is no agreed upon idea on how it should be designed (Cope & Kalantzis, 2015; Kuo, et al., 2017; McDermott & Hand, 2013; New London Group, 1996; Nam & Cho, 2016; Selander & Kress, 2012; Tolppanen, Rantaniitty, & Aksela, 2016). The review identified three interrelated methods: How of pedagogy (New London Group, 1996), Design by learning (Cope & Kalantzis, 2015), and Design for learning (Selander & Kress, 2012).

How of pedagogy and Design by learning approaches are proposed by the researchers as a pedagogy of multiliteracies in which multimodality is embedded into teaching and learning process in literacy. Both of them include similar contents regarding how to integrate multimodality to the teaching and learning of the literacy. Design by learning has made more specific and clear the pedagogical sequences of how of pedagogy approach. It converted the title of *situated practice* into *experiencing* which proposes preparing a learning environment based on what the students become familiar and unfamiliar. It renamed the process of *overt instruction* in the first approach as a *conceptualizing* in which the learner become active conceptualizers who learn metalanguage of different modes. It re-stated *the critical framing* part more clearly as *analysing* that aims to provide the learners with critical perspective towards their multimodal texts. How of pedagogy has explained this step in a general way as standing back and looking critically what the learners have learned in the context learning occurred. The last step of *transformed practice* is re-explained by Design by learning as *applying* that the students put what they have learned before into different contexts.

Although the third approach –Design for learning- does not express how to integrate multimodality into the teaching process, it provides guidance on how the multimodal learning process takes place and how to design it. The main aim of this model is to enlighten design activity, formation and transformation of knowledge in learning sequences as students engage in tasks such as problem solving, knowledge construction, and sign production activities. It makes a theoretical mapping on how the learning process takes place by using different modes and media tools in the learning process.

This draws attention to the fact that constructing knowledge within the mode and transforming it between the modes plays an important role in the design of the learning process, since, in the digital world, knowledge is no longer something that is consumed by users, but something that is produced. At this point, design refers to the construction and communication of knowledge using modes and media tools. Design deals with changing trends in social, economic, semiotic and technological towards information and knowleeedge. Based on these changes, it tries to explain the learning environment and how the learning process takes place with a design process. The concept of “Learning Design Sequences” is a way of emphasizing the activities of creating and transforming knowledge by looking closely at both modes and media in meaning making and learning, and activities and processes of interpretation and design. The sequence starts with designing a learning environment by the teacher based on the institutional norms, curriculum, and available learning sources. In this step, the teacher informs students about key concepts, the idea of the activity, what is demanded by them as a learning product, and how the product will evaluate. In the second step of these sequences, the learner seeks information, and forms and transforms information to the his or her own learning product (a typical representation) by way of using modes and mediums. At the end of the sequence, the learner presents the learning product, and discuss with peers and teacher regarding the product depended on the criteria of judgment, revises the product, and then the teacher provides a summative assessment.

Even if rest of them (apart from those threes) did not propose any method about how to embed multimodality into pedagogical process, they brought some insights about the content and activity types of model. These threes and additional studies inform the current study about the components and theoretical and practical principles of Multimodal Pedagogical Model (MpM) which explains detailly how human mind works, how learning occurs, how to learn with multimodal representations realizes, and how the teaching should be (Chapter 3).

At the end of the review, it was concluded that there is a need to design a comprehensive pedagogical model regarding multimodality by making collaboration with in-service teachers and experts in order to improve their RC skills.

1.2 Objective of the Thesis

The study aims to design a teaching and learning activity sequences (pedagogy) model for ToGs considering the elements of enrichment in order to improve their representational competence skills. In other words, within the terms of Gagne's DGMT, the researcher proposes a pedagogical model as an environmental catalyst which acts through the developmental process in order to develop a specific talent called representational competence. Hence, at first, a Multimodal Pedagogical

Model with theoretical and practical design principles for gifted education was constructed through educational design research. The model aims to provide teachers of gifted with differentiated teaching method, content, activities, and materials since their students demand challenging tasks which engage their attention and curiosity, trigger higher level thinking skills, and provide independence in learning. The present study claims the significance of this aim because of the following reasons. (1) Gifted students experience boredom in the classroom environment due to lack of challenging teaching and learning activities, over repetitions of basic ideas, over generalized explanations, and inadequate details. And, in a study conducted in Turkey, gifted students stated that these problems originated from teacher ineffectiveness (Mammodow, 2019), so it seems that teachers of gifted students to overcome such an issue. Research suggested a strong need for designing differentiated pedagogy which propose differentiated challenging teaching activities and materials that engage gifted students' attention, curiosity and creativity, prompts higher order thinking skills (Hobden, Hobden, Douglas, & Hardman, 2012; Housond, 2016; Mammadov, 2019; Stott & Hobden, 2016; Tabber, 2014; Ulger & Irving, 2019; VanTassel-Baska, 2011). (2) Although many researchers pointed out this need, few efforts were found in literature (Chan, 2011).

A differentiated program to teachers of gifted in such a multimodally rich environment was designed due to the reasons mentioned detailly in the introduction part. To summarize these reasons, first, new instructional technologies and also the digital world changed dispositions towards access to information, knowledge construction, and their representations. Moreover, these tools enabled greater opportunities for designing and disseminating various forms of teaching materials as multimodal representations (e.g. animation, video, simulation, and etc.). In other words, multimodal based pedagogical representations replaced the dominance of paper based pedagogical texts via the prevalence of educational technologies (Jewitt, 2008). Thirdly, multimodal studies enable to design challenging teaching materials from simple (that is, texts that appeal to low-level cognitive processes) to advanced (appeal to high-level cognitive processes) by integrating different modes for gifted students who are bored and do not care when information is presented in a uniform way. Fourthly, studies indicated that designing and presenting these multimodal representations to the students considering intermodal relations and patterns of text coherence provide unique pedagogical opportunities ranging from improving attention, interest, motivation, engagement, and interaction to enhancing higher order thinking skills and creativity. However, research reveal that teachers had problems in selecting and designing multimodal representations regarding challenging teaching materials and pedagogical purposes (Andersen & Munksby, 2018; Danielsson, 2013; Daniellsson & Selander, 2016; Kuo, et al, 2017; Rappoport & Ashkenazi, 2008; Stieff, 2011; Tang & Moje, 2010; Tang et al., 2014;). That is, they lack RC skills. Hence, the problem arises here about how to guide students and teachers to design coherent-orchestrated-embedded multimodal representations, or in other words how to equip them with the skills of RC.

1.3 Original Contribution

At this point, from both national and international perspective, the study contributes to the literature of gifted and multimodal research by proposing: (1) a pedagogical model with theoretical and practical principles which aims to act as an environmental catalyst in a developmental process in order to improve RC skills of ToGs; (2) Awareness-Recognize-Design-Evaluation (ARDE) that is a new approach to learning with multimodal representations; (3) Cattell Horn Carroll-Based Multimodal Generative Learning Approach which tries to explain how learning with multimodal representations occurs, which cognitive parts take active roles, and clarify how cognitive load on the working memory can be decreaesed or increased through strentegtening or weakening interacction between modes; (4) analytical frameworks that guide researchers and teachers to examine intermodal relations and text coherence attributes in multimodal texts, and to design these types of multimdoal artefacts.

1.4 Research Questions

1. How does designed Multimodal Pedagogical Model (MpM) improve representational competence of teachers of gifted students?
    a. To what extent do teachers identify and aware of intermodal relations between modes and attributes of text coherence?
    b. To what extent do ToG identify differences between monomodal texts regarding attributes of text coherence and differences between multimodal texts concerning intermodal relations?
    c. Which criteria do teachers use when selecting multimodally rich representations at the end of the MpM?
    d. How do teachers design intermodal relations between image-text and aspects of text coherence at the end of the MpM?
    e. To what extent do teachers assess intermodal relations and text coherence attributes of multimodal representations at the end of MpM?
2. What problems do teachers encounter when constructing intermodal relations image-text and text coherence?
3. What are their views and perceptions about multimodal representations and the MpM?

1.5 Limitations and Assumptions

Among the limitations of the study, the followings can be listed:

- The implementation period is limited to one term.
- The implementation of MpM was carried out online due to the Covid-19 pandemic, which caused difficulties in offering instant feedback and organizing group work.
- Participants have little experience in using online tools and instructional technologies.

- Due to lack of funding, the tools for designing representations could not be presented to the participants.
- Instructional technologies offered have inherent limitations, which may have influenced teachers' designs.
- Since the participants are in-service teachers, it can be seen as a limitation that they cannot allocate enough time and concentrate on tasks due to the intensity of their own teaching responsibilities.

Assumptions can be listed as follows:

- It is assumed that all of the teachers had a sufficient background on the subject content of the activities at the secondary school level in order to complete the requirements
- It is assumed that the participants do not receive support from anyone, as the designs are not made in one-on-one, face-to-face, physical environments. To confirm that this is not the case, discussions about the designs were conducted.
- It is assumed that they answer the questions in the interviews honestly.
- Although they are in different regions, it is assumed that the participants faced the same difficulties in terms of accessing the Internet, using instructional technologies, taking time, and concentrating while designing the activities.

2
THEORETICAL FRAMEWORKS

2.1 Systemic Functional Theory

Systemic Functional Theory (SFT) focuses on understanding and evaluating the meanings in the context in which they are used. SFT claims that potential meanings of semiotic sources are presented in system networks and also metafunctionally organized. Within the scope of SFT, semiotic resource refers to a resource used for meaning making such as language and image. Meaning has an expression and content plane in which systems operate within a network on them in order to realize metafunctions (Halliday, 1978; Lim, 2011).

Systemic is a key term in SFT, and implies centrality of the system network framework to represent available potential meanings of semiotic resources (Lim, 2011). The system offers a set of options including an entry condition, paradigmatic choices, and syntagmatic selections. That is, meanings are constructed, interpreted, and exchanged as a network of available interlocking options (Halliday, 1994). This shows that choice of meaning maker is a foregrounded factor in SFT (Halliday, 1978; Lim, 2011), so Halliday (1994) expresses this situation as “systemic theory is a theory of meaning as choice, by which language, or any other semiotic system, is interpreted as networks of interlocking options”. The phenomenon of ‘choice’ is further elaborated by Kress (1993, 2009) as a term of ‘interest’ of the sign-maker. He claims that the meaning making process is motivated by interests. He defines interest as “the articulation and realisation of an individual’s relation to an object or event, acting out of that social complex at a particular moment, in the context of an interaction with other constitutive factors of the situation which are considered as relevant by the individual” (Kress, 1993: 174).

2.1.1 System Network

SFT clarifies both paradigmatic choices and syntagmatic relations. It models the semiotic resource as a system of interrelated options. Meaning is realized through exchanging by choosing available options. These interrelated sets of options are called as the system network. A simplified system network is shown in Figure 2.1.

The system network enlightens the present study in accounting for intermodal (intersemiotic) relations between semiotic resources of image and text (written text). It manifests all types of semantic relations provided by integration of image and text modes. For instance, the entry condition here proposes two sets of options: *interdependency* and *logico-semantic relations*. Intermodal relations in a multimodal representation can be defined in terms of *interdependency* and *logico-semantic relations*. That is, relation in these options can be either equal or unequal and either concurrence or complementarity. For example, if 'equal' is chosen, the relation can be designed further 'independent' or 'complementary'.

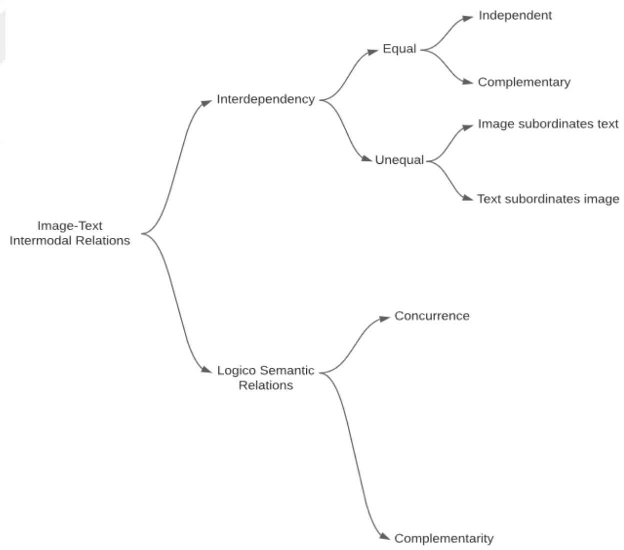


Figure 2. 1 An example of system network

2.1.2 Function

SFT is concerned with the meanings made in the semiotic resource through the paradigmatic choices and syntagmatic relations around functions (Halliday, 1985/1994; Halliday & Matthiessen, 2013; Lim, 2011). This means that meaning has functions in social context. In other words, semiotic resources have meaning potentials that are not only represented in the system network but also they are organised metafunctionally. They have three metafunctions: (1) *Ideational meaning* which is used for constructing the nature of events, including the objects, participants, and circumstances in order for making sense of human experience (Halliday, 1978, 2008; Halliday & Matthiessen, 2013). It focuses on the "knowledge". (2) *Interpersonal meaning* which is used for enacting social relations, identifying how the semiotic resource positioned the learner in relation to knowledge. (3) *Textual meaning* refers to arrange ideational and interpersonal meaning in a coherent text. Since the significant part of the present study pertains to teach ToGs to design different levels of multimodal representations regarding ideational metafunction during a multimodal pedagogical model approach, comprehending ideational meaning guides constructing activities of the MpM with respect to this metafunction.

2.1.3 Dimension

The system network and metafunctions enable a specific dimension in order to examine and understand architecture of the semiotic system: *the cline of instantiation* (Qiuping, 2019).

2.1.3.1 The Cline of Instantiation

Instantiation integrates the system and the context. The former defines the relation between the instance pole and the potential pole. The instance pole refers to observable and selected instances of meaning making in any kind of text (monomodal or multimodal). However, the potential pole refers to all possible meanings provided by the semiotic system (image or language system). That is, the potential pole enables all sets of options to the meaning-maker/sign-maker, and s/he constructs the instance pole according to his or her choices. Thus, the semiotic system is related to texts through instantiation.

The latter is located above the semiotic system, and called "a higher-order semiotic system" (Matthiessen, Teruya, & Lam, 2010). Similar to the semiotic system, the context also includes instance pole (context of situation) and potential pole (context of culture). Context of culture consists of all particular instances of the overall system in a social culture. Context is realized by three variables: (1) *field* involves human experiences and social activities (ideational meaning), (2) *tenor* covers relationships between participants and participants-texts (interpersonal meaning), (3) *mode* handles with role of semiotic system in the context (textual meaning) (Halliday, 1978). Therefore, realization occurs between the semiotic system and context. Whereas context of culture is realized in any semiotic system, context of situation is realized in mono or multimodal text.

Briefly, as shown in Figure 2.2, the semiotic systems provide all possible meaning potentials with sub-potentials to the meaning maker in culture of context, then the meaning maker constructs an instance pole in context of situation by choosing according to his or her motivated interest, and finally realization occurs. In other words, meanings are conveyed to someone else through intrasemiotic meaning-making, and at last intrasemiotic meanings are interacted to realize intersemiotic meaning making.

What the researcher is particularly interested in this study is to understand the realization of multimodal texts, how multimodal texts are realized via image and language systems. This perspective provides us the opportunity of viewing a multimodal text as a product and a process where first ideational meanings are organized internally between semiotic systems, and then externally the product is designed as a representation (multimodal text).

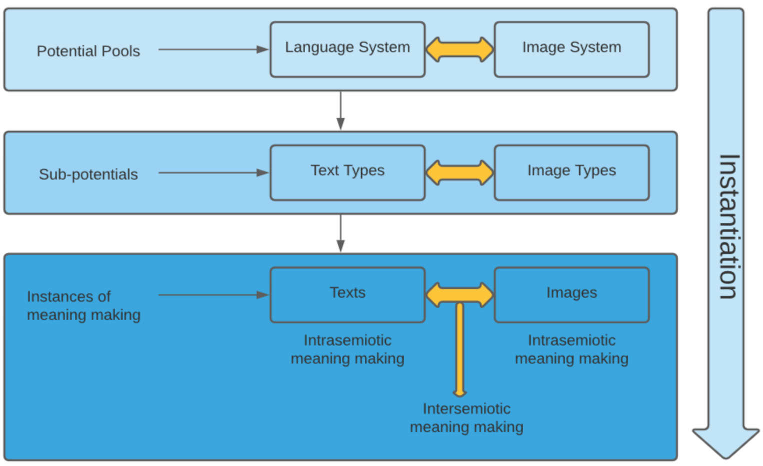


Figure 2. 2 The cline of ınstantation process

2.2 Social Semiotics

Social semiotics is improved based on the studies of traditional semiologist Charles Sanders Peirce. He tried to investigate the nature of signs and representations and stated that “a representation is an object which stands for another so that an experience of the former affords us a knowledge of the latter” (Peirce, 1873, p. 62) and “a sign is an object which stands for another to some mind” (Peirce, 1873, p. 66). Finally, he concluded that there is a triadic relationship between objects, signs, and their interpreted meanings, as shown in Figure 2.3. That is, meaning is realized through the interactions of these three components, and every new interpretation of a new sign re-activates a new interplay of this triad. A sign signifies something (a key idea or explanation) about the object (or referent) to someone (the learner). Elements of the sign construction process according to this model; the object of meaning (the phenomenon / concept / subject to be taught / signified), how it is shown (sign, representation, signifier) and the interpretation left by the sign in the mind (interpretant).

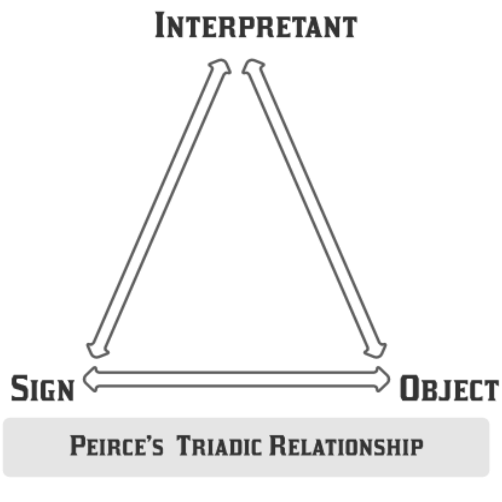


Figure 2. 3 The triadic relationship

For example, in science, flow-chart depiction of energy refers to sign or signifier, energy operation examples on objects in the world refers to object or signified, and the scientific idea of energy refers to interpretant (Lemke, 2003).

Based on the traditional semiotics, Hodge and Kress (1988) elaborated and replaced some notions of it and they improved the theory of social semiotics. They stated that:

> "*Traditional semiotics likes to assume that the relevant meanings are frozen and fixed in the text itself, to be extracted and decoded by the analyst by reference to a coding system that is impersonal and neutral, and universal for users of the code. Social semiotics cannot assume that texts produce exactly the meanings and effects that their authors hope for: it is precisely the struggles and their uncertain outcomes that must be studied at the level of social action, and their effects in the production of meaning* (Hodge & Kress, 1988, p. 12)."

They advocated that traditional semiotics excluding the social context in which signs are constructed, and evolved continuously. They emphasized that two key concepts should be taken into consideration: meaning maker and social context. And then, they replaced 'sign' with 'semiotic resource' because "it avoids the impression that what a sign stands for is somehow pre-given, and not affected by its use" (van Leeuwen, 2005, p. 3). van Leeuwen identifies semiotic resource as follows: "Semiotic resources are the actions, materials and artifacts we use for communicative purposes, whether produced physiologically – for example, with our vocal apparatus, the muscles we use to make facial expressions and gestures – or technologically – for example, with pen and ink, or computer hardware and software – together with the ways in which these resources can be organized. Semiotic resources have a meaning potential, based on their past uses, and a set of affordances based on their possible uses, and these will be actualized in concrete social contexts where their use is subject to some form of semiotic regime (van Leeuwen, 2005, p. 285)."

Hodge and Kress (1988) also criticized the other traditional semiologist Saussure's notion of arbitrary relationship between signified and signifier, they asserted that the relation between signified and signifier is motivated by the interest of the meaning maker. Thus, they proposed the theory of social semiotics.

Social semiotics accounts for the socially, culturally, and historically constructed meaning of semiotic systems (e.g., language, images) (Bezemer & Jewitt, 2010). Social semiotics is a generalized theory improved to comprehend how human beings use different semiotic systems to make meanings in any social context (Halliday, 1978; Lemke, 1990; Tang, et al., 2014; Tang, Ho, & Putra, 2016). Three key components are integrated to construct the theoretical underpinnings of social semiotics: *semiotic system, text, and choice.*

Semiotic system refers to accumulation of socially shaped signs which are improved and used by a particular community as resources for making meaning (Bezemer & Jewitt, 2010; Bezemer & Kress, 2010; Serafini, 2011; Tang, et al., 2019). Each semiotic system has an evolutionary character, that it is evolved regarding the interests and communicative needs of society in order to make certain meanings demanded in that community (Halliday, 1978; Kress & van Leeuwen, 2006). Semiotic system in the present study refers to grammer of image system, text system, and image-text system. Whereas a semiotic system is a whole set of options in system network, a *text* is an instantiation of intended meaning in a specific context. The text in this study pertains to monomodal texts including just image or text, and multimodal text involving image-text. The system and the text have mutual and dialectical relationship in which while the semiotic system limits and affords possible meanings in text, in turn constructed text determines new boundaries of system network. The last term of *choice* clarifies how a meaning-maker selects semiotic sources while instantiating intended meanings in a particular community. Within the terms of this study, the choice refers to how a participant selects a particular semiotic system in order to desing a mono or multimodal text. The choice is impacted by two main factors. The first is due to limitations and affordances of semiotic system itself. This situation determines what meanings could be made or not. The second factor is *interest* of meaning-maker who determines how to express what he or she is mind through selecting apt and salient features from a semiotic system (Kress & van Leeuwen, 2006). Shortly, analysing these choices and interests can show how a meaning-maker construct an aspect of reality in a particular way using the semiotic systems (Tang et al., 2019).

This theory assumes that meaning making is about one's reconstruction and recontextualization of semiotic resources (Hodge & Kress; 1988, Lemke; 1990; Thibault, 1990). Social semiotics theory is concerned with meaning, it states that meaning is born in the social environment and with social interaction. Therefore, according to this theory, society is the creator of meaning and semiotic sources (Hodge & Kress, 1988). Social semiotics examines meaning within the framework of "text" and "context" by considering the social processes of meaning. In other words, meaning making is realized when we connect things to the context.

Lemke (1990) elaborated the concept of 'context' and stated that there are three kinds of contexts in social semiotics. (1) Syntagmatic context deals with the sequence and the structure of any semiotic system. (2) Paradigmatic context refers to possible relations between similar contexts. (3) Indexical context concerns actions in the particular community which has a specific discourse such as actions in the classroom environment.

Social semiotics also concerns meaning makers who use socially generated various languages which could be non-scientific or scientific (Hodge, 2009). In brief, human beings make meanings by using social tools and transfer their understanding of the world with various representations by the media of dissemination. These representations reflect the meaning makers' conceptual, cognitive, and affective 'inner' world. At this point, social semiotics analyze transferred representations in order to examine the production of discourse in social and cultural contexts (Hodge, 2009).

Meaning is formed by a set of intermodal relations selected from a network of options offered by modes in different contexts. The situation emphasizes the importance of the designer who play active roles in selecting most appropriate signifier for the signified. Under this scope, it can be claimed that the relation between twos (signifier-signified) couldn't be viewed as arbitrary, it is a conscious process. Signs/semiotic sources/modes are impacted by the interest of the sign maker. That is, a teacher or a student selects appropriate signifier and signified, and integrates them intentionally by designing teaching and learning products according to his or her interests.

Preferring one mode to another emerges the question of what motivates a designer's selection of mode. Kress (1993) answered this question with the concept of 'interest' as follows:

> "*Interest is the articulation and realization of an individual's relation to an object or event, acting out of that social complex at a particular moment, in the context of an interaction with other constitutive factors of the situation which are considered as relevant by the individual* (Kress, 1993, p. 174)."

The concept of 'interest' is defined as the designer's relationship to the social context of representational production, which includes the potentials of modal resources offered by the context. Thus, social semiotic alters the perspective from the modal system to the process of meaning making (signs). The term 'interest' conceptualizes the relation between signifier and signified as an evidence of the characteristics of the designer. The representation is an outcome of the complex interaction of the designer's "physiological, psychological, emotional, cultural, and social origins (Kress, 1997, p. 11)". For instance, a multimodal representation manifest a teacher's pedagogical approach applied in the classroom environment.

Halliday (1978, 1985) claimed that meaning making system and the grammar/the metalanguage provided by the system presents infinite options in order to combine components of the signifying stuff, the resources of the system, people's use of these resources, and finally new signifiers and signified. In parallel with Halliday, Kress (1997) indicated that each use or design of new representation results in altering the affordance of the signifier to mean. Each signifier are continuously remade in the process of meaning making.

The sign motivated by the interest of the designer emphasizes the significance of providing various kinds of semiotic sources that are available to the designer to select from. These sources are inherently connected with the context in which the designer experiences the world. In each process of meaning making, new signs/semiotic sources/representations come into fore, and this situation change both the metalanguage and the components for meaning making.

2.3 Multimodality

Multimodality is a terminology used in social semiotics has improved in response to paradigmatic changes in social and semiotic landscapes over the last few decades (Jewitt, 2008; Jewitt, Kress, Ogborn, & Tsatsarelis, 2001; Kress & van Leeuwen, 2002; Shannon, 2014). These changes include two main dimensions, on the one hand, image is replacing the long dominance of writing, and on the other hand, the medium of screen is taking over the role of the medium of the book (Selander, 2008). Image and the medium of screen became the central sources of communication (Bezemer & Kress, 2010). The new dominant ones have made profound impacts on arrangements for meaning making (Kress, 2003). In this context, multimodality claims that (1) meanings are made through multiple semiotic sources, of which language is only one (Kress & van Leeuwen, 2002). Namely, language is only one part of representation and communication. Modes never exist alone in a text. (2) Meanings are socially and culturally constructed by assemblage of semiotic sources. As Jewitt (2008) indicated, for something to be a semiotic resource, it should be a socially and culturally shaped outcome. (3) And, finally, the meaning-making process is about representation and communication, which often coexist but have distinct focuses (Bezemer & Jewitt, 2010; Kress, 2010). Representation refers to the meaning the designer desires to show, whereas the communication deals with the interest of the recipient. That is, multimodality concerns with representations and communication processes including more than one semiotic source, for instance image, gesture, gaze, posture, spoken words, and writing (they are called as mode from now on) (Daniellson, 2016). Since multimodality views meaning beyond spoken and written language, it addresses the question of how modes are integrated to make meaning (Jewitt, 2003, 2008). It examines how human beings make meanings through orchestration of various modes within and across representations during communication (e.g., Airey &

Linder, 2009; Jewitt, et al., 2001; Lemke, 1998). In this context, Jewitt (2008) indicated that each mode has dynamic and fluid characteristics in meaning making process, rather than static skill replication and use.

Apart from these, Zhang (2013) stated that the purpose of a multimodal approach is not to investigate what each mode means in text, rather the point should examine "the complexity of interlinked communicative modes or the intensity of a specific mode or several modes employed by the social actor" (Norris, 2004, p. 104).

Multimodality has different meanings in different contexts (Lim, 2011). It has been defined as phenomenon (O'Halloran, 2011; Scollon & LeVine, 2004), a domain of enquiry (Kress & van Leeuwen, 1996/2006; Kress, 2009; Bezemer & Jewitt, 2009) and an analytical approach (Jewitt, 2008; O'Halloran, 2007). Multimodality is a phenomenon because all life we experience consists of multimodally rich environments, digital and real world. Multimodality is a domain of inquiry because it provides improving theories and approaches specific to a multimodal study (O'Halloran, 2011). Multimodality is an analytical approach because it enables investigating the full range of meaning in a multimodal ensemble, helps and guides researchers in the collection and analysis of multimodal texts (Jewitt, 2009).

Multimodality has three distinct terms explained in the following titles: mode, modal affordance, and multimodal representations.

- **Mode**

Modes can sometimes be considered as sensory modes like taste, smell, touch, hearing, and taste, because we experience the world multimodally (Tippett, 2011). However, specifically, within the perspective of social semiotics, a mode more often is defined as historically, culturally and socially formed and organized for achieving representational and communicational needs (Kress, 2003, 2009). Namely, mode is an organized set of semiotic resources in sign systems, it is used for articulating meaning (Jewitt, 2008). Writing, spoken words, image, gesture, and pose can be accepted as a mode, because each one has different organizational structures in order to convey socially shaped meanings (Kress, 2009). As O'Halloran (2011) stated that mode is used to describe language, image, gesture, and etc which orchestrate across sensory modalities (visual, aural, tactile…) in multimodal discourses, events, and texts. Each mode has distinct semiotic resources for articulating meanings. For instance, image mode includes colour, icon, symbol, layout, diagram, and etc. Written mode involves punctuations, letters, words, sentences; spoken mode also has semiotic resources of intonation. Human beings use a certain grammar systematically, while making meaning within the mode mentioned. Since each mode has distinct attributes in terms of meaning potential it offers, the orchestration of different modes creates a meaning (called as multiplying of meaning) which is greater than the sum of the meaning in each mode (He & Forey, 2018). This originates from the terminology of modal affordance.

- **Modal Affordance**

Modal affordances refer to the perspective that each mode has potentials and limitations for meaning making (Selander & Kress, 2010). Since each mode has specific logic, grammer, and regularized sets of semiotic sources, modal affordance can be described as which parts of meaning can be easily and most appropriately realized, expressed, and represented easily by which mode (Jewitt, 2003). This issue arises the question of what mode is best for, what arrangements are best for given its social context. In this regard, multimodality plays a critical role in investigating the affordances and potentials in the different modes as well as how they integrate coherently in their joint co-deployment (Lim, 2011). In other words, it examines functional specialisation of modes to understand meaning multiplied (Kress, 2003), and it states that understanding whole meaning presented by multimodal texts or actions requires to comprehend modes' own inherent set of rhetorical devices because of the fact that all modes are carrying a part of the message only (Shannon, 2014).

As stated above, different modes propose quite different potentials for meaning making in a multimodal text or action. Simply, for example, the semiotic resources of writing mode (punctuation, letters, bolding, or highlighting) offer different potentials for meaning making, as do the sources of speech (intonation, pause, or volume) too. When meaning makers orchestrate both of them, the new meaning arises. While writing and speech mode can be convenient for naming phenomena, the image can be used to illustrate, and the gesture can be used to enact things.

- **Multimodal Representations**

Representation can be described as a device used to symbolize a type of information or an idea via conceptualization of an item in a certain mode (Andersen & Munksby, 2018). They are used for communication purposes. Representation brings meaning and form together to carry meaning in a certain context and situation (Kress, 2010). Meaning is realized in the content plane, where mode is used according to logic of grammar systematically, regularized sets of semiotic sources, and its own inherent set of rhetorical devices. However, form is realized in the expression plane, where the content plane is operated (Lim, 2011). Integrating meaning and form requires a motivated transformational process which is impacted by creators' choices and interests (Jewitt, 2013). As Kress (2009) indicated, representation can be viewed as motivated when form and content are embedded.

Representations can be classified ranged from monomodal text (the form of a written text, a graph which includes symbols, a diagram) to multimodal text (infographics, simulation, animation) (Lemke, 1990). Any multimodal text or representations were described as an interwoven combination of various modes (Airey & Linder, 2009; Andersen & Munksby, 2018), at this point, multimodality claims that interweaving modes requires a *design* (Bearne & Wolstencroft, 2007) because transfering the message across can be achieved through a meaningful integration. In this design process, at first, a representation acts as a prompt, and then a designer tries to interpret and understand the meaning of the representation *inwardly* by designing in mind. Finally, the designer creates another representation *outwardly* (multimodal representation) in order to show his or her understanding, thus multimodal communication occurs (Kress, 2009).

2.3.1 Theory of Learning: Design

Based on the SFT, social semiotics theory and multimodality, the learning approach of the Multimodal Pedagogical Model proposed in the study is explained by the term of 'design' in the following statements.

It is clear that the definition of learning needs to be re-defined in this age of increasingly growing virtual environments and new types of communication, since the digital world changed dispositions towards access to information, knowledge construction, and their representations (Mayer & Moreno, 2003). It also provided greater facilities for disseminating and accessing different forms of texts which include more detailed definitions and representations of knowledge (Kress & Selander, 2012; Tang, 2016). These changes mean that new communicative patterns do not rely on verbal text only, visual text and other modes also play crucial roles in communicating and disseminating information. Communication is realized in a wider variation of forms than earlier (Akerfeldt, 2014). That is, communication occurs with the integration of simultaneous aid of different modes and medium of disseminations (Kress, 2010).

These processes and tools show that learning is a matter of communication (Jewitt, 2008; Kress & Selander, 2012). This communication process consists of three basic elements. The first is the message itself. The second is the medium that conveys the message. The third is the sender (teacher) who transmits this message through modes that can be perceived by five sensory organs. Viewing learning from this perspective requires a semiotic perspective to understand learning processes (Fredlund, Airey, & Linder, 2015). This semiotic perspective is based on Peirce's (1931) triadic model and the social semiotic perspective (Halliday, 1978), which assumes that meaning is filtered from context. This process consists of (1) the concept or process itself learned, (2) how this concept or process is represented or demonstrated, and (3) the learner's interpretation, which is the concept or the structure of the process that the student has designed in his mind. Social semiotic theory, on the other hand, assumes that this meaning is context-specific, and thus learning takes place through context.

Elements of learning process according to this model; the object of meaning (the phenomenon /concept /subject to be taught), how it is shown (sign, representation) and the interpretation of the sign. That is, meaning is not conveyed, it is redesigned in the learner's mind (re-construction and re-contextualization)(Figure 2.4).

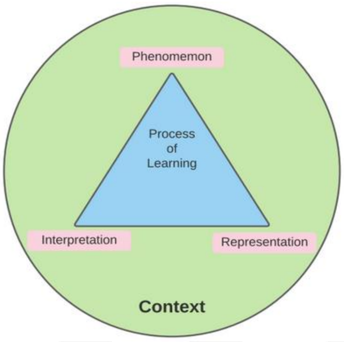


Figure 2. 4 Process of learning

At this point, Lemke (2003) stated that disciplinary meaning making practices also can be explained by a triadic account of how signs have meaning. For instance, there is a triadic relationship between a flow-chart depiction of energy (representation), examples of operation of the energy (phenomenon), and the scientific idea of energy (interpretation). Each interpretation re-activates new interplay of this triad, because meaning making is a continuous process. These repetitions are not copies of teacher's representation, it is a new one, transformed one. This means that all activities performed by learners for comprehending concepts include representational work in which cognitive and representational sources are used to understand concepts that are new to them. It is a re-iteration process. As Lemke (2003) and Peirce (1910) pointed out that learning is "the process and outcomes whereby students come to understand how to interpret and construct scientific meanings, processes, and reasoning procedures using the representational conventions of this subject?"

From the perspective of social semiotic approach to multimodality, these aspects of communication bring new approaches to learning. At this point, the social semiotic approach has been provided as an advanced theory of learning (Kress & Bezemer, 2016). Learning is now seen as a multimodal communication, and this is conceptualized within the terminology of 'multimodal design', 'design', 'design theory of learning' (Kress & Selander, 2012).

Design studies are a new and expansive approach in the last few decades depended on social semiotic and multimodal theories (Forsling, 2019; Selander, 2008; Selander & Kress, 2010; Sheridan & Rowsell, 2010; West & Kempe, 2010). Design theory accounts for understanding multimodal orchestration of linguistic, visual, audio, gestural, and spatial meaning (Jewitt, 2008). Design theory concerns issues related with communicative affordances in the digital environment and how these affordances impact the conditions for learning. Design theory states that learning is a process in which a designer (teacher or student) uses a set of options available in system networks, given information and given representations, then transforms them into new representations (Kress & Selander, 2012). Learning here can be described as a process of interpretation and representation construction (Selander, 2008). The process of learning requires the transformation of meaning from one form of text to another (Kress, 2012). In a collaborative classroom environment, students together with teachers reconstruct their understanding of subject content into new representations (Forsling, 2019). Teachers' coherent, embedded, and meaningful designs encourage, stimulate, and motivate students to be more competent in designing their own representations. Designer uses existing products and artefacts in new ways concerning new situations, new problems, or demands. In other words, designers participate in actively remaking the messages (teacher's written, spoken words, multimodal representations) given in the classroom environment. Then, the designer adapts given representation in other context or problem situations (Jewitt et al., 2001). Hence, the notion of design refers to an active and dynamic process of learning where representations in different mediums are elaborated, and where re-configuration and re-contextualization of new representations occurs (Kress, 2000; Selander, 2008). At this point, learning can be identified as increased capacity to design new recognizable representations by intended context or subject area, in other words having abilities of designing new canonical representations, it is a transformational process (Selander, 2008). Design does not only refer to constructing an external representation, it firstly takes place in the human mind, internal representation (Russell, 2015).

Design theory provides different perspectives to the learning process different from the notion of Piaget (concept building), and the notion of Vygotsky (social constructivist approach). The new paradigm accounts for learning with the designer's sign production and meaning making by way of modes and media (Selander, 2008).

The design process is realized through the relationship between Available Designs (existing representations, signs, modes, and etc), Designing (process of transformation), Redesigned (transformed representations, in other words new Available Design) (New London Group, 1996). Available design simply refers to the resources of Design including grammars of all semiotic systems such as language, image, and gesture. It also consists of the meaning potentials of the modes and the new meanings that emerge with their integration because the meaning potential of multimodal text is greater than the meaning provided by the sum of modes. Designing refers to the process of transforming available designs in order to shape a new meaning, make new use of old materials. It involves re-representation and re-contextualization. All processes encountered with available designs are called designing. For instance, reading, writing, drawing, seeing, and listening are all productive activities, forms of Designing. The outcome of Designing is defined as Redesigned, a new meaning, a transformed representation. It is not a simple integration of available design, it is a new and unique product so it is also called as a new available design, a new meaning making choice. From this perspective, the students' designs, artefacts, and representations can be seen as one kind of their learning.

All these conceptualizations took into consideration, the ways of how knowledge is represented, the chosen mode, and their orchestration are crucial factors of learning in design theory (Jewitt, 2008; Selander & Kress, 2010; Leijon & Lindstrand, 2012). Thus, the multimodality gains importance because it investigates semiotic affordances within and among modes, the designer's interests, choices, context, and audience (Kress, 2000, 2003). It also provides a metalanguage which means a language for talking about meaning making interactions between modes.

2.3.2 Learning with Multimodal Representations - ARDE

How learning occurs with multimodal representations in the Multimodal Pedagogical Model is re-stated with a new approach called as ARDE (Awareness, Recognize, Design, and Evaluation) (Figure 2.5).

Studies showed that learning with representations (LwR) is a complex field of study (Prain & Tytler, 2012; Tippett, 2016), and needs an exploratory framework which addresses and enlightens different dimensions of it (Ainsworth, 2006; Tippett, 2011). Although there are some existing models (e.g. DeFT (Ainsworth, 2006), IF-SO (Waldrip et al., 2010), and RCA (Prain & Tytler, 2012)) which account for parameters of LwR, still there is a requirement for a comprehensive framework. It is due to that DeFT focuses on learning from representations rather than LwR, IF-SO emphasises the teacher, not all designers (meaning makers), RCA seems most comprehensive one since it clarifies three dimensions of meaning making: semiotic, epistemic, and epistemological (Tippett, 2016). However, it fails to explain (1) how to know form and function of different types of representation, (2) how to integrate form, function, and domain, (3) how the design should be, (4) and how the epistemic authority (teacher) in the classroom should evaluate about adequacy and competency of representations. For these reasons, from the perspective of multimodal social semiotic approach, design theory of learning, and cognitive approaches referenced in this study, new models are needed on LwR. The study proposes a new LwR approach considering the following dimensions.

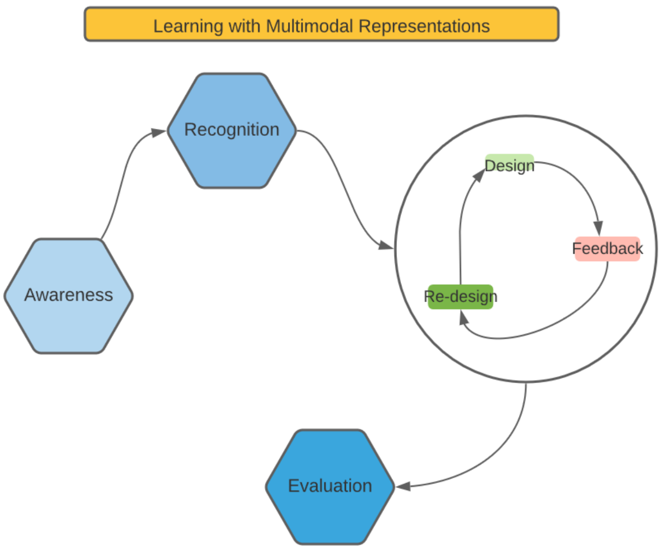


Figure 2. 5 Learning with multimodal representations

Awareness

The first step of LwR is to gain awareness and sensitivity about modes and their interactions -called as intermodal relations-, so the designer (the teacher) should arrange activities and dialogues among the designers (the students) that will improve awareness about potentials and limitations of modes and their interactions in each representation (Andersen & Munksby, 2018; Lim, 2018).

These activities should initiate negotiations on, (1) how and what modes are used in a specific subject area, (2) which mode is best suited for accomplishing different semiotic, epistemological, and cognitive demands, and (3) how and what kind of intermodal mechanisms are used and should be used in the construction of explaining a phenomenon (Jewitt et al., 2001). For instance, students are asked to identify the differences within monomodal texts including only one mode like written language or image, then they are asked which text helps them to comprehend the content better. Afterwards, teachers distribute multimodal texts which have different level of intermodal mechanisms, and ask first students why and which one (monomodal or multimodal) is better to understand the idea presented, and second ask students how modes are integrated, do they dependent or independent, in what ways they complement each other (Linebarger & Meier, 2016; McDermott & Hand, 2016). Throughout this step, students gain awareness about why and how it is important to represent a concept with multimodal representations.

Recognition

In this step, teachers should introduce underlying principles in designing coherent multimodal representations which decrease cognitive load. To do this, they should emphasize on (a) number of representations, (b) form and functions of modes, (c) how information is distributed among modes, (d) how they are orchestrated (Ainsworth, 2006). Finally, before designing, (e) they should design a representation construction process which challenges students to apply these principles.

During the recognition process, students should understand that decreasing the number of representations seems wise due to limited capacity of working memory and to minimise split attention effect. Teachers should make explicit instruction about the form and function of modes if they start a novel representation which is crucial to understand the topic (Waldrip et al., 2010). Students should understand how the function of mode is realized by its form. Thus, students recognize meaning making toolkits in reasoning, questioning, explaining, and communicating, and they comprehend what is possible to tell or not with the affordances of modes (Lim, 2018), how a representation presents and encodes information (Ainsworth, 2006). Students should understand how information is distributed among modes which can complement or constrain each other. Instructors should introduce different types of intermodal mechanisms (concurrence and complementarity) via multimodal representations. They range from decorative ones to interpretational ones. These mechanisms provide students with the metalanguage of representations. All these parameters play a crucial role for guiding refinement of representation work which will be realized finally (Tytler & Hubber, 2016). Representational work should pose representational challenges in which students come across the problematic nature of phenomena or an ill structured problem (key concept of topic), and then try to design an explanatory representation that has similarities with canonical representations. This is the last step of Recognition that initiates the design process.

Design

When the designer faces representational challenges which encourages them to investigate and extend their ideas in new contexts, a problematized issue demands them to design a multimodal representation to overcome it (Waldrip et al., 2010). In this case, the designer integrates modes considering affordances of modes and intermodal mechanisms in order to create reasonable claims (McDermott & Prain, 2016). In this design process, the designer should be encouraged to produce their own representations and hands-on activities should be applied about the topic under investigation whether in real or digital environment (Tippett, 2011). Hands-on activities should provide strong perceptual and experimental contexts and engage students' agency (Tytler & Hubber, 2016). That is, these contexts should pay attention to students' interests, values, and personal histories and perceptions which activates working memory properly. Students are directed to make interaction between content and form in multimodal representations, and how the orchestration of different modes can lead to arising coherent meaning, and thus realizing the intended aims (Lim, 2018). Students are asked to make translation and transduction within and between modes. The process can be planned from domain general to domain specific, and from simple to complicate according to students' expertise.

In brief, design is a process which emphasizes conceptualisations of the form of semiotic products (modes) (Kress & van Leeuwen, 2001, p. 21). The conceptualization may be realized internally or externally.

Evaluation

Teachers evaluate usefulness, adequacy, and competence of particular multimodal representations presented (Tippett, 2011), then give feedback to students, and ask them to re-design their external representations. Teachers are realized this process via analytical frameworks for text coherence and intermodal mechanisms proposed in this study.

2.3.3 Teaching Process

Teaching process of the Multimodal Pedagogical Model is explained with respect to Peirce's triadic relationship between sign, object, and interpretant, Robert's (1996) trialogue, and considering the parameters of social semiotic theory: semiotic system, text, and choice (interest).

Since the study claims that learning is a design, explains how to learn with multimodal representations, the aim of explaining teaching process is to describe how the learning processes should be organized as a teaching process by adapting models of New London Group (1996), Robert's (1996) trialogue, Designed by Framework (Cope & Kalantzis, 2015), and Design for Learning (Selander & Kress, 2012). In other words, it explains how the teaching process is formed according to learning steps and how learning occurs mentioned before.

The study argues for the teaching process within the same scopes of New London Group, but just making some adaptations from studies of Cope and Kalantzis (2000, 2015), Selander and Kress (2010, 2012), and Lim (2018).

Experiencing

Immersion of learners in a semiotically rich environment and meaningful practices is provided by the teacher in this step. That is, the teacher presents diverse available designs based on the world of learners' designed experiences and the new ones they do not encounter before (Jewitt, 2008; Lim, 2018). Available designs should be builded on familiar and unfamiliar ones which are scaffolded by teachers (Cope & Kalantzis, 2015). Available designs may include defined and prefabricated curricula (textbook, exercise book etc) and also may involve more sophisticated and complicated ones considering the expertise level of students (Selander, 2008).

The step can be called the preparation phase of the teaching process, because, in a sense, the teacher designs the learning environment and processes of learning first internally (theoretically), and then externally (practically) according to his/her interests. The designer determines activities of forming and transforming knowledge, informs students about key concepts of the subject, the expected product, and judgment criteria (Selander, 2008).

Conceptualizing

This phase starts with a representational challenge presented by the teacher, the challenge includes a task –according to students' interests- wherein students are encouraged to accomplish more complex tasks than they can accomplish on their own. Thus, this situation leads to collaboration between teacher and student, and makes both of them active. During the collaboration, students gain conscious awareness about teacher representation and the use of metalanguages which refer to inner and intermodal mechanisms within and between modes (New London Group, 1996). Teachers' coherent multimodal representations motivate and encourage students in accomplishing complicated tasks (Forsling, 2019).

Overt instruction is a crucial pedagogical strategy in which students are taught and recognized design elements, systematic knowledge about analytical vocabulary in meaning making, and how modes are orchestrated in constructing multimodal representations (Cope & Kalantzis, 2015; Jewitt, 2008; Lim, 2018).

Critical Framing

The students create their internal design first by analyzing teacher curated representations and then by transforming the known representations to new ones to the current contexts wherein problem is situated, using metalanguage that they become aware of. Moreover, students reflect on their conceptual understanding, designing, and design (Kress & Selander, 2012). In this step, students integrate new schemas with existing schemas in long term memory by internalizing. That is, critical framing includes two basic steps: *analyzing* and *internalizing by design*.

Critical framing is a basement for transformed practice because this process helps designers frame their growing mastery in designing, analyzing, conscious control, and understanding.

Transformed Practice

In this process, students are denaturalized and made strange what they have learned before. A new representational challenge is presented in different contexts. They are asked to recreate and recontextualize meaning across context (Jewitt, 2008). In one respect, transformed practice starts the teaching process again, returning to where we began.

Designer applies learnings, and takes experiential, critical, and conceptual knowledge from one context and adapting them to a different context (Lim, 2018). Briefly, getting out of current context, students are introduced to a new task, in order to show whether the representation works in new contexts, and are asked to apply it in a new context. Thus, the teaching cycle starts over again. That is, as stated by Kress: “engagement with it in transformative action; which constantly remakes my inner resources; and in that, changes my potential for future action in and on the world.” (Kress, 2010, p. 14).

All these four stages mentioned above are operationalized around different Peircian triads of meaning making. The study explains these triads based on the interlocking triad of Waldrip, Prain, and Carolan (2010). The triad is based on Peirce's triangular model of meaning making. According to this framework, the learning process includes “Teacher Conception (TC)”, “Teacher Representation (TR)”, “Student Conception (SC)” and “Student Representation (SR)” elements (Figure 2.6). Each pair forms Peirce meaning trialogy with the content to be taught / learned, "Domain (D)". That is, teaching and learning is a dynamic cyclic ‘designing’ process among the domain taught (D), teacher representations (TR), teacher conceptions (TC), student representations (SR), and student conceptions (SC) (Waldrip et al., 2010).

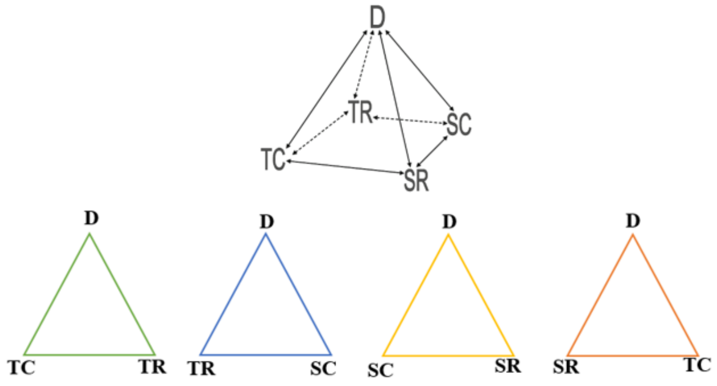


Figure 2. 6 Interlocking triad of Waldrip, Prain, & Carolan (2010)

In situated practice, teacher selects key concepts (domain) to tell, design his or her internal representations by choosing among all available design options (TC), and s/he constructs external representations (TR), analyze RPS's adequacy and competency, and then plans how to present them considering two important patterns: (1) decreasing extraneous load and increasing/decreasing intrinsic load according to the level of student expertise, (2) designing a representational challenge process.

In overt instruction, domain (coherent and meaningful multimodal representations) and representational challenge presented by teachers become a set of all new available designs for students (D). Teachers introduce metalanguage/intermodal mechanisms of multimodal representations (TR), and then students construct their own new conceptions/new schema in their mind/internally (SC). In the intersection of overt instruction and critical framing, internal designing continues. At the end of critical framing, students design their external representations combining existing schema with new schema (SR).

In transformed practice, students are immersed into a new context (D). According to the needs of new context, they construct their conceptions (SR).

Briefly, (1) teachers firstly design multimodal representations internally, then externally (teaching materials), (2) present them to the students, (3) students comprehend these texts, and design what they learn as a multimodal text in their minds, (4) and then they design a learning product multimodally to show what they have learned, (5) finally teachers assess these products, and give feedbacks.

2.3.4 The CHC-Based Multimodal Generative Learning Approach

The approach proposed in here aims to explain how multimodal learning occurs cognitively through synthesizing three distinct approaches (The CHC theory, Cognitive Load Theory, and Generative Learning Theory), since one of the most important pillars of a pedagogical model must also consider the cognitive aspect of teaching and learning.

Since the knowledge is presented through a complex combination of modes – multimodal texts- with different types of mediums, the new digital world needs a distinct type of problem solvers and meaning makers (Pellegrino & Hilton, 2012; Fiorella & Mayer, 2015). Social semiotics approach to multimodality calls those meaning makers as 'a designer'. The designer is capable of understanding meaning arising from a combination of modes, interpreting these meanings, selecting appropriate modes and orchestrating them in order to solve new problems posed by new contexts. Finally, he or she presents his or her understandings through multimodal representations to particular social communities. That is, s/he designs his or her representations internally in mind, and then designs outwardly as an external representation. Therefore, the new and effective teaching and learning approaches should consider what content is presented in which ways by paying attention to the functioning of the learners' cognitive architecture in designing process, and designer's cognitive activity in order to design such a pedagogical model (Donnelly, 2010; McDermott & Hand, 2016; Schnotz & Kürschner 2007).

In this respect, the new approach explains these elements through explicit integration of Multimodal Theory of Learning-Design, Cattle-Horn-Carroll Theory of Cognitive Abilities, Cognitive Load Theory, and Generative Theory of Learning. Shortly, the former implies that each mode provides different potential and limitations for meaning making, and also orchestration of modes enables meaning greater than the sum of each mode. Thus, designers should have gained awareness about semiotic affordances of modes, and encounter different types of multimodal texts. The instruction should provide opportunities for students to analyze intersemiotic mechanisms within multimodal text and to design new ones in new context by transforming the available one. The latter accounts for explaining how information processing occurs, which cognitive parts are being activated in the designing process. Third one clarifies categorization of the types of cognitive load placed on working memory, and guides researchers about the most desirable learning situations in which instruction is designed to initiate appropriate cognitive load. The last one which is stemmed from dual coding theory refers to how students actively engage in three cognitive processes (selecting, organizing, and integrating) during learning.

Central to this offered cognitive based theory is to explain how appropriate cognitive load can initiate in representing an idea designed with different modes during the cognitive procecsses being activated by distinct cognitive parts (Donnelly, 2010).

The next section is about addressing this claim by clarifying each theory first, and then is about how these are elaborated and extended in the approach of CHC Based Multimodal Generative Learning. A distinct researcher Gunther Kress also addressed the need in which multimodal theory and a cognitive approach on teaching and learning is incorporated:

> "…enable the beginnings of working descriptively and analytically… whether around social, communicational and/or semiotic categories… or epistemological categories such as information and knowledge, or semiotic categories such as modes and their affordances, or pedagogic and/or psychological categories such as learning (Kress, 2005, p. 21)."

As multimodal learning theory has been explained in previous sections, we will just mention about CHC Theory, Cognitive Load Theory, and Generative Learning Theory here.

2.3.4.1 The Cattle-Horn-Carroll (CHC) Theory of Cognitive Abilities

The CHC theory tries to classify the intelligence factor and explain how and why individuals differ in different intelligence elements by gathering two intelligence theories related to the cognitive abilities of the most well-known person

(Schneider & McGrew, 2018). McGill and Dombrowski (2019) identified CHC theory as a combination of Horn and Cattell's Extended Gf-Gc theory (E Gf-Gc; Horn & Blankson, 2005; Horn & Noll, 1997) and Carroll's Three-Stratum Theory (3S; Carroll, 1993). The theory involves two components. The former is about a taxonomy of cognitive abilities. The latter is about explaining how and why people differ in their distinct cognitive abilities (Schneider & McGrew, 2012).

In 1993, the American psychologist John B. Carroll, in his book Human *Cognitive Abilities: A Survey of Factor-Analytic Studies*, presented 'A Theory of Cognitive Abilities: The Three-Stratum Theory'. Carroll had meta-analysed 461 classic factor analytic studies of human cognition, and proposed a solid theory on human intelligence (Carroll, 1993, p. 78-91). The theory includes three levels of cognition from specific to general: narrow abilities (stratum I), broad abilities (stratum II) and general abilities (stratum III).

General abilities refers to general intelligence, and it is symbolized as *g* which classifies into two main factors *general fluid* (*Gf*) and *general crystallized* (*Gc*) (Cattell, 1943). He defined two terms as:

> *"Fluid ability has the character of a purely general ability to discriminate and perceive relations between any fundamentals, new or old. It increases until adolescence and then slowly declines. It is associated with the action of the whole cortex. It is responsible for the intercorrelations, or general factor, found among children's tests and among the speeded or adaptation requiring tests of adults.*
>
> *Crystallized ability consists of discriminatory habits long established in a particular field, originally through the operation of fluid ability, but no longer requiring insightful perception for their successful operation. (p. 178)"*

Cattell (1943) answers the question of why and how people differ in their cognitive abilities with the terminology of *investment*. He states that all of these differences originate from investment in societal, familial, and personal areas. As shown in Figure 2.7, *gf* and *gc* are strongly correlated because *gf* causes *gc* via investment (Schneider & McGrew, 2012).

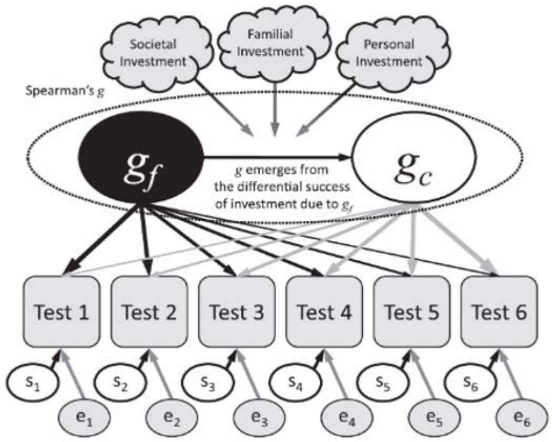


Figure 2. 7 Cattell's investment theory (Schneider & McGrew, 2012, p.104)

From 1965 to 1990, several researchers studied to extend the theory, in 1991, Horn (supervised by Cattell) expanded the Gf-Gc theory by adding 9-10 broad abilities, they are called as fluid intelligence (Gf), crystallized intelligence (Gc), short term acquisition and retrieval (Gsm), visual intelligence (Gv), auditory intelligence (Ga), long-term storage and retrieval (Glr), cognitive processing speed (Gs), correct decision speed, and quantitative knowledge (Gq) (Schneider & McGrew, 2012).

Over 100 years of research by a diverse set of scholars, Schneider and McGrew (2012) has revised and described the CHC theory in the third edition of the book: Contemporary Intellectual Assessment.

- **Revised CHC Theory**

As shown in Figure 2.8, general intelligence is the broadest of all cognitive ability constructs, including broader abilities. And, broad abilities consist of narrow abilities. In the following section, broader abilities and narrow abilities will be described.

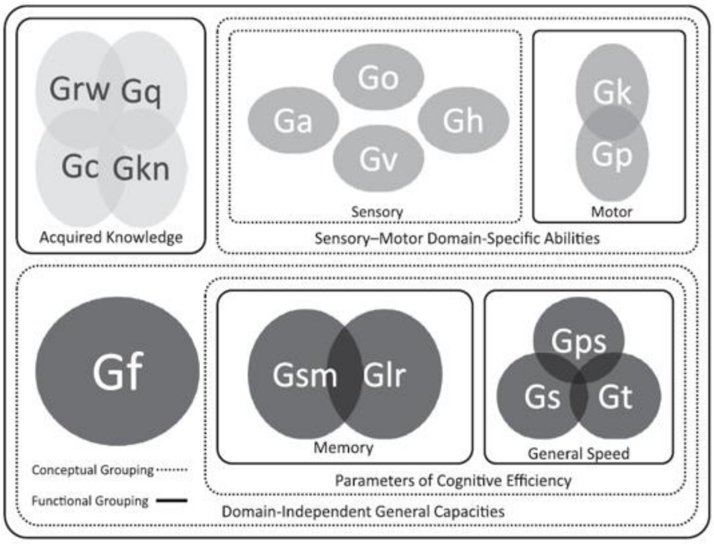


Figure 2. 8 Conceptual and functional groupings of broad CHC abilities (Schneider & McGrew, 2012, p.135)

Fluid Reasoning

Gf can be described as solving unfamiliar problems which are novel and "on-the-spot" problems by controlling the attention. It rarely depends on prior learning and previously learned habits. It is most shown in abstract reasoning. It is operated through conjunction of background knowledge and automatic responses. It is generally used if current schemas are inadequate to meet the demands of a new situation. It is revealed in the processes of hypothesis generation and confirmation, classification of unfamiliar stimuli, identification of relevant similarities, inferential reasoning, and so on.

It includes three narrow abilities. (a) Induction (I) refers to the ability to observe a phenomenon and discover the underlying principles or rules that determine its behavior. (b) General sequential reasoning (Gr) refers to the ability to reason logically, using known premises and principles. (c) Quantitative reasoning (Gq) refers to the ability to reason, either with induction or deduction, with numbers, mathematical relations, and operators.

Memory

Memory splits into two categories: *primary and secondary memory.* The former concerns information packaged in short-term memory, accessible to consciousness. The latter deals with information packaged in long-term memory, not easily accessible to consciousness.

- **Short Term Memory (Gsm)**

Gsm can be described as encoding information, and maintaining it in one's immediate consciousness.

It involves two narrow abilities. (a) Memory span refers to encoding information in primary memory, easily accessing the information in the same sequence in which it was represented. (b) Working memory capacity implies orienting the focus of attention to the transformations of information within primary memory.

- **Long Term Memory (Glr)**

Glr is capable of storing, consolidating, and retrieving information over long periods of time.

Glr consists of two narrow abilities. (a) Learning efficiency means having abilities of recalling by combining previously unrelated information, remembering semantically related information like narrative, and listing the information recalled in any order. (b) Retrieval fluency refers to the speed of accessing information in long-term memory. The more one can construct ideas rapidly from memory, the more one has potential to combine ideas in creative ways. In other words, retrieval fluency facilitates the process of creativity. Retrieval fluency abilities can be described in various forms: ideational, associational, expressional, naming, word, and figural fluency, also in the form of figural flexibility.

Glr and Gc have distinct focuses. While Glr deals with the process of memory (storage and retrieval), Gc concerns the breadth of information stored in long-term memory.

Cognitive Speed

- **Processing speed**

Gs refers to the fluency and quickness in performing simple and repetitive cognitive tasks. For example, the speed of reading a text with full comprehension, the rate of writing correctly by generating or coping, the speed of comparing similarities and differences between visual stimuli.

- **Reaction and Decision Speed (Gt)**

Gt can be described as the rate of making simple and plausible decisions when choices are presented once. For instance, speed of reaction time to the stimulus or speed of making simple choices.

- **Psychomotor Speed (Gps)**

Gps refers to speed and fluidity in movements of the physical body, such as speed of arm and leg movement, writing speed, and speed of articulation.

Acquired Knowledge

- **Comprehension knowledge (Gc)**

Gc can be identified as having depth and breadth knowledge and skills which seems valuable by one's culture because each culture appreciates certain skills and knowledge distinct from others. These knowledge should be practical in culture, these skills should be valued. Gc includes narrow abilities of language development, general verbal information, listening ability, lexical knowledge, communication ability, and grammatical sensitivity.

- **Domain-Specific Knowledge (Gkn)**

Similar to Gc, Gkn refers to being mastered in a specialized content area, and having depth and breadth knowledge about this subject area. It is obtained according to interest, career, and hobby of one's. Gkn involves narrow abilities of knowledge of signing, foreign-language proficiency, geography achievement, and general science information, mechanical knowledge, knowledge of culture, and knowledge of behavioral content.

- **Reading and Writing (Grw)**

Grw is having the depth and breadth of knowledge and skills in reading and writing. Having mastered skills in Grw facilitates reading and writing, the one with high Grw spend little effort and experience little difficulty in this process. This ability can give clues about one's language improvement. Grw includes narrow abilities of reading decoding, reading comprehension, reading speed, spelling ability, writing ability, and writing speed.

- **Quantitative Knowledge (Gq)**

Gq is having the depth and breadth of knowledge and skills in mathematics. People with high Gq easily comprehends mathematical symbols, operations, computational procedures, and other math related skills. It includes two narrow abilities: mathematical knowledge and mathematical achievement.

Sensory and Motor-Linked Abilities

Sensory and motor linked abilities are attached to well defined regions and functions of the cerebral cortex as distinct from other general abilities, and they address sensation and perception. The first refers to detection of stimulus, the other refers to making sense of stimulus.

- **Visual Processing (Gv)**

Gv implies having abilities of solving simple or difficult problems by using simulated mental imagery which refers to a combination of transmitted visual information and perceived images. It includes an array of various narrow abilities, e.g. visualization, speeded rotation, visual memory, spatial scanning, perceptual alterations, and etc.

- **Auditory Processing (Ga)**

Ga can be described as the ability to detect and process nonverbal information in sound. It consists of phoenetic coding, speech sound discrimination, resistance to auditory stimulus distortion, memory for sound patterns, musical discrimination and judgment, absolute pitch, and sound localization.

- **Olfactory (Go), Tactile (Gh), Kinesthetic (Gk), Psychomotor (Gp) Abilities**

Go refers to the abilities to detect and process meaningful information in odors. Gh in haptic sensations, and Gk in proprioceptive sensations. Gp can be identified as using physical body movements with precision, coordination, and strength.

At this point, giftedness is defined as having outstanding aptitudes in at least above mentioned ability domains by Gagne (2004). In other words, gifted have a degree which placed him or her among the top ten percentage of their peers in at least one specific ability domain (memory, cognitive speed, comprehension knowledge skills, and sensory and motor linked abilities).

Information Processing in CHC Theory

All these abilities taken into consideration, CHC theory proposed that information processing is operated through a model as shown in Figure 2.9 (Schneider & McGrew, 2012). This model has powerful attributes in describing how meaning making or learning occurs.

Briefly, the model states that environmental input stimulates sensory receptors, then sensory-perceptual linked abilities (Gv, Ga, Go, Gh, Gk) describe and detect the complexity of perceptual processing, and then transfer meaningful information in working memory. At this point, Gsm encodes information, maintains and processes it in one’s immediate consciousness. Then, Gf discovers the underlying principles or rules that determine behaviour of stimulus. Glr strives to store the information transferred with the help of Gc, Gkn, Grw, and Gq in long term memory. After the storage is completed, new schemas are constructed. When a person encounters a problem that is required to be solved, Glr becomes activated, and the abilities in Glr, general speed and the psychomotor abilities determine how to overcome it with precision, coordination, and strength.

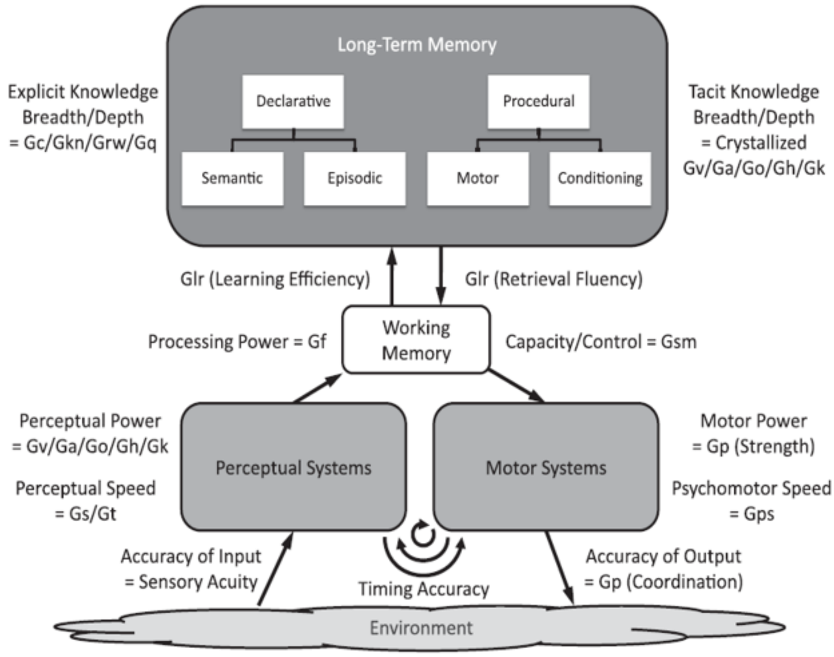


Figure 2. 9 CHC abilities as parameters of ınformation processing (Schneider & McGrew, 2012, p.136)

2.3.4.2 Cognitive Load Theory (CLT)

CLT accounts for determining types of cognitive load builded on working memory (Schnotz & Kürschner, 2007). The study uses the theory in explaining how the interactivity level between image and text modes burden a cognitive load on working memory, how it can be decreased or increased. The theory is constructed depending on three premises.

1. *Multiple Memory Stores*: CLT categorizes memory stores into two parts. While working memory is identified as a limited capacity to hold information temporarily, long-term memory has extensive capacity to hold information permanently (Sweller, 2005). Information in working memory is losted if it is not rehearsed and assimilated into long-term memory.

2. Cognitive Schemata: Storing information meaningfully in long-term memory is realized through constructing new schemata or adapting the old one with new one.

3. *Cognitive Load:* The term basically refers to the need for a required resource for handling a particular task in working memory. Any input from sensory modes

burdens a cognitive load on working memory for processing. Hence, the more information and noncoherent presentation students are exposed to, the more cognitive load increases and the harder it is to process the information into long-term memory.

There are two types of cognitive load placed on working memory: intrinsic and extraneous load. Intrinsic load arises from the nature of a particular activity itself. It is called a natural complexity (Schnotz & Kürschner, 2007). The degree of complexity differs according to interactivity between different elements of information represented by a multimodal text. If the elements are independent of each other, the low interactivity occurs. The more dependency results in higher interactivity. The higher the interactivity, the greater the intrinsic load (Sweller & Chandler, 1994). Based on the level of learner –expertise or lower level-, interactivity should be determined (Schnotz & Kürschner, 2007). Extraneous load origins from the attributes of instructional techniques used. Poorly designed instruction causes more extraneous load, so instructional design should be oriented to decrease the extraneous and overall load in learning situations. However, in some cases researchers state that cognitive load can improve learning, this is called a germane load, thus, the desirable learning environments aim to decrease extraneous load while increasing germane load.

Depending on these premises, learning is described as changes in schemata in CLT. It means that information is processed from working memory to long term memory by designing new schemata or changing existing schemata. The cognitive load emerges from the nature of activity and instructional techniques should be aligned regarding the needs of learners (e.g expertise or low level students) in order to realize effective teaching and learning.

2.3.4.3 Generative Learning Theory

Multimodal representations dominantly include verbal (written text, spoken words) and nonverbal (image) modes. Generative theory guides the present stuyd in explaining how a designer’s cognitive system first processes imagery and linguistic information separately in nonverbal and verbal mental systems, and then how he or she integrates these information in order to achieve an understanding of the content implied by the representation (Clark & Paivio, 1991; Donnelly, 2010). In short terms, generative theory mentions in which ways the designer processes the interplay between text and image (Mayer, Steinhoff, Bower, & Mars, 1995). Such an interplay is multimodal by nature. It includes the combination of definite principles of design and orchestration.

Generative theory accounts for information processing based on Dual Coding Theory (DCT) studies. DCT explains information processing as making connections between mental representation in verbal and visual systems (Cheng & Gilbert, 2015; Donnelly, 2010). Two important claims of DCT are that (1) visual and verbal systems are two independent but interconnected functional systems for information processing, and (2) encoding information in both systems makes recalling and manipulation easier (Paivio, 1986). According to DCT, coherent combinations of verbal and visual systems facilitate learning (Cheng & Gilbert, 2015). These assumptions seek to explain associative relations within verbal and visual systems, and clarify referential connections between them as shown in Figure 2.10 (Paivio, 2014).

From the perspective of DCT, generative learning indicates that learning starts from instruction to sensory motors. That is, multimodal representations transferred by the instructor enters designers' cognitive systems through sensory memory. The designer selects appropriate ones according to his or her interests, and then transfers them to the working memory. In working memory, the designer makes referentional and associative connections between and within visual and verbal systems. Finally, learners activate prior knowledge in long term memory and incorporate the new one and old one into a new conceptual schema which is a unique text of their own. That is, information is processed actively by designers, and then the information is transformed into knowledge by making conscious interactions among prior knowledge, current experiences, and external information resources (Tippett, 2016).

As seen in Figure 2.10, the designer makes senses –learns- the instructional material presented to them applying appropriate cognitive processes including selecting, organizing, and integrating (Fiorella & Mayer, 2015). The former refers to pay attention to relevant external representations (*spoken words, printed words, and graphics*, *visual images and auditory sounds*). The latter refers to organizing them in working memory by making associations and referential connections. The last one refers to integrating organized multimodal representations with relevant prior knowledge –schema, models, and principles- retrieved from long-term memory.

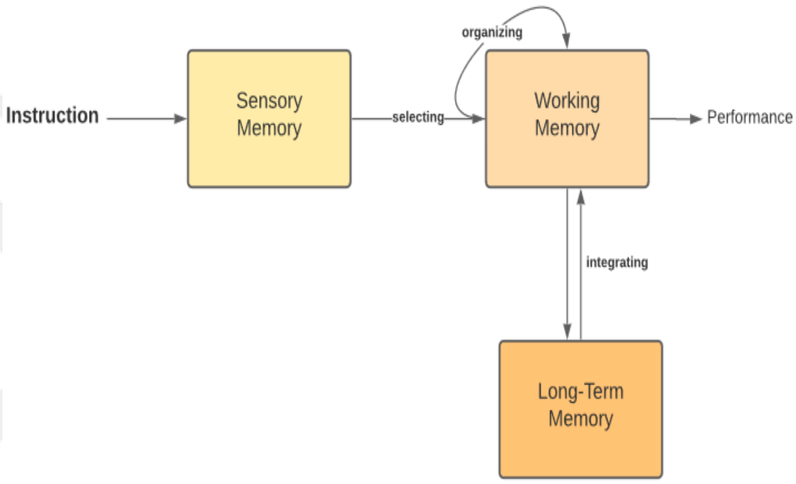


Figure 2. 10 Generative theory of learning

That is, learning can be defined as transforming the external representation into the internal representation. Therefore, learning not only depends on the materials presented by the instructor, but also individual backgrounds.

All the theories mentioned above considered, CHC-Based Multimodal Generative Learning Approach ensue from synthesizing Multimodal Theory of Learning-Design, Cognitive Load Theory, Generative Learning Theory, and Cattle-Horn-Carroll's Cognitive Theory, in order to show how learning occurs in multimodally rich environments, and how multimodality is important in the process of learning as seen in Figure 2.11. The theory also guides how the teaching process should be designed according to the level and needs of students.

Classroom environment (teaching materials, available designs, teachers' external representations, and teachers' instructional design) is organized by way of decreasing extraneous load, and increasing or decreasing intrinsic load considering level of students. Intrinsic load refers to interactivity between different dimensions of information represented by available designs. Dimension means the extent to which each representation contributes to the overall message transmitted by the multimodal text. Intrinsic load is also impacted by intersemiotic (intermodal) relations between modes in each representation. Intermodal relations are important attributes of multimodal texts which create integration of verbal and imagery modes rather than a mere linkage between the two modes. Each intermodal mechanism (concurrence, complementarity) results in a different level of intrinsic load.

CHC-Based Multimodal Generative Learning Approach simply states that available designs stimulate functional systems of verbal and imagery. In sensory and perceptual systems, the ability of visual processing (Gv) and auditory processing (Ga) perceive, select appropriate stimuli; manipulate, discriminate, reason and work on them with the help of the ability of processing speed (Gs). Gs is defined as attentional fluency or attentional speediness which means controlling attention automatically and quickly. It is about concentrating on comparing or scanning similarities and differences in each stimulus. After this initial processing, sensory and perceptual systems transferred information to working memory (Gwm).

In Gwm, verbal and imagery information are encoded, maintained and manipulated in active attention which focuses on task relevant stimuli and ignores task irrelevant stimuli. The capacity of realizing this process is determined by two factors: short term storage and attention control. Thus, working memory capacity can be described as the ability of encoding and maintaining information in active attention. Throughout this process, at first, verbal and imagery information are organized separately by making associative connections. Then, verbal and imagery information are integrated by making referential connections with the help of fluid reasoning (Gf). Gf is used to solve on-the-spot problems that we encounter in daily lives, the solution of these problems less depends on previously learned schemas, and they require automated responses. It seems mostly in abstract reasoning, inferential reasoning, generalization of old solutions to new problems (maybe incorrectly), the perception of relevant consequences of newly acquired knowledge, and so on. Fluid reasoning includes three narrow abilities: induction, deduction, and quantitative reasoning. At the end of information processing in working memory, initial mental representation (internal representation) is formed.

Initial mental representation is *transformed* into final mental representation as a knowledge (new schema-transformed knowledge) through learning efficiency (Gl). Gl refers to the ability of learning and storing new information in long term memory. Gl helps to construct a meaningful link between initial mental representation and existing schema, and then form declarative (semantic and episodic) and procedural (motor and conditioning) knowledge. In this forming process, comprehension knowledge (Gc), domain specific knowledge (Gkn), reading and writing (Grw), quantitative knowledge (Gq) play crucial roles. Gc can be described as the ability to comprehend subject related knowledge. It consists of the depth and breadth of both declarative and procedural knowledge.

In the process of handling problems individuals encountered or during a simple communication, they use the ability of retrieval fluency (Gr) in order to *construct and present* their external representations. Gr can be described as retrieving verbal and nonverbal information or declarative and procedural knowledge stored in long term memory fluently. Gr with narrow abilities facilitates designing external representations in creative ways. It plays a crucial role before performing, presenting, or communicating external representations. The following narrow abilities of Gr take part in realizing this: ideational fluency, expressional fluency, word fluency, figural fluency, and figural flexibility. The former is about producing a set of ideas regarding a specific condition rapidly. The latter refers to expressing an idea in different ways. The third one is about producing words which have common phonological or semantic features. Figural fluency is about drawing a set of visual elements to solve figural problems. All these abilities are performed in precision and coordination with the abilities of psychomotor abilities (Gp), reaction and decision speed (Gt), and processing speed (Gs). Gp can be described as performing physical body motor movements. Gt refers to making simple and correct decisions or judgments when encountered a problem.

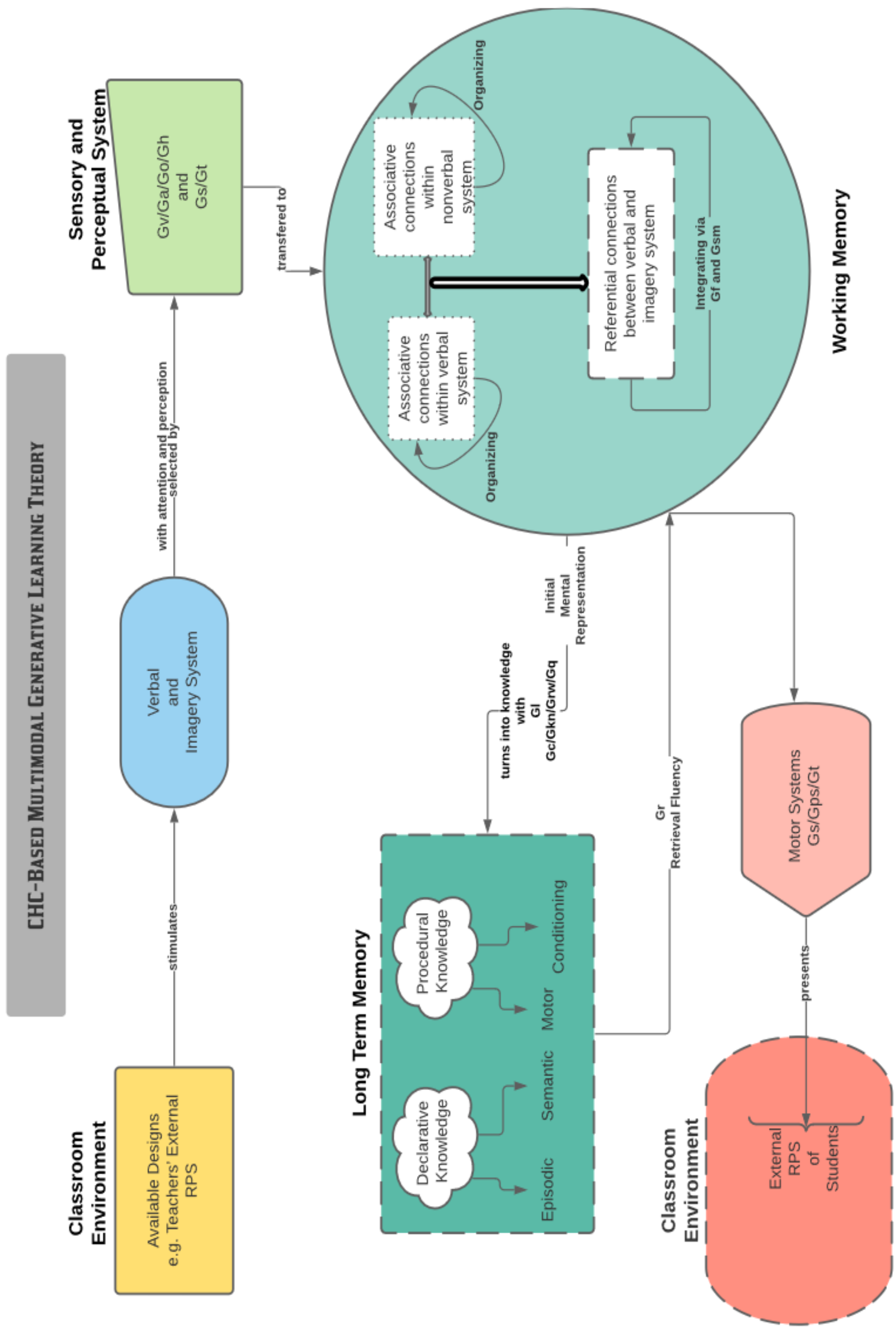


Figure 2. 11 CHC-based multimodal generative learning approach

2.4 The Multimodal Pedagogical Model (MpM)

The MpM is constructed upon by considering how learning and teaching process occur multimodally, and how cognitively these processes realize. The aim of designing such a model is proposing an environmental catalyst in order to improve a specific talent of ToGs called representational competence considering the elements of enrichment.

All these theories are considered, the definition of pedagogy regarding this study is a design of learning activity sequences, the method and practice of teaching (Cope & Kalantzis, 2015; Lim, 2018). Pedagogy is about how any subject content is taught and how learning occurs.

In this context, the study claims that any successful theory of pedagogy is builded on how the cognitive system works, how learning occurs, and how the teaching should be taking into account the first two. The model (Multimodal Pedagogic Model-MpM, Figure 2.12) explains all of these with the theories mentioned above: Theory of Learning-Design, CHC-Based Multimodal Generative Learning Approach, Learning with Multimodal Representations, and Multimodal Teaching Process. The MpM clearly defines and describes how learning occurs, how the teaching should be in four main steps in which teachers and students are active designers of their teaching and learning processes.

These four steps are realized around different Peircian triads between 'Domain', 'Teacher Conception (TC)', 'Teacher Representation (TR)', 'Student Conception (SC)' and 'Student Representation (SR)'.

2.4.1 Designing Pedagogical Environment (DPE)

First step is called DPE in which learners are immersed into a semiotically rich environment and meaningful practices. This step reflects the attributes of *activities* subcomponent of the development process in Gagne's DGMT. That is, learners are provided to gain access to learning environment, content, a differentiated challenging teaching and learning approach with regard to enrichment modalities, such as enrichment in density, enrichment in difficulty, enrichment in depth, and enrichment in diversity (Gagne, 2007).

The teacher presents diverse available designs based on the world of learners' prior designed experiences and the new ones they do not encounter before (Jewitt, 2008; Lim, 2018). Available designs should be builded on familiar and unfamiliar ones which are scaffolded by teachers (Cope & Kalantzis, 2015). In this step, teachers design this environment as a scaffolder by harmonizing and orchestrating available designs and identifying key concepts in order to send conscious signs towards students' sensory and perceptual system (Cope & Kalanzis, 2000; The New London Group, 1996; Waldrip et al., 2010).

The step can be also called the preparation phase of the teaching process, because, in a sense, the teacher designs the learning environment, available designs, and processes of learning first internally (theoretically, in mind), and then externally (practically). The designer determines activities of forming and transforming knowledge, informs students about key concepts of the subject, the expected product, and judgment criteria (Selander, 2008). Representational challenge enabled by topic and guidance on representational task should be considered in order provide students to consolidate their understandings at the completion of the topic (Waldrip et al., 2010).

Available designs include defined and prefabricated curricula and beyond the curricula as an enrichment in density, depth, and diversity; and teaching materials (textbook, exercise book, other multimodal representations in real or digital world such as infographic, animation, video and etc) and also involve more sophisticated, complicated and challenging teaching materials as enrichment in difficulty (Selander, 2008). Available designs also consist of teacher's representational competence and students' prior knowledge. RC refers to the ability of selecting the best suited signifier of the concept taught or designing best suited one regarding learners' interest in order to scaffold interpretation made by them. Selecting and designing the most appropriate one also requires the ability of having awareness and analyzing intermodal mechanisms in representations. RC also refers to enable them to explore and explain their ideas, preparing representational challenges which elicit their causal accounts of phenomena, allow opportunities to integrate their representations into a meaningful summative account of the topic, and extend these ideas to a range of new situations. The teacher plans and manages the learning process where knowledge is redesigned and contextualized as if it was a research process, and guides them to design learning products. The main purpose is to ensure that information is learned in a transformational way.

The sequence includes three elements: (a) student representation, (2) student interests, and (3) student perceptions. Teachers provide opportunities for students to re-represent their claims in generating, manipulating and refining representations. They encourage them to be active and exploratory in this process. Activities need to take into account students' interests and values, and also need to have a strong perceptual context.

All those available designs mentioned above should be designed considering two important factors. (1) They should be arranged in order to send signs and modes to sensory and motor linked abilities (sensation and perception) (McGrew & Schneider, 2013). *Sensation* refers to the detection of a stimulus. *Perception* refers to complex processing of sensory information to extract relevant information from it (i.e., literally to make *sense* of it). (2) They should be organized by way of decreasing extraneous load, and increasing or decreasing intrinsic load considering the level of students. These arrangements and organizations improve awareness and sensitivity towards modes and their interactions -called as intermodal mechanisms- by nature, because all are constructed according to semantic and paradigmatic principles in the semiotic system. At the end of the DPE, available designs stimulate functional systems of verbal and imagery.

Briefly, in DPE, teacher selects key concepts (domain) to tell, design his or her internal representations by choosing among all available design options (TC), and s/he constructs external representations (TR), and then plans how to represent them considering two important patterns: (1) decreasing extraneous load and increasing/decreasing intrinsic load according to the level of student expertise, (2) designing a representational challenge process.

2.4.2 Teaching Metalanguage (TM)

This phase starts with a representational challenge in a complicated task posed by the teacher. The complicated task is obligated to a collaboration between teacher and learner, and makes both of them active. The task should be arrenged in a way that push students to the cutting edge of their learning capacity and also do not make their feel helplessness. During the collaboration, teachers present their own external representations, and start negotiations with learners. The process is called metalanguage teaching, or as stated by New London Group (1996) overt instruction. Overt instruction is a crucial pedagogical strategy in which students are taught and recognized design elements, systematic knowledge about analytical vocabulary in meaning making, and how modes are orchestrated in constructing multimodal representations (Cope & Kalantzis, 2015; Jewitt, 2008; Lim, 2018). In a sense, the learner is presented with a science toolkit of types of representations for using them in reasoning about and explaining phenomena.

In this way, students gain conscious awareness about and recognize affordances and limitations of teacher representation and the use of metalanguages which refer to inner and intermodal mechanisms within and between modes (New London Group, 1996). During the recognition process, teacher pays attention to make explicit instruction about the followings. (1) The form and function of modes if he starts a novel representation, (2) how the function of mode is realized by its form, (3) how a representation encodes and presents information, (4) how information is distributed among modes which can complement or constrain each other, and (5) introduce different types of intermodal mechanisms (concurrence and complementarity).

While this recognition, awareness and negotiation process continues, the learner begins to design his own internal representation, that is, to conceptualize the subject taught in his mind. In broad terms, conceptualization starts from stimulations arising from representations to sensory and perceptual systems. That is, multimodal representations transferred by the instructor enter designers' cognitive systems through sensory system. Those are accepted as a set of all new available designs for students (D). In the sensory and perceptual system, the designer selects appropriate ones according to his or her interests with the ability of visual processing (Gv) and auditory processing (Ga). The abilities perform perceiving, selecting appropriate stimuli, manipulating, discriminating, reasoning and working on them with the help of the ability of processing speed (Gs). Gs is about concentrating on comparing or scanning similarities and differences in each stimulus.

New ones are selected and manipulated by Gv and Ga with the help of Gs, and then transferred to working memory (Gwm). In Gwm, available designs are encoded, maintained, manipulated and finally organized verbally and imagery separately by making associations, and then they are integrated by making referential connections with the help of Gf, finally initial internal representation is designed (freshed/pure SC). Gf is used to solve on-the-spot problems that we encounter in daily lives, the solution of these problems depends less on previously learned schemas, and they require automized responses. At the end, Freshed SC/ pure schema constructed is transferred to long term memory.

In overt instruction, domain (coherent and meaningful multimodal representations) and representational challenge presented by teachers become a set of all new available designs for students (D). Teachers introduce metalanguage/intermodal mechanisms of multimodal representations (TR), and then students construct their own new conceptions/new schema in their mind/internally (SC). In the intersection of overt instruction and critical framing, internal designing continues.

2.4.3 Critical Framing (Internalizing) (CF)

The phase includes two main parts: analyzing and internalizing. The former means that a designer views and analyzes patterns and features of multimodal texts curated by teachers or any designers according to metalanguage that are taught by teachers. Analyzing involves making logical connections like deduction and induction, process of reasoning, and establishing functional relations such as causation. The process is realized functionally through analyzing structure, function, context of knowledge and the way how the knowledge is presented. Learners ask themselves, and interrogate the texts provided by the pedagogical environment the following questions, what does it do? How does it do it? What are its structure, function, relations, and context? (Cope & Kalantzis, 2015; Lim, 2018).

The latter refers to the internalizing process in which the designer constructs a final schema in mind by viewing and analyzing teacher-curated multimodal texts with respect to his/her interests and choices.

Based on these views and analyzes, the designer transforms initial mental representation in working memory to final mental representation in long term memory as a knowledge (new schema-transformed knowledge) through learning efficiency (Gl). Gl refers to the ability of learning and storing new information in long term memory. Learning and storing are realized through comprehension knowledge (Gc), domain specific knowledge (Gkn), reading and writing (Grw), quantitative knowledge (Gq).

Critical framing is a basement for transformed practice because this process helps designers frame their growing mastery in designing, conscious control, and understanding. At the end of critical framing, students design their external representations combining existing schema with new schema (SR).

2.4.4 Transformed Practice (Externalizing) (TP)

The stage is called *the applying* process by Cope and Kalantzis (2015). It is about students "learning by applying experiential, conceptual or critical knowledge" (Cope & Kalantzis, 2015, p. 21). This includes the designers constructing external representation as a way of learning and sign of their learning. The design is realized in two distinct ways, applying appropriately and applying creatively. The former refers to applying designed representation in similar contexts, its consequences are predictable and typical.

The latter simply refers to adapting representations to a quite different setting. External representation is recreated and recontextualized across new contexts. Designer applies external representation, and takes experiential, critical, and conceptual knowledge from one context and adapting them to a different context (Lim, 2018). With statements of Cope and Kalantzis (2015, p. 22) “It is a process of making the world a new with fresh and creative forms of action and perception. Now learners do something that expresses or affects the world in a new way, or transfers their newly acquired knowledge into a new setting.” In a sense, the designer is made strange to the current context, is introduced to a new task, and is asked to re-form designs in the new context in order to examine whether the representation works or not. In one respect, transformed practice starts the teaching process again, returning to where we began, but now it is performed as reflective practice. New practices are transferred to a pedagogic environment with its own goals and values. This process provides designers to revise what they have learned before, and expands the network of schema in their mind. That is, as stated by Kress “…engagement with it in transformative action; which constantly remakes my inner resources; and in that, changes my potential for future action in and on the world.” (Kress, 2010, p. 14).

Briefly, in this stage in, the design (SC) created in the mind is transformed into a learning product, that is called externalization – external representation (SR). The students create their design by transforming the known representations to new ones to the current contexts wherein problem is situated, using metalanguage that they become aware of. The student expresses the signs, modes, and scientific conventions that he perceives through an external representation. This product is a representational work and shows the student's current conceptual structure and epistemological value of knowledge. According to social semiotics, external design is any representation that other people can perceive physically. These representations can be text, speech, model, graphic, infographic, diagram or an animation. As scientific knowledge is inherently multimodal, students are expected to design rich signs and representations with a multimodal structure of their own reality, that is, their internal design (Kress, 2008; Selander, 2008; Andersen & Munksby, 2018; Tang et al., 2019).

Within the external design process, student interests, abilities, and preferences are taken into account (Tang et al., 2019; Waldrip et al., 2010). Learners are asked and encouraged to make their own representations. They are exposed to strong perceptual and experimental contexts which engage and activate them. Since semiotics counts design as an individual initiative, the learner is freed as much as possible for the design. Students create awareness of the scientific conventions and epistemological value they learn during the teacher's direct teaching of the scientific values and originality of the products they will design. The most important role of the teacher in this phase is negotiator. The learning process is monitored here, the meaning of the student's meaning in the stage where the teacher is scaffolding is monitored in the design process, and when the teacher realizes a problematic or developmental point, he intervenes at an intellectual level and does not intervene in student designs.

In this step, students use retrieval fluency (Gr) abilities and cognitive speed abilities (Gs and Gt) with acquired knowledge abilities (Gc, Gkn, Grw, and Gq) in order to construct external representations. Retrieval fluency ability refers to accessing stored information in long-term memory rapidly. Gr can be described as retrieving verbal and nonverbal information or declarative and procedural knowledge stored in long term memory fluently. Gr with narrow abilities facilitates designing external representations in creative ways. It plays a crucial role before performing external representations. The following narrow abilities of Gr take part in realizing this: ideational fluency, expressional fluency, word fluency, figural fluency, and figural flexibility. The former is about producing a set of ideas regarding a specific condition rapidly. The latter refers to expressing an idea in different ways. The third one is about producing words which have common phonological or semantic features. Figural fluency is about drawing a set of visual elements to solve figural problems.

Taking all theories, conceptions, views, and adaptations into considerations, the MpM involves a set of basic theoretical and practical principles as follows. These are called draft design principles.

- **Draft design principles**

Theoretical Design Principles

1. Teaching and learning in the classroom is a multimodal experience and a design.

Explanation: Design is about people *engaging in any communicative form* that can be *shared with others*.

2. "Learning", consequently, is defined as an increased capacity to use signs (modes/representations) and engage them meaningfully in different situations.

Explanation: Learning is here understood as a process of interpretation and sign production (Selander, 2003; 2008). The use of modes and media in processes of interpretation and identity construction is 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. Learning is a design, and it includes internal and external design of representations.

4. The multimodal texts and artifacts that designers make can be seen as one kind of sign of learning, a material trace of semiosis.

Explanation: We suggest that pupils' learning products which include image, text, gesture, and spatial elements can be viewed as 'one kind of evidence' of their cognitive processes.

5. Multimodal learning environment requires representational competent teacher.

Explanation: S/he can select appropriate modes, harmonize and orchestrate semiotic sources and modes effectively in order to design a meaningful teaching experience to engage, motivate, and educate students, and finally can evaluate adequacy and competency of multimodal representations.

6. Multimodal texts have manipulable characteristics, they provide designers to attend text in different entry points.

7. Teachers/Students are active designers of their learning products.

Explanation: They view, manipulate, interpret, and transform teacher's available multimodal representations into new and meaningful ones.

Practical Design Principles

1. Designers should be situated and immersed into a semiotically/multimodally rich classroom environment.

2. Teachers should present designed multimodal texts by harmonizing and organizing available designs.

3. The teacher should design multimodal texts and to organize student activities, dialogues, and discussions as a mediator and negotiator in order to enhance (a) comprehending fundamental and functional semiotic forms of various typess of modes, (b) understanding conceptual structures of the modes, and (c) awareness of the potentials enabled by the different structures of representations.

4. Teachers should encourage explicit discussion about the appropriateness of particular multimodal representational forms.

5. Tasks should be involved for the transformation, transduction, and re-representation of concepts and ideas from one mode to another.

6. Designers require to encounter representational challenges, which elicit their causal accounts of phenomena.

7. Multimodal learning environment enable designers to design their conceptual understanding to re-represent their claims by using multi modes in their science content.

Explanation: Students should have multiple opportunities to re-represent, translate, integrate, re-interpret, justify and refine understanding multimodal representations through processes of collaborative peer learning, experimentation, consultation and teacher-guided consensus around representational adequacy.

8. At the end, designers' learning products (multimodal representations) should be assessed by the teacher who is an epistemic authority according to multimodal assessment rubrics.

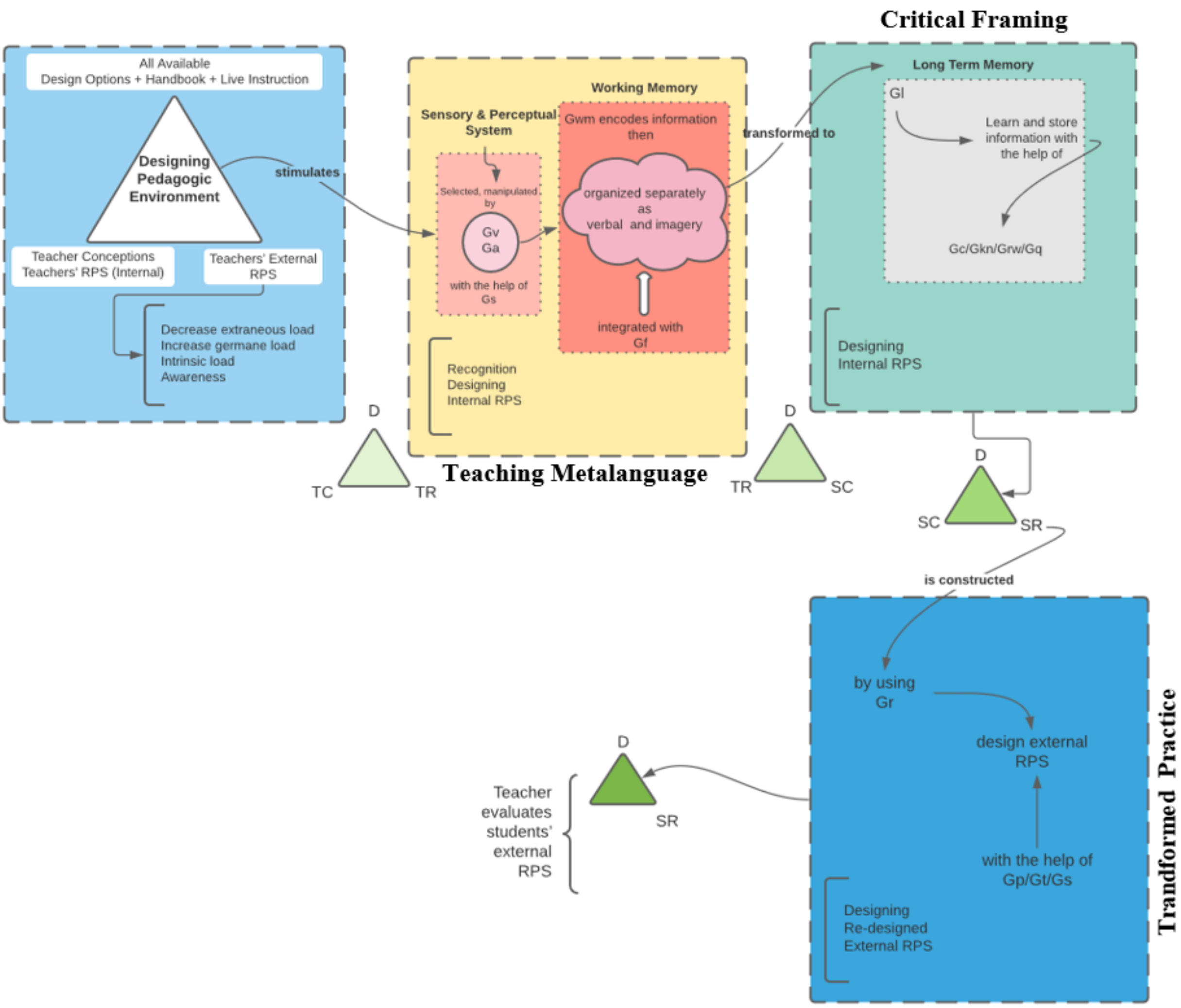


Figure 2. 12 Draft model of the MpM

3
METHOD

3.1 Participants and Settings

Participants were chosen by convenience sampling. There were one or two science teachers in these schools. They were invited to participate in this study with online and face to face meetings. In these meetings, the process and purposes of the study, the role and responsibilities of researchers and practitioners, what is expected from them, and the calendar about this research were shared clearly. They were also informed about what objective they will attain at the end of the process, how collaboration between researcher and practitioners is realized, the scope, content, and products of the research.

The six ToG voluntarily accepted to participate in this research. Two of them are male, the rest of them are female. One of them has a bachelor's degree, two of them have a master's degree, two of them are PhD candidates, and one of them has PhD degrees. They are all experienced in science teaching for gifted students, the average teaching experience was 7 years (see Table 3.1). They work in different regions of Turkey, but schools have the same attributes. Schools are designed to educate gifted students after formal education as an enrichment program. They are called Science and Art Centers (SACs).

Table 3. 1 Demographics of the participants

Participant	Bachelor/Ms/PhD	Years in Teaching	The level s/he taught
Ahmet	Bachelor	8	Primary/Secondary
Aslı	Ms	7	Primary/Secondary
Mustafa	PhD	7	Primary/Secondary
Zeynep	PhD Candidate	8	Primary/Secondary
Ceren	PhD Candidate	7	Primary/Secondary
Suna	Ms	8	Primary/Secondary

Each city has at least one SAC in Turkey. SACs select students according to some criteria. Firstly, prospective students are chosen by teachers to take the group scanning exam. Then, successfull ones take individual exams regarding general ability, music, and art. If they succeed in these two sequential exams, they are accepted as gifted (Bildiren, 2018; Sayi & Yurtseven, 2021). SACs provide enrichment education which aims to develop their thinking skills, problem solving skills, and ability (Kaplan & Sayi, 2020). SACs try to realize these aims by following four educational phases: orientation, supporting education, recognition of individual talents, and development of special talents. The former refers to expose to activities that introduce SACs. The latter means students engage in activities about higher order thinking skills. The third means that students select activities in some disciplines according to their interests, the last one refers to generate projects in specific subjects (Ministry of National Education, 2015).

3.2 Research Design

EDR is the methodological framework of this study. As stated by Plomp (2013): "EDR is a systematic way of design, development and evaluation processes of an educational intervention or innovation". EDR aims to examine possible solutions for complicated educational problems encountered in a real context by making a systematic analysis of designing and developing an intervention. It contributes to not only our knowledge about the theory but also practice and our knowledge about characteristics of intervention and its designing and developing processes (Plomp, 2013). In other words, as explained by McKeeney and Reeves (2012): "EDR is 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 (p. 7)".

EDR is a set of research approaches (survey, case, action, grounded, and experimental). It includes some attributes of these approaches, but usually differentiates from them with specific patterns. For example, while experimental research is testing theory, EDR develops and tests theory simultaneously. The researcher can only be a participant in action research, while in EDR s/he can be also an observer. In grounded theory, the researcher develops theory at the end of the study while s/he starts from a theory, then develops it in EDR (Bakker, 2018).

EDR mainly focuses on how education could be or even as it should be (Bakker, 2018). This means that educational researchers have a wishful desire to solve a problem they encountered. They pursue the answer of questions like what is possible potential of new educational technologies for teaching concept X, or which skills needed in the future and in what ways they should be improved to help learners-citizens of futures. In EDR, research and design are intertwined and dependent on each other. Designing of teaching materials or a professional development program is interwoven with the iterative cycles of testing and improving of theory, or vice versa (Bakker, 2018). That is, design tests and improves theory in different contexts, and improved theory provides constructing new designs.

EDR proposes solutions to the two long lasting problems in the history of education. The former one is that the improvement of new educational approaches does not depend on the knowledge base available from research. In EDR, the adequacy of the new approach is tested in different contexts and if necessary it could be developed by depending design on research. The latter is that most research in the educational area enables little insight to practitioners on how to perform the new approach in their learning environments (Bakker, 2018).

3.2.1 Characteristics of EDR

Based on the studies of Phillips (2006), McKenney and Reeves (2012), Confrey and Maloney (2015), and Bakker (2018), EDR includes five basic characteristics inherently.

1. EDR is theoretically oriented. This means that theoretical approaches inform the design and process of a solution to a real problem, and in turn the design and process improve theoretical understanding through testing. EDR is oriented to

theory in shaping of intervention, and thus intervention helps in the assessment and improvement of the theory.

2. EDR is interventionist by nature. Evolvement by explaining the changes is a crucial factor and main purpose of EDR. That is, EDR strives to make a real change in the context the intervention is applied. While doing this, it pays attention to this: “If you want to change something you have to understand it, and if you want to understand something you have to change it (Bakker, 2018, p. 16)”.

3. EDR includes collaborative action between researchers and practitioners who encourage and learn from each other during the implementation in continuously adapting the design to reach the goals (refinements in both theory and design).

4. EDR is cyclic by nature. This means that it involves revisions and iterations. The intervention, draft model, design principles, or conjectured maps are first prepared as theory-laden, second they are put into practice, and finally they are analyzed retrospectively. At the end of the retrospective analysis, alternative conjectures or revised design principles can be generated and tested. And, the new cycle can repeat until the intervention reaches a solid solution/a desirable design.

5. EDR has reflective and prospective components. At the end of each iteration and during intervention, the proposed model is evaluated and reflected by contributors e.g. researchers, practitioners, and experts. Reflection and evaluation can be done in each cycle in order to feed and revise models in order to reach the ideal intervention.

Based on the characteristics, EDR in this study is conducted through intervention. In the context of this study, here, the intervention is to design and develop a multimodal pedagogical model to improve representational competence levels of teachers of gifted students. The intervention is designed regarding the educational problems that is the need for differentiated pedagogical approach in gifted education and difficulty experienced by ToG in constructing intermodal relations between image-text and text coherence while designing multimodal representations. In other words, the problem is that teachers lack representational competence skills.

While reaching a solid solution to this educational problem, the steps mentioned below are followed in the generic model.

- Problem or needs analysis.
- Initial formulation of a potential solution to the problem.
- Implementation of the intended solution.
- Evaluation of to what extent the intended solution indeed solved the problem.

Generally, the EDR has commonly three phases of research that are:

- preliminary research phase,
- prototyping or development phase,
- and evaluation phase (Nieveen & Folmer, 2013; Plomp, 2013).

3.2.1.1 Preliminary Phase

In general, the preliminary research phase examines and determines existing problems to solve, or needs and possibilities for interventions in order to conceptualize them. The timeline of this phase is shown in Figure 3.1.

In this phase, at first, the researcher conducted a one year long literature review in order to identify problem, to determine possible solutions and teaching and learning activities, to decide theoretical and conceptual frameworks of the study, to construct intervention model and its principles, and analytical frameworks. In this year, the researcher also attended national and international academic meetings about the subject of gifted education. He determined that there is no attempt and study to design a pedagogical model in order to make ToGs representationally competent.

After conducting literature review, the researcher invited teachers of gifteds to attend the study by explaining the purpose and process of the study, and what roles they plan and responsibilities they should take during the study. Six of them accepted to attend voluntarily to the present study. Then, the researcher asked participant teachers to send their teaching materials they used in real or digital classroom environments. The researcher analyzed these mono or multimodal texts to determine their representational competence levels. The researcher also realized semi-structured interviews with them one by one by asking questions about (1) participant teachers' pedagogical practices; (2) their awareness on multimodal text design and multimodal representations regarding image-text intermodal relations and text coherence; (3) their views on impacts of these texts on learning and meaning making; (4) and how they plan and organize teaching process by using representations (Appendix A: Pre-Interview Questions). The researcher also observed these teachers online classroom teaching experiences.

At the end of all these processes, the researcher developed conceptual or theoretical framework of the study, determined theoretical and practical principles, and finally designed draft model for intervention (Bakker, 2018; Plomp, 2013). That is, a draft model with a set of draft design principles is improved to solve the problem at the end of the preliminary phase. In the context of the draft intervention model, the issues of -how human mind works, theory of learning, how learning occurs with multimodal representations, and how the teaching process should be- was determined.

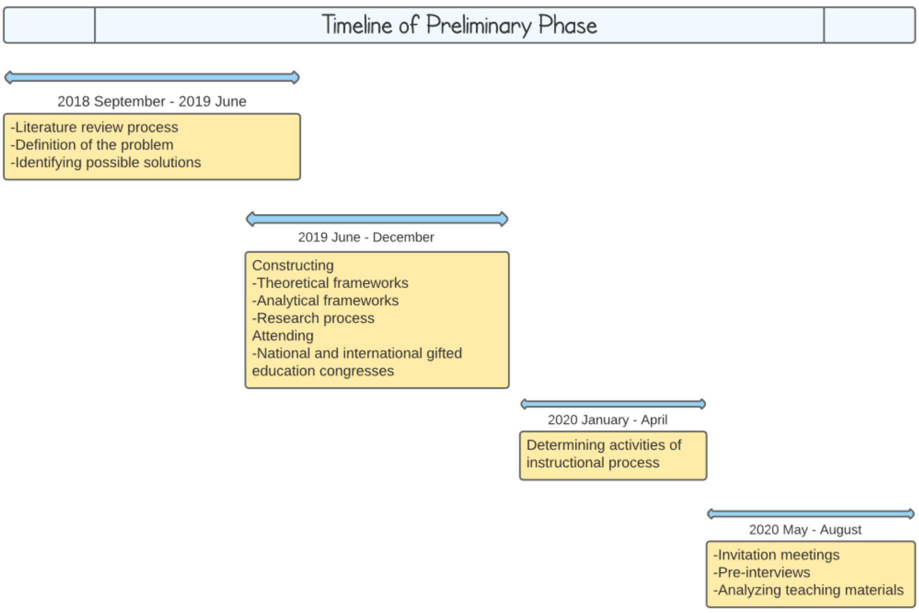


Figure 3. 1 Timeline of preliminary phase

3.2.1.2 Prototyping Phase

Prototyping phase is the second step of EDR. It includes iterative applications of draft model, or in other words micro cycles. Each being micro cycle was undergone to formative evaluation in order to revise and develop intervention. Five micro cycles were conducted to be able to attain a solid model which capable of improving representational competence of ToGs in the study. That is, the researcher decided that the intervention evolved to an effective model to develop RC of ToGs at the end of fifth micro cycles.

Each micro cycle reflects sequences of multimodal teaching process and learning with multimodal representations.

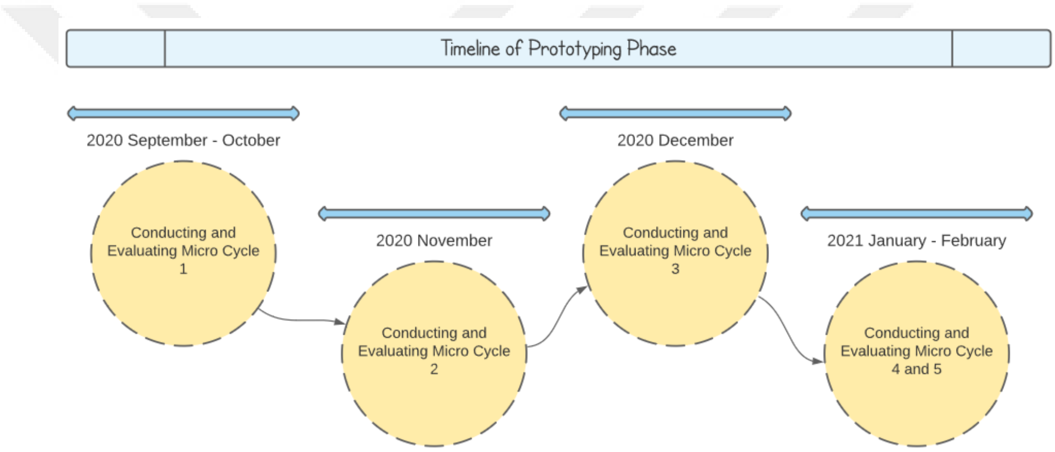


Figure 3. 2 Timeline of prototyping phase

Micro Cycle 1

The first micro cycle was conducted over four weeks. Awareness activities were realized through discussions with participant teachers. Recognition activities were provided with videos describing intermodal relations and text coherence attributes that the participants were not aware of in the previous activity. Design activities were given considering criteria of applying properly and applying creatively. Evaluation activity was carried out directly. That is, the researcher gave explanatory feedbacks to designs of ToGs, and asked them to re-design their multimodal representations. Each step of first micro cycle is explained below.

- **Designing Pedagogical Environment (DPE)**

The researcher prepared six monomodal texts in three different groups regarding text coherence (Kloser, 2013, 2016; Meneses et al., 2018; Ozuru et al., 2009). The first group has criteria of (1) including headings as expository text or research question, (2) body text as expository-informative or narrative-argumentative, (3) involving scientific process (hypothesis, research question, data, and conclusion) or not. The second group is prepared according to criteria of (1) replacing ambiguous pronouns with nouns or not, (2) adding descriptions with examples or not, (3) inserting connectives to promote relationships between sentences or not. The third group is constructed through the principles of (1) including non-scaffolding academic vocabulary or not, (2) and highlighting with italic, bold, and underlying or not.

The researcher also designed multimodal texts in eight categories regarding intermodal relations between image-text (Daly & Unsworth, 2011; Keles, 2016; Meneses et al., 2018; Tang, et al, 2019; Zhao, Djonov, & van Leeuwen, 2014). Intermodal relations classify into two groups and eight categories. The first group is concurrence. The concurrence is classified into four categories sequentially according to intermodal relationships: 1) decorational, 2) exemplary, 3) representational, and 4) extension. Decorational is the weakest intermodal relations in this category, and extension is the strongest one in primitive form. The second group is complementarity. It is classified into four categories regarding intermodal mechanisms: 1) comprative, 2) organizational, 3) augmentation, and 4) interpratational. Comparative is the weakest one, and interpretational is the strongest one in advanced form of multimodal representations.

- **Teaching Metalanguage (TM) and Critical Framing (CF)**

The researcher distributed different types of monomodal and multimodal texts to the participants. Five minutes were given for each monomodal text, and three minutes were given for each multimodal text to teachers to view and criticize these texts by comparing. Then, the researcher and participants discussed differences within monomodal and multimodal texts, and discussed what purposes each texts serve, through the given activities (Table 3.2). Each teacher was asked to noted differences between these texts.

Table 3. 2 The first activities of micro cycle 1

Activity 1	Activity 2
-Examine the text on each page within five minutes. -Compare the texts on each page in terms of text coherence. - State how and why text differ. - Explain what changes you would make in the texts on each page to increase text coherency.	-Examine the multimodal texts on each page within three minutes. - Compare the multimodal texts on each page within and between each other. - State how and why multimodal texts differ. - Explain how images and texts are related to each other in the same and different representation. - If you wanted to change the pictures and texts of these representations or the relationships between them, how would you like to change? Why is that?

At the end of this stage, the researcher collected these notes, and prepared two videos as an overt instruction considering the differences that teachers are aware of. The videos include information about intermodal relations and text coherence attributes, design process of monomodal and multimodal texts, what instructional purposes these texts serve, and how to increase and decrease the semantic and epistemic level of these representations. Then, the researcher presented activities of the next stage in which participants were encountered with a new representational challenge (Table 3.3). In the first activity, the researcher asked teachers to design epistemically and semantically low and high texts by only manipulating aspects of text coherence. In the second activity, the researcher asked participants to select appropriate images and texts given, and integrate them according to the principles of intermodal relations.

Table 3. 3 The last activities of micro cycle 1

Activity 3	Activity 4
-Watch the video on differences between monomodal texts. -Prepare two texts between 200 and 300 words by choosing a topic from the topics (Conservation of Energy and Environmental Science - Reproduction, Growth and Development in Living Things - Structure of Matter - Matter and Heat). -Enrich the first text and the second text by considering all the differences between the texts explained in the video. -In other words, prepare two epistemically and semantically low and high texts, one low and one high.	-Watch the video on intermodal mechanisms within multimodal texts. -In the video, only one example is explained to illustrate the image-text intermodal relations. Do not forget to stop and review for others. -The texts and images we have prepared for you to design these relations have been shared with you on the drive (four different texts and ninety images). -Choose any sentence in the texts, and any images in the drive file, and then orchestrate them for preparing a presentation about greenhouse effect considering text coherency and intermodal mechanisms (Appendix D).

- **Transformed Practice (TP)**

Teachers experienced their learnings by applying in different contexts in this step. They were introduced to a new task and asked to design external representation as a sign of their learning. The process was realized in two distinct ways, applying appropriately and applying creatively. During the first iteration, researchers demanded teachers to apply appropriately as he provided all available designs for activity 4. And, he asked them to apply creatively for activity 3. Thereafter, the researcher evaluated their external representations in terms of text coherence and intermodal relations, and gave progressive and explanatory based feedback in order to re-design. In a sense, overt instruction continued.

Micro Cycle 2

The researcher took the refinements into consideration in the previous cycle, and designed a new micro cycle. He increased representational challenge by providing teachers with half-completed infographic about vaccination. He distributed infographic to the teachers with digital tools. He asked them to complete the visual of the section given as text and vice versa considering intermodal relations and text coherence elements. He introduced a new educational technology which facilitates infographic design with a video. He asked them to complete this infographic, choosing images and texts according to their interests. The researcher gave questioning based feedback when teachers designed their representations.

Briefly, in this cycle, participants were again put through a transformed practice process in a new and difficult representational challenge with extended available designs (Table 3.4). In this way, first, the researcher enriched the pedagogical environment with new available designs, and as a second, proposed a new representational challenge which should be handled in a different context. Afterwards, participants designed their external representations, applied creatively. Participant researchers gave feedback to them as an overt instruction. Finally, critical framing was realized in which teachers find the opportunity to compare the differences between what they should have done and what they have done.

Table 3. 4 Activity 5

-Piktochart application has been introduced in the video. This application provides us flexibility in infographic design (Appendix E). -Images for Piktochart are shared with you as Activity 5 in Drive. You can download the picture from Piktochart and upload it to your drive file. 1. Half-completed infographic designed for you, shown in three sections on different pages. 2. Considering in-text meaning relations and meaning relations between text and visual, a. Add text to the part given the visual, b. Complete the visual of the part given the text. Blank pages have been added for completion and design.

Micro Cycle 3

- **DPE**

Based on the revisions and interviews, the researcher enriched the pedagogical environment with a handbook on text coherence and intermodal relations between image and text since participants demanded this type of available designs (Appendix F).

The book mentions attributes of text coherence by identifying/describing what they are, and gives examples by focusing on two points. One, while designing text coherence, the texts are constructed semantically considerate or not according to purpose. The second, they are designed epistemically considerate or not according to purpose. The book gives lots of examples from different contexts how these two points can be realized.

The book also gives information about the purposes of intermodal mechanisms and describes each intermodal relation by giving lots of examples from different contexts. The purposes of intermodal relations can be listed as follows: paying attention, showing examples, replicating meaning, presenting meaning in same generality with different modes, providing compare and contrast situations, distributing meaning between image and text in a process, scaffolding learning, augmenting meaning by modelling, constructing causal relationships.

- **TM, CF and TP**

As a process of teaching metalanguage, feedback was continued. Live instruction was added. The researcher conducted live lectures on how to design multimodal texts. These lessons were usually carried out on the representation designed by the teacher, and how these intermodal relations were applied in practice.

In this cycle, participants were again put through a transformed practice process in a new and more difficult representational challenge with extended available designs (Table 3.5). In activity 6, researchers aimed to increase representational challenge and decrease scaffolding level. To do this, the researcher provided seven questions with only three images. Other than these, no support or clue was provided. They were asked to design their external representations by answering given questions, and apply creatively. Then, the participant researcher gave feedback to them as an overt instruction and critical framing in which teachers find the opportunity to compare the differences between what they should have done and what they have done.

Table 3. 5 Activity 6

This week we are introducing a new platform called THINGLINK. You can do our activity through this application (Appendix E). -Watch the video. -Click on the button shared below. https://www.thinglink.com/scene/1394983408311992323 -Click on the tags to answer the questions by considering text coherency and intermodal relations between image ans text. -Share the link of your design with us here. Or, if you want, answer the questions in the tags by seesaw, piktochart, or on a platform where you can design more comfortably.

In addition, depending on evaluations of micro cycle 1, 2, interviews, revised design principles and model, researchers asked teachers to evaluate their external representations with respect to the criteria on text coherence and intermodal relations. Regarding the new design principles, participants are also allowed to use any platform to design their representations.

Micro Cycle 4

In this cycle, participants were again put through a transformed practice process in a new and difficult representational challenge (Table 3.6). In this way, first, the researcher proposed a new representational challenge which should be handled in a different context. The researcher only determined the titles of subject, and asked them to select one of them, and design its representations.

Afterwards, participants designed their external representations, applied creatively. Participant researcher gave feedback to them as an overt instruction. Finally, critical framing was realized in which teachers find the opportunity to compare the differences between what they should have done and what they have done. Critical framing was also realized in a way that participants evaluate their designs, they try to explain how they realize or not any kind of intermodal relations with a critical perspective. Teachers also shared their design in an online platform, in this way DPE was enriched.

Table 3. 6 Activity 7

Select at least three biotechnology titles given below. -Biotechnology: a. Gene transfer, b. Gene therapy (therapy), c. Cloning, d. GMO, e. Artificial selection, f. DNA fingerprint -Prepare a representation in any platform you want regarding intermodal relations and text coherency. You can upload it to the activity 7 file in your Google Drive file.

Micro Cycle 5

Researcher extended available designs of pedagogical environment with teachers' presentations. In teaching metalanguage, two processes played active roles in this cycle. The former, feedback of researchers to teachers' representations, and the later peers' feedbacks to each other's representation. In the critical framing period, students were attended to the role of evaluating peers' materials. They were confronted with the most difficult sequence of representational challenges in transformed practice where participants assess peers' external representations (Table 3.7). In this step, researchers provided an assessment matrix to the participants, and asked them to evaluate peers' artefacts. At the end of the activity, researchers interviewed them, and asked two basic questions to them (1. Which features of text coherence did you have difficulties in designing and analyzing? Why is that? And 2. Which intermodal relations did you have difficulties in designing and analyzing? Why is that?)

Table 3. 7 Activity 8

-Share your representations -Select the representation of one of your friends. -Evaluate it according to the principles of text coherency and intermodal relations. -The guide on how to evaluate will be put in the Activity 8 file in your Drive.

3.2.1.3 Evaluation Phase

Retrospective analysis was realized in this phase from the beginning of the preliminary phase to the end of the development phase. Individual process of participants, and analysis of intervention model were evaluated as a whole within a comprehensive perpective. In this way, the study reported the final version of intervention model and further implications of it.

3.3 Data Collection

The present study used gualitative data to investigate ToGs' developments of representational competence skills during and after exposed to MpM. Data triangulated by representations designed by teachers in each micro cycle, the reflections and interpretations made by them to their representations, the discussions made on designs during online classrooms. The semi-structured interviews realized with participants and experts on their views and perceptions regarding the model, the teaching and learning processes, and activities. Data was collected on 2020-2021 spring semester. Data collection instruments are presented in Table 3.8.

Table 3. 8 Data collection tools

Construct	Instrument
Intermodal Relations Between Image-Text	Analytical Framework for Intermodal Relations
Coherence in Monomodal Text	Analytical Framework for Text Coherence
Views and Perceptions	Semi-structured Interviews

3.3.1 Data Collection Tools

The researcher proposes two analytical frameworks for analyzing teachers' generated representations in terms of intermodal relations and text coherence. Content validity of these analytical frameworks were realized by asking pioneered researchers who study image-text relations and systemic functional multimodal discourse analysis. The researchers stated as follows:

Expert 1:

> "*Thanks for your email. The frameworks look comprehensive and the productivity of it can only be seen in how useful it is in helping you explain your analyses, and the insights it offers. In addition to the neat range of references you have cited, you may also wish to look at this book – I believe it has some of the scholar's latest thinking on image-text relations.*"

Expert 2:

> "*Thank you so much for getting in touch about your framework for intermodal relations between image and text. The framework looks very comprehensive and you have provided clear definitions for each choice in the system network. I would suggest that you apply the framework to some further texts to see if any adjustments are necessary.*"

Expert 3:

> *"The analytical framework suits your purposes to maintain the theoretical position you have adopted."*

Experts' views were taken into consideration, and the researcher applied these frameworks to presentations (277 representations) which were used in the 16 middle school online science lessons. Findings showed that these frameworks work properly.

3.3.1.1 Analytical Framework for Mapping Intermodal Relations Between Image and Text

A research shift was experienced in the focus of Systemic Functional (SF) approaches to Multimodal Discourse Analysis (MDA) in recent years (O'Halloran, 2007). Based on the studies of Halliday's (1978, 1985) systemic functional grammar, SF-MDA researchers mainly interested in adapting attributes of systemic functional grammar to non verbal modes involving visual design (Kress & van Leeuwen, 1996), mathematical symbolism (O'Halloran, 2007), and action (Martinec, 2000). SF-MDA approach includes improving theoretical and practical approaches of analysing meaning arising from the use of multiple modes such as visual imagery, spoken and written language, sculpture, mathematical symbolism, gesture, architecture, and other physiological modes (Bateman, 2008; O'Halloran, 2004; van Leeuwen, 2005).

Drawing on SFL and social semiotics, the SF-MDA approach was developed to investigate the meaning arising through the written language and image modes - which semantically complement each other in order to produce a coherent multimodal text- in multimodal texts in terms of metafunction of ideational meaning (Halliday, 2004). In printed or synoptic texts, written language and image modes are integrated through intermodal relations where semantic expansions of co-contextualizing and re-contextualizing relations occur between them (O'Halloran, 2007). Intermodal relations are important attributes of multimodal texts which create integration of words and images rather than a mere linkage between the two modes.

Investigating intermodal mechanisms –which are realized through intermodal relations- between modes contribute to understand principles for interaction across different modes deeply. In this way, from the SF-MDA perspective, researchers can distinguish what relations make multimodal text visually and verbally coherent.

In this context, the SF-MDA approach deals with meaning potential of modes distributed across three different planes: the expression plane, the content plane, and the context plane. Intermodal relations are builded on the planes in order to realize meaning making in three distinct metafunctions. Those are ideational meaning, interpersonal meaning, and textual meaning (O'Halloran, 2007). Hence, at first intermodal relations and planes should be constructed in order to capture meaning created or cohesion in multimodal text which takes place when visual and linguistic forms integrate. From these perspectives, the major strength of SF-MDA arises from Halliday's (2004) metafunctional principle which enables an integrating platform for conceptualizing how different modes interact to create meaning (Baldry & Thibault, 2006; Kress & van Leeuwen, 2006; Van Leeuwen, 2005). In SF Theory, language and other modes interact to realize three kinds of meanings (metafunctions) simultaneously: (a) *ideational* meaning, structures verbally and visually construct the nature of events, the objects and participants involved, and the circumstances in which they occur; (b) *interpersonal* meaning, for enacting social relations, verbal and visual resources construct the nature of relationships among speakers/listeners, writers/readers, and viewers and what is viewed; and (c) *textual* meaning, are concerned with the distribution of the information value or relative emphasis among elements of the text and image , for arranging meanings in coherent text (Halliday, 1978, 2009; Halliday & Matthiessen, 2013).

The principle enables a basis for investigating the functionalities of modes and for analysing in which ways modes combine in multimodal texts to realize specific goals such as knowledge construction in school textbooks. Examining the functionalities of modes and analyzing coherent combinations of them which are realized through intermodal mechanisms (involves intermodal relations) on content stratum require constructing an analytical framework. The analytical framework is builded upon grammar-based approach to SF-MDA (Halliday, 2004; Martinec & Salway, 2005; Unsworth, 2006) in order to investigate intermodal relations between image and text which construct ideational meaning on the content plane. It enables valuable insights into mapping intermodal relations between image-text.

The analytical framework is improved based on the grammar-based approach to SF-MDA follows Halliday's (2004) lexico-grammatical formulation of (1) interdependency, and (2) logico-semantic relations. Martinec and Salway (2005) re-formulated this approach to a generalized system of image-text intermodal relations in the categories of (1) relative status and (2) logico semantic relations. Then, Unsworth (2006) classified logico semantic relations into two general forms as concurrence and complementarity. These classifactions enlightened the present study in order to contruct system network of intermodal relations between image and text while analyzing multimodal representations through systemic functional multimodal discourse analysis appraoch.

- **Interdependency**

Similar to the relationship between clauses in a paragraph, images and texts are classified into two statuses as *equal* and *unequal* (Figure 3.1). Statuses are determined by the criterion of modifying effect. If one modifies the other, status is unequal, they can not stand on their own; if not, status is equal, and they can both stand on their own. Equal status is also divided into *independent* and *complementary*. The former means image or text do not modify each other, each one exists in parallel, and they are not a part of larger syntagm. The latter refers to image and text combining equally in order to construct a larger syntagm. In other words, both of them play active roles in a type of process. While a whole image is related to a whole text in equal status, the image is related to only a part of text or vice versa in unequal status. When an image is subordinate to a text, the image is related to only a part of the text. For example; when a text is subordinate to an image, the text may well be related to only a part of it, but this is not the only possibility.

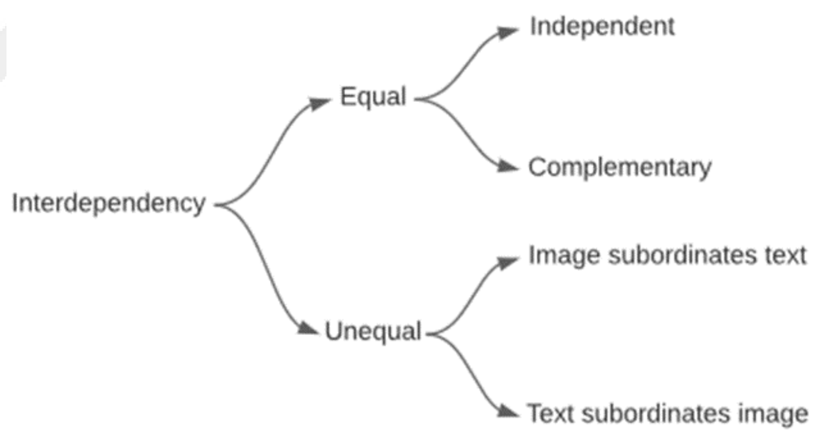


Figure 3. 3 Relative status of intermodal relations

- **Logico Semantic Relations**

In a multimodal text, image and text are related to each other by logic of semantic relations. Barthes (1977) simply classified these relations into three categories: *anchorage, illustration, and relay*. Anchorage means text supports image that is text describes and interprets image. Illustration refers to an image that supports text by elucidating and realizing. Relay decribed as: "Here text and image stand in a complementary relationship; the words, in the same way as the images, are fragments of a more general syntagm and the unity of the message is realized at a higher level (Barthes, 1977, 41)".

Parallel to Barthes, but a more detailed and systematic distinction between logico-semantic relations between image and text was made by Halliday (1985, 1994, 2004), Martinec and Salway (2005), and Unsworth (2006a). Halliday stated that there are two main types of logico-semantic relations in order to map image-text relations. Those are *expansion* and *projection*. The former deals with relations between represented events, the latter deals with events that have already been represented. In this study, the researcher focuses on expansion in a detailed way. Further research clarified logico-semantic relation of expansion in the form of ideational concurrence and ideational complementarity (Figure 3.4) (Unsworth, 2006a, 2006b).

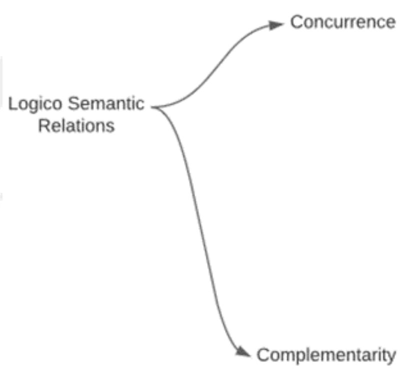


Figure 3. 4 Types of logico semantic relations

The current study extends and elaborates image and text relations by referencing the studies of Unsworth, 2001; Carney & Levin, 2002; Mayer & Moreno; 2003; Lim, 2004; Ainsworth, 2006; van der Meij & de Jong, 2006; Chan & Unsworth, 2011; Tippett, 2016; Unsworth, 2014; Keles; 2016; and Meneses, Escobar, & Velis, 2018. These studies guided the current study in terms of determining levels of intermodal relations (from simple to complicated) by providing qualitative and quantitative data. These studies also enlightened the present study in terms of naming and classifying intermodal relations, and how to distinguish one form to another with characteristic aspects.

Ideational Concurrence

Ideational concurrence refers to ideational equivalence between image and text (co-variation or co-variate unity) or ideational meaning corresponds across semiotic modes. From an equivalence perspective, image and text have similar participant-process-phenomenon configuration (Gill, 2002). This perspective is identified by the term of *co-variate unity*, which reveals "(thematic) continuity across structural-unit boundaries of cohesive chains', which may be semantically or grammatically interconnected (Lemke, 2006:50)"; this view is oriented towards relations of similarity across semiotic modes

From the corresponding perspective, it is a type of logico semantic relations in the expansion category where image or text elaborates on the meaning of another by further specifying or describing it while no new element is introduced. There is a correspondence between image and text which meaning arises from modes that are similar (Unsworth, 2006b). Ideational concurrence is divided into for main themes decorational, exemplary (text more general-image more general), representational, and exposition (Figure 3.5).

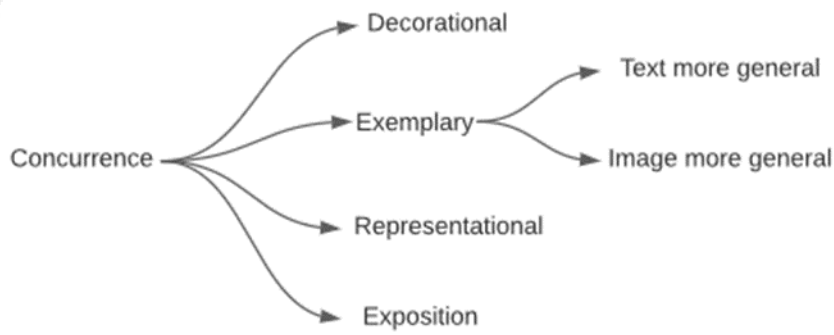


Figure 3. 5 Types of intermodal relations in concurrence

Decorational

In the decorational representations, image and text have no or few correspondences. They do not refer to each other properly, few meaningful links can be established between them. Image or text mirrors few aspects of each other, reflecting minimal information about themes. Images may not be integrated in the written mode or vice versa.

Briefly, they do not encourage learners to understand concepts, and simply decorate the multimodal text, bearing little or no relationship to the text content. However, they can be used frequently at the beginning of the unit in order to engage students interactively, and pay attention to them (Carney & Levin, 2002; Unsworth, 2006b; Tippett, 2011).

Exemplary

In this image-text relationship, image exemplifies text or text exemplifies image; text and image represent different levels of generality, either text more general or image more general (Chan, 2011; Martinec & Salway, 2005). Image functions as an example or instance of what is in the text, or the text may include an example of what is depicted more generally in the image. Image and text partly refer to each other, do not reflect the whole image or whole text (Ainsworth, 2006; Daly & Unsworth, 2011; Keles, 2016; Mayer, 2002; Unsworth, 2006b, van der Meij, & de Jong, 2006).

Representational

Image and text have exact correspondence in terms of redundancy of meaning, image mirrors the information contained in the text or vice versa (Unsworth, 2006a). It can be used as a type of illustration, clarification, description, and equivalence. Image makes the text precise and concrete since it clarifies the text (Carney & Levin, 2002). Representational relations also highlight structures, patterns, and functions of an observation related to what an object is made of and how it is shaped (Keles, 2016). Moreover, image and text are operationalized as equivalence in terms of participant-process-phenomenon configuration. They mutually reinforce the meanings of each other (Chan, 2011; Mayer, 2002).

Exposition

Exposition is another type of ideational concurrence, the image or the text re-expresses and re-formulates the meanings of each other with different alternative modes in terms of the same level of generality (Unsworth & Cleirigh, 2014). An example of exposition where the image expands on attributes of the text and vice versa, (e.g. when the word 'weighs' is reinterpreted visually as a balance scale) (Daly & Unsworth, 2011).

Ideational Complementarity

Image or text extends the meaning of another by adding new and related information regarding how, when, where or why in relation to each other (Martinec & Salway, 2005; Unsworth, 2014). Both of them play different and complementary roles in the structures of ideational elements: participants, processes and circumstances (Chan, 2011). Complementarity relations provide causality and generative descriptions of a phenomenon, present explanations about how and why the process is happening (Keles, 2016). They try to awaken cognitive processes involving remembering, decision making, problem solving, and reasoning.

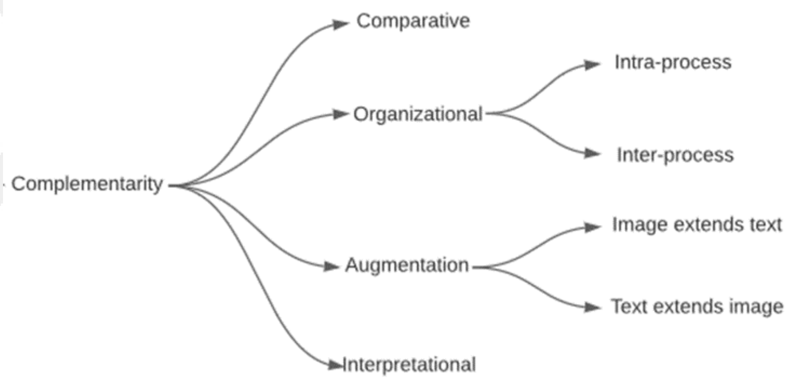


Figure 3. 6 Types of intermodal relations in complementarity

Briefly, complementarity relations mean what is represented in images and what is represented in text may be different but complementary and joint contributors to different aspects of ideational meaning (Figure 3.4)(Daly & Unsworth, 2011; Painter, Martin, & Unsworth, 2011). Both construct a multivariate and coherent unity, it is called multimodal text.

Comparative

Comparative relations provide learners to make comparisons and to understand similarities and differences between information presented by image and text. Comparative multimodal representations include two or more objects' dimensions, or two different topics. Readers can compare and contrast the phenomenon presented. They also improve students' comprehension of how to construct relations among the two concepts (Keles, 2016; Liu & O'Halloran, 2009).

Organizational

Organizational representations where complementary meanings (activities and processes) are distributed across image and text (Chan & Unsworth, 2011; Daly & Unsworth, 2011). Image and text are jointly constructed activity sequences (Chan, 2011; Unsworth & Cleirigh, 2014). Image provides potential signals to written mode or vice versa, in this way the reader establishes coherent relations between them, and then constructed links result in deeper processing of information (Meneses, et al., 2018; Tippett, 2011).

There are two types of organizational relations (Gill, 2002). The former is intra-process which means images and text share different aspects of a process. For instance, an image might depict the end result of a process described in the verbal text. The latter is an inter-process which occurs when images fill a gap in the meaning in the text (Chan, 2011).

Augmentation

Ideational meanings made in multimodal text are extended in augmentation relations. Images enable supplementary ideational elements to those realized by the text or the text extending the meanings realized in the image (Chan, 2011; Daly & Unsworth, 2011). Image augments meanings in the text by modelling in order to make it easier to visualize in mind. For instance, in a text explaining how insulin works, the images can widen this meaning with lock-key modelling, or in a water cycle image, text can extend the meaning of how precipitation occurs.

Interpretational

Interpretational relations include image and text together demanding students to establish and understand the causal relationships provided in representations. It involves causality and generative descriptions of a phenomenon. Image promotes the text by qualifying it in terms of time, place, cause, and purpose (Martinec &

Salway, 2005; Unsworth, 2006). In other words, text adds new information such as how, when, where or why in relation to the image or vice versa (Unsworth, 2014).

Briefly, these types of relations have following attributes: (1) presents a cause and effect system, (2) includes difficult material (scientific process and concepts), (3) provides opportunities for students to construct their own causal or purposeful links between image and text, and (4) encourages students to solve problems presented, (5) requires substantial cognitive demand like reasoning (Keles, 2016; Meneses et al., 2018; Tippett, 2011). Hence, interpretational relations provide opportunities for students to understand knowledge presented deeply. Therefore, it helps students to form well-designed mental/internal representations.

Figure 3. 7 Intermodal relations between image and text

3.3.1.2 Analytical Framework for Text Coherence

Textbooks or teaching materials are written in authoritative, passive writing style, expository, informative, and compact syntax format, so they are challenging for students to learn with text (Kloser, 2013, 2016; Uccelli, Barr, Dobbs, Galloway, Meneses, & Sanchez, 2013; Uccelli, Galloway, Barr, Meneses, & Dobbs, 2015). Scientific texts also have a typical genre which includes a distinct 'jargon' like nominalisations and lexical metaphors that generally makes the learner feel alienated from the subject matter (Halliday, 1993). They differ from social and historical text in that they include abstract concepts and their relations (Graesser, Leon, & Otero, 2002). For instance, they include morphologically complex derived words, embedded clauses, and extended noun phrases.

In this perspective, the claim in the current study is clear that learning with text is a difficult inquiry process in which students should infer meaning from text, and interpret text. Interpretation means investigating meanings reasonably justified by the text (Philips & Norris, 2009). Texts in the twenty-first century demand students to engage in comprehension, analyzing, critiqing, and generation of arguments based on information in texts (Goldman & Lee, 2014). However, results indicated that students have difficulties in interpreting the role of statements in scientific reasoning, they simply paraphrase parts of the text without supporting their positions. These difficulties are arised from the lack of coherence in text and unjustified claims which fail students to participate in scientific process, in other words, text in low cohesion do not lead students to one step forward - from what we know to how we know- (Phillips & Norris, 2009). Hence, instructors state that there is a need to make the text more coherent/concrete/apparent in order to scaffold students' learning (Norris, Stelnicki, & de Vries, 2012). In support of that claim, studies of McNamara showed that text cohesion moderates comprehension of expository materials (McNamara, 2001; O'Reilly & McNamara, 2007).

At this point, the study used the term text coherence to refer to make explicit and clear the text by manipulating some patterns of it such as its argumentative structure, epistemic stance, syntax, text structure, lexicogrammatical sources, conceptual overlapping, and so on (Uccelli et al., 2015).

Using argumentative-narrative structure and scaffolding scientific language with daily language have positive impacts on students' comprehension of scientific epistemology (Norris et al., 2012). Argumentative text leads students to ask questions that show a higher level of thinking which concerns causal relationships between variables (Brill & Yarden, 2003). These types of genres improve students' abilities of summarization, inferencing, and inquiry (Baram-Tsabari & Yarden, 2005). The high-cohesion texts enhanced text-based comprehension (Ozuru, Dempsey, & McNamara, 2008). Participants who are exposed to high cohesive text generate higher quality explanations and form coherent mental representations (Ozuru, Briner, Best, & McNamara, 2010). Kloser (2016) also showed that epistemically enriched text with justified claims with quantitative and qualitative data support learning and comprehension in students. These texts improve abilities of analyzing, interpreting, critiquing, and greater interest in science (Norris et al., 2012). McNamara, Ozuru, and Floyd (2011) indicated that narrative-argumentative texts are more challenging than informative texts which is crucial for gifted students. Sánchez, García, and Bustos (2016) stated that if the text is organized narratively, students performed better in attending to the text than students who read authoritative text. On the contrary, students experience difficulties in analyzing components of text, establishing meaningful links between sentences, and making conceptual connections when they encounter expository text/low cohesion texts (Ainsworth & Burcham, 2007; Goldman & Bisanz, 2002).

Analytical Framework

Since textbooks and other text based teaching materials are powerful catalysts for improving comprehension and inquiry skills in teaching, we need an analytical framework in order to analyze cohesion in text (Roseman, Stern, & Koppal, 2010). The framework can be used both analyzing the texts and constructing low and high cohesive texts. Hence, the current study constructs analytical framework of text coherence by adapting the studies of Tsabari and Yarden (2005); McNamara, Ozuru, and Floyd (2011); Kloser (2016); Goldman and Lee (2014); Uccelli et al (2015); Sanchez, Garcia, and Bustos (2016); Tolppanen, Rantaniity, and Aksela (2016).

The framework of text coherence consists of four different themes as followings: (1) text structure, (2) lexicogrammatical sources, (3) syntactic complexity, and (4) organizing argumentative text.

Text structure

Text coherence level is changed through three attributes of text structure.

(a) Topic headers can be added in the form of expository and explicit questions. For instance, 'pancreas' or 'how does the pancreas control blood sugar?'.

(b) Bold, italics, and underlying text can be used as rhetorical devices as visual forms in order to identify and emphasize key terms.

Low: The process of green plants capturing light energy and converting it into chemical energy is called photosynthesis.

High: The process of green plants capturing light energy and converting it into chemical energy is called ***photosynthesis***.

(c) Temporal cohesion tools can be arranged in order to present information in plausible order. They are organizational devices which create an overall framework for the text, connect and indicate the main ideas, and alert the reader to the text's structure. Temporal sequences of events can be realized in this way.

Low: There are two characteristics that distinguish birds and mammals from the rest of the animal kingdom. First, they keep their body temperature within narrow limits regardless of the ambient temperature. For this reason, they are often described as homeothermic. Second, they are endothermic; the heat they retain is produced in the body.

High: 1. Warm-blooded animals are homeothermic. In other words, unlike other animals, birds and mammals keep their body temperature within narrow limits regardless of the surrounding temperature.

2. Two warm-blooded animals are endothermic. Endothermic animals are different from cold-blooded animals whose body temperature is protected by heat from external sources.

Syntactic complexity

Syntax difficulty can be manipulated by one specific aspect.

(a) Adding connectives. The revision includes adding connectives such as however, because, although, and etc. They provide more resonance between successive sentences. These precise markers provide logical relations and discourse transitions.

Low: The term warm-blooded is the name given to those who can keep their body temperature higher than those in their environment. Birds and mammals can be given as examples.

High: The term warm-blooded is a name given to birds and breasts because they can keep their body temperature higher than their surroundings and are generally able to do this.

Lexicogrammatical sources

Text cohesion is improved by following two criteria of lexicogrammatical sources.

(a) *The former* is replacing ambiguous pronouns with nouns.

Low: They are endothermic; the heat they retain body heat is produced in the body.

High: Warm-blooded animals are endothermic.

(b) *The latter* is adding descriptive elaborations that link unfamiliar concepts with familiar ones. This provides explanatory coherence. All these criteria are realized through using synonymous terms, explanatory text, and scaffolding academic vocabulary. Explanatory text types make it easier to understand abstract and complex scientific processes. Academic vocabulary is scaffolded with daily language, such as scaffolding ‘transferred’ term with ‘shifted’.

Low: The mineralization by covering the hard parts of the creature with sediments after death is called fossilization.

High: The mineralization (*the combination of minerals in the shell's structure and surrounding minerals such as calcium and iron*) by covering the hard parts (*skeleton*) of the creature with sediments (*sand and sea*) after death is called fossilization.

Organizing argumentative text

The more cohesive texts present the same concepts as narratives of historical experiments, phrase headings as research questions rather than declarative statements because the nature of scientific inquiry requires starting with questions about phenomena rather than with statements to be learned. Coherent texts also include investigations made by scientists to address research questions, reference existing theory, summarizes the methods used to test the research question, includes quantitative and qualitative data, and justifies claims using the data in order to make readers more familiar with the scientific inquiry process. They help students follow the internal logic of the scientific process as it unfolds. In this way, students gain acquaintance with the rationale of the research plan, the language and structure of scientific communication, and the continuity of the scientific research process. Texts are taken from a study of Kloser (2013).

Low: “Diabetes is a condition that affects millions of people. People with diabetes either have a pancreas that does not produce enough insulin or their body cells cannot use insulin properly. As a result, a person with diabetes has a high blood sugar level and even sugar is found in their urine. In fact, hundreds of years ago, people with diabetes were identified by their sweet-smelling urine. People with diabetes often have diets that limit the amount of sugar they eat. Their body doesn't break down sugar. Unused sugar is excreted in the urine and cannot be used…”

High: “In 1889, two scientists named Joseph von Mering and Oskar Minkowski believed that the pancreas, an organ close to the stomach and intestines, could help the body use sugar for energy. In their animal experiments, they detected high levels of sugar in the blood of an animal without a pancreas and a low amount of sugar in the blood of those with a pancreas. After scientists learned that the pancreas helps the body use sugar molecules for energy, they wanted to know how this happened. Frederich Banting and Charles Best believed that the pancreas secretes a hormone, a small molecule that affects the function of other cells, into the blood to help cells take up and use sugar. Banting and Best conducted an experiment to test their hypothesis…”

3.3.1.3 Semi-structured Interviews

Semi-structured interviews are conducted with participants. These interviews are prepared by taking the recommendations of experts. Before conducting the interviews, pilot interviews were realized with two experienced teachers in order to revise interview questions. One of them is male, the other is female. Male has a bachelor’s degree, female is a PhD candidate (See Table 3.9). Interview questions were tested and then revised in this way.

Table 3. 9 Demographics of the participants of pilot interview

Participants	Bachelor/Ms/PhD	Years in teaching	The level s/he taught
Mert	Bachelory	8	Primary/Secondary
Ayşe	PhD	6	Primary/Secondary

Interviews are realized before, during and after the intervention. These interviews can be classified into three categories. The former is pre-interview which is conducted before the intervention in order to investigate (1) participant teachers’ pedagogical practices; (2) their awareness on multimodal text design and multimodal representations regarding image-text intermodal relations and text coherence; (3) their views on impacts of these texts on learning and meaning making; (4) and how they plan and organize teaching process by using representations. The latter is mid interviews which are conducted during the intervention. These interviews are generally about comprehending, (1) how they design multimodal representations considering the elements of intermodal relations and text coherence; (2) their evaluations and views on intervention model, its teaching and learning activities, and its application process, (3) difficulties they have experienced. The last one is post interview which is conducted after the intervention. This interview was to evaluate the effectiveness of the model, its teaching and learning activities, and its application process, and its implications.

3.4 Data Analysis

3.4.1 Analysis of Interview Data

Interviews and discussions were analyzed qualitatively via content analysis. The data were coded, categorized, and finally themes were defined (Savin-Baden & Major, 2013; Yıldırım & Şimşek, 2016). Content analysis means gathering related data under certain themes, and then organizing and interpreting data (Yıldırım & Simsek, 2016). Stages of content analysis can be defined as follows: collecting data, coding, creating categories and themes. During analysis, a code is given to each analysis unit. Categories are created according to the similarities or differences between the codes. Themes are created from the categories according to their meanings.

Each participants' explanations were evaluated individually. Apart from discussions made on their designs, the interviews include the followings: (1) their views and perceptions about multimodal representations and the MpM, (2) their experiences about designing intermodal relations and text coherence, (3) opportunities of the MpM for the education of gifteds, (4) what purposes multimodal texts designed according to these intermodal relations serve in the classroom, (5) how preparing teaching materials according to these principles affect learning products designed by students.

The interviews were transcribed and analyzed. Each participant‘s explanations were evaluated individually. Their thoughts about the MpM, their experiences, choices, designs, and evaluations on intermodal relations and text coherence, purposes of intermodal relations serve in the classroom, and contributions of model to the education of gifted were some of the basic topics of the interviews. Students' expressions were coded and categorized. The quotes from the interviews used as examples have been translated from Turkish.

3.4.2 Analysis of Intermodal Relations Between Image-Text in Multimodal Representations

Data obtained from artefacts designed by participants were analyzed according to the analytical framework improved. Framework was constructed regarding systemic functional multimodal discourse analysis approach. Based on the analytical framework, intermodal relations between image-text are classified into two groups, four levels, and eight categories. Two groups refer to concurrence and complementarity. The former one includes two levels (Level 1 and 2) and four categories (decorational, exemplary, representational, and exposition). The latter also consists of two levels (Level 3 and 4) and four categories (comparative, organizational, augmentation, and interpretational) (See Table 3.10).

Table 3. 10 Categories of intermodal relations

Concurrence	
Level 1	Decorational
	Exemplary
Level 2	Representational
	Exposition
Complementarity	
Level 3	Comparative
	Organizational
Level 4	Augmentation
	Interpretational

The researcher coded each representation of participants by identfying levels and categories. To do this, first, researcher divided multimodal representations into dimensions. Dimension refers to a specific aspect of represented topic. In other words, what each representation in multimodal whole contributes to overall meaning by refering to only one specific respect. For instance, in a global warming subject, while one representation signifies dimension of causes, the other refers to effects dimension. After determination of dimension, the researcher identified categories of each representation in multimodal representations at regular intervals (15 days). Besides, an expert categorized multimodal representations independently. Finally, the expert and researcher discussed about categorizations in order to reach a consistent classification.

3.4.3 Analysis of Text Coherence in Multimodal Representations

In the same way, the researcher, at first, classified attributes of text coherence into four groups and six categories (see Table 3.11). While analyzing aspects of text coherence, the researcher read written text in multimodal representation many times at different times, and then decided what attributes the multimodal text had. Another expert also identified these aspects. Finally, the researcher and the expert reached a consensus by discussing.

Table 3. 11 Text coherence attributes

Attributes	Low Level Cohesion	High Level Cohesion
Headings	Expository text	Research question
Body Text	Descriptive,informative	Narrative, explanatory
Examples	X	Examples with descriptions
Pronouns	Include pronouns	Replacing ambigious pronouns with nouns
Connectives	X	Adding connectives to specify relationships between sentences
Highlighting	X	With italic, bold, and underlying
Academic vocabulary	Non-scaffolding	Scaffolding
Scientific Process (Argumentative Text)	X	Includes research question, hypothesis, and results
Conceptual Overlap	X	Replacing and inserting words

3.4.4 Validity and Reliability

In order to ensure the reliability and validity of the current research, the concepts of internal validity (credibility), external validity (transferability), reliability (dependipality) and confirmability (dependability) (Lincoln & Guba, 1985; Yıldırım & Simsek, 2016) were taken into consideration. The issues about validity and reliability asked by Bakker are answered in a sequence in the following topics (Table 3.12).

Table 3. 12 Aspects of validity and reliablity in a research study (Bakker, 2019)

Aspect of the study	Validity	Reliability
Instruments	Is it a valid instrument?	A reliable instrument?
Data collection	Is the data of high quality? (internal validity)	Making audio and/or video recordings to avoid memory problems Making transcripts
Data analysis	Has data triangulation or member checking been applied? (internal validity)	Using a coding scheme and measuring interrater agreement (interrater reliability)

3.4.4.1 Validity

Internal validity

Credibility is about the accuracy of research findings and results (Merriam & Tisdell, 2015). Credibility of findings is realized through experience over time, triangulation, member checking, and expert views (Savin & Baden, 2013). The researcher spended lots of time (six months) staying in the research field, in this way he was exposed to detailed dimensions of researched issue. Triangulation has been made using analytical frameworks -which analyzes participants' representations-, interviews, and discussion on participants' representations. Member checking was realized by sharing a summary of findings to the participants about their designs to check accuracy. In addition, expert views were used in the evaluation of the MpM, in the development of activities, data collection tools and rubrics, and in the interpretation of the data.

External validity

Transferability can be achieved with detailed description and purposeful sampling strategies in qualitative research (Merriam & Tisdell, 2015). In order for the results to gain meaning for the reader, it is important to describe in detail and to explain for what purpose the sample was selected (Yıldırım & Şimşek, 2016). In this study, the collection and analysis of qualitative data are explained in detail. In order for readers to interpret the results more easily, examples of participants' designs and views are presented.

3.4.4.2 Reliability

Coding

The intermodal relations in multimodal representations were coded based on the following two categories. The former is *concurrence* which is called as *low level including* level 1 (monomodal, decorational, and exemplary relations) and level 2 (representational and exposition relations). The latter is *complementarity* which is called a high *level* including level 3 (comparative and organizational relations) and level 4 (augmentational and interpretational relations).

Reliability of coding

Reliability of coding is defined by intra-rater and inter-rater reliability. For intra-rater reliability, the same researcher coded representations in two distinct times (2 weeks long time gap). For inter-rater reliability, each of two researchers coded and compared the consistency among given categorical responses. Researchers recorded concurrence and complementarity features of all image-text relations in distinct times. We used Cohen's Kappa test to see consistency between observations (Table 3.13) (Cohen, 1960; Kottner & Streiner, 2011).

Cohen's kappa results showed that there is substantial agreement between two codings at different times in the subjects of global warming, vaccination, and biotechnology. There is perfect agreement between two measurements in the subjects of liquid pressure and assessment activity in terms of intra-rater reliability.

Findings indicated that there is substantial agreement between two different researchers in the subjects of global warming, vaccination, liquid pressure, and biotechnology. And, there is perfect agreement between researchers in the subjects of assessment activity in terms of inter-rater reliability.

Table 3. 13 Cohen's kappa results of different subjects

Subjects	Intra-rater	Inter-rater
Global warming	,785	,720
Vaccination	,761	,716
Liquid Pressure	,823	,762
Biotechnology	,736	,710
Assessment activity	,840	,848

3.4.4.3 Confirmability

In qualitative research, the concept of verifiability is used since its full objectivity is not possible (Lincoln & Guba, 1985). The results obtained in this study are presented in comparison with the data collected and the data are interpreted in order to realize dependability.

4
FINDINGS

4.1 Findings of Preliminary Phase

In the preliminary phase, the researcher aimed to determine problem experienced by ToGs in the real educational context regarding using and designing multimodal representations. To do this, representations of teachers were collected and analyzed case by case whether they are representationally competent or not. While presenting examples of ToGs' representations, only one example of each type of intermodal relations and text coherence attributes used is given in the tables.

After analyzing teachers curated artefacts, the researcher also conducted pre-interview with each participants one by one. Teachers were asked how they plan, select, sequence representations in a challenging way, and design processes for their representations both in monomodal (written or visual text) and multimodal texts. They were asked about how to realize coherence in a written text. They were shown four different multimodal representations which serve different purposes, and asked him how they differ, and discussion was realized on their affordances and limitations. Finally, they were asked about how to integrate written and image mode in a meaningful way.

4.1.1 ToGs' Representations

Case 1 – T1

Data revealed that T1 used thirteen representations while telling the subject of plants. The researcher examined all these representations and found that T1 uses only a low level of intermodal mechanisms, such as an exemplary one (See Figure 4.1, and Table 4.1).

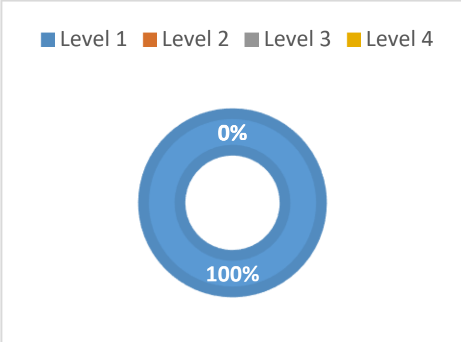
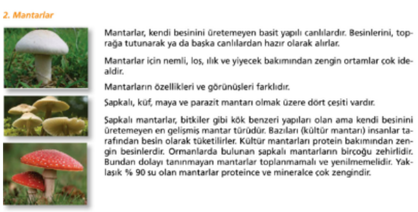


Figure 4. 1 Intermodal relations levels in T1's representations

As shown in Table 4.1, T1 lacks abilities of designing written mode in coherence. He has no awareness about coherence patterns. He does not use explicit questions in order to invite students to the text. He does not link unfamiliar concepts with familiar ones, adding words, descriptions and examples in order to increase argument overlapping.

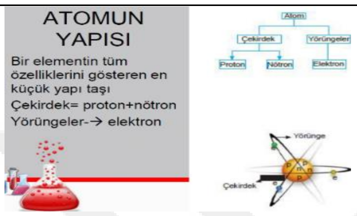
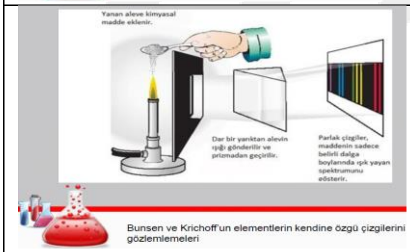
Table 4. 1 Representations of T1 before MpM

Representation	Text Coherence Attributes	Intermodal Relation Types
	Text Structure -Expository heading -Bold text for emphasizing -Partly temporal cohesion	Concurrence -Exemplary
	Text structure -Expository heading -Bold text Syntactic Complexity -Connectives	Concurrence -Exemplary
	Text structure -Expository heading Syntactic Complexity -Connectives Lexicogrammatical Sources -Replacing ambigious pronouns with nouns	Concurrence -Exemplary

Case 2 – T2

In terms of text coherence, representations of T2 do not consist of explicit questions, highlighting with italics, bold, and underlying, scaffolding academic vocabulary, and adding examples with descriptions (Table 4.2).

Table 4. 2 Representations of T2 before MpM

Representation	Text Coherence Attributes	Intermodal Relation Types
	Text Structure -Expository heading	Concurrence -Exposition
	Text Structure -Expository content	Concurrence -Exemplary
	Text structure -Expository heading -Temporal cohesion Syntactic Complexity -Connectives Argumentative text -Investigations made by scientists -Including qualitative data	Complementarity - Organizational

Data showed that, T2 used seven representations while telling the subject of light. The researcher examined all these one according to analytical frameworks. Two of them have exemplary relation at level 1, three of them have exposition relation at level 2, and two of them have organizatioan relations at level 3 (see Figure 4.2, and Table 4.2)

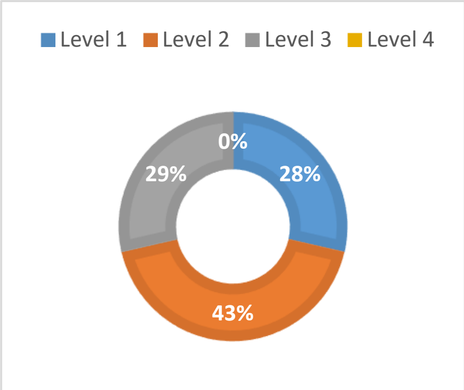


Figure 4. 2 Intermodal relations levels in T2's representations

Case 3 – T3

Examined representations of T3 revealed that she used five representations in order to tell the subject scientific method and process. Two of them include exemplary relation at level 1 and three of them consist of decorational relation at level 1 (see Figure 4.3 and Table 4.3).

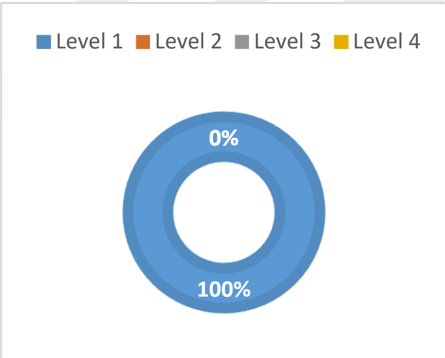


Figure 4. 3 Intermodal relations levels in T3's representations

Examined representations of T3 showed that text coherence in her designs is at slightly good level. Her representations do not include following elements: organizing argumentative text, linking unfamiliar concepts with familiar ones, and scaffolding academic vocabulary (see Table 4.3).

Table 4. 3 Representations of T3 before MpM

<table>
<tr><th>Representation</th><th>Text Coherence Attributes</th><th>Intermodal Relation Types</th></tr>
<tr><td>
</td><td>Text Structure
-Explicit question
-Underlying
-Temporal cohesion
Syntactic complexity
-Connectives</td><td>Concurrence
-Exemplary</td></tr>
<tr><td>
</td><td>Text Structure
-Expository heading
-Highlighting
-Temporal cohesion
Syntactic complexity
-Connectives</td><td>Concurrence
-Decorational</td></tr>
</table>

Case 4 – T4

Her representations seem very poor with regard to intermodal relations, dominantly include written mode, and just involve exemplary relations. She used nine representations while telling the subject of density. Four of them include only written mode, and the rest of them involves exemplary relation (see Figure 4.4 and Table 4.4).

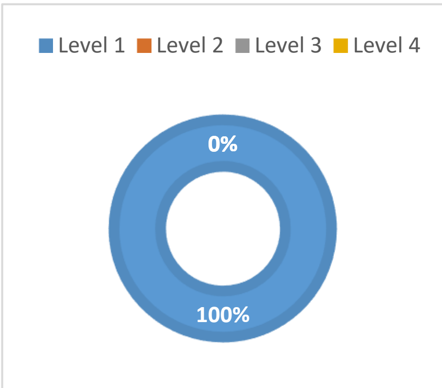
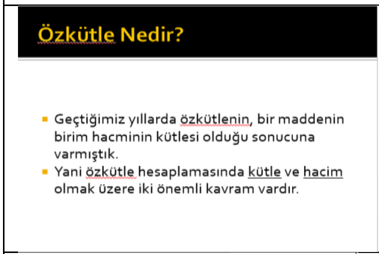
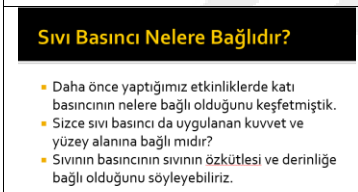


Figure 4. 4 Intermodal relations levels in T4's representations

Investigations of T4's representations revealed that she pays attention to use explicit question, highlighting, temporal cohesion, linking unfamiliar concepts with familiar ones in order to improve text coherence, however, her representations do not include most elements of text coherence, specifically factors of argumentative text, lexicogrammatical sources, and syntactic complexity (see Table 4.4).

Table 4. 4 Representations of T4 before MpM

Representation	Text Coherence Attributes	Intermodal Relations
	Text Structure -Explicit question -Underlying	Monomodal
	Text Structure -Expository heading -Bold -Temporal cohesion Lexicogrammatical sources -Link unfamiliar concepts with familiar ones	Concurrence -Exemplary
	Text Structure -Explicit question -Temporal cohesion	Monomodal

Case 5- T5

T5 used seventeen representations to tell the subject of genetics. Data revealed that he designs only primitive level of intermodal relations. Six of them include exemplary relation and four of them consist of decorational relation at level 1, and Examination of T5's representations showed that he is good at using explicit question, highlighting, connectives, temporal cohesion, and linking unfamiliar concepts with familiar ones for coherence of the text. On the contrary, he is not qualified at applying lexico-grammatical sources and organizing argumentative text (see Table 4.5).

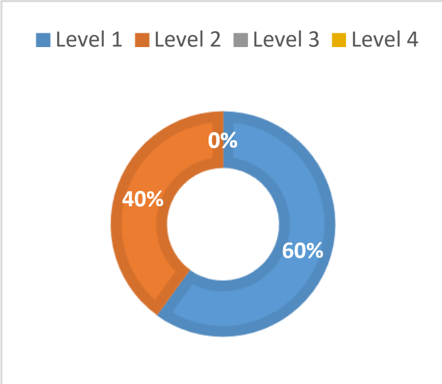
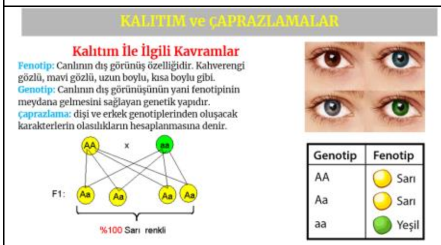


Figure 4. 5 Intermodal relations levels in T5's representations

Table 4. 5 Representations of T5 before MpM

Representation	Text Coherence Attributes	Intermodal Relation Types
	Text Structure -Explicit question and expository heading -Underlying and highlighting Syntactic complexity -Connectives	Concurrence - Decorational
	Text Structure -Expository heading -Highlighting -Temporal cohesion Lexicogrammatical sources -Link unfamiliar concepts with familiar ones	Concurrence -Exposition
	Text Structure -Expository heading -Highlighting -Temporal cohesion Lexicogrammatical sources -Link unfamiliar concepts with familiar ones	Concurrence -Exemplary

Case 6 – T6

T6's representations include generally monomodal representations, she rarely uses exemplary and representational. One of them includes decorational relation, one of them involves representational relation, and the rest of them includes just written mode. She used nine representations while telling the subjetc of inertia.

Data showed that she does not have awareness about high levels of intermodal relations (see Figure 4.6, and Table 4.6).

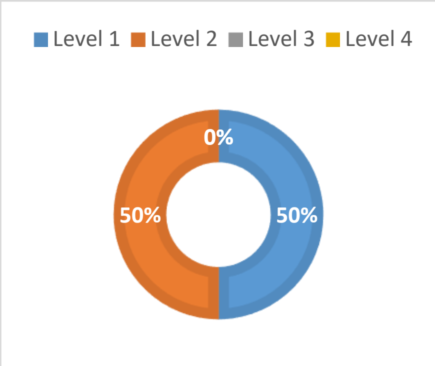
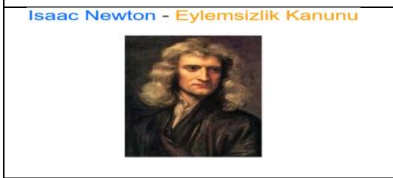
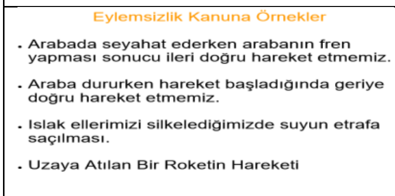


Figure 4. 6 Intermodal relations levels in T6's representations

Examination of T6's representations showed that she sometimes uses explicit question, highlighting, and connectives. On the contrary, she is not qualified at linking unfamiliar concepts with familiar ones and applying lexico-grammatical sources, organizing argumentative text, and syntactic complexity (see Table 4.6).

Table 4. 6 Representations of T6 before MpM

Representation	Text Coherence Attributes	Intermodal Relation Types
	Text Structure -Expository heading -Highlihting with coloring	Concurrence -Decorational
	Text Structure -Expository heading -Explanatory text with examples	Monomodal
	Text Structure -Explicit question	Concurence -Representational

4.1.2 Pre-Interview Findings

Pre-interviews were conducted in the present study to determine current problems existed in real educational context regarding selecting, using, sequencing, designing multimodal representations. The researcher tried to investigate how teachers plan their teaching process considering representations, for what purposes they are using representations, to what extent participant teachers aware of multimodal representations in terms of intermodal relations and text coherence, how to realize challenge by designing them, and how write a high cohesion text, and how to integrate image and text for different pedagogical aims.

At the end of the interview, data were transcribed from Turkish to English, and the researcher analyzed them through content analysis. Defined themes are presented below.

Representations are generally used for a limited number of pedagogical purposes.

Data showed that teachers advocated that using multimodal representations generally served as paying attention of students, surprise and engage them, and thus provide attendance of them to in the classroom. Five of them clearly indicated that they used representations in order to engage students. They stated that while visuals are usually used for concretizing the subject told, texts are used for clarifiying what the image is about. For instance, T1 stated that:

> "*…First, I start the presentation with a screenshot or short video that will interest and surprise the students, so after I get the students' attention, I asked them how could this be, then I will develop it a little more and ask the question in a different context and ask how it would be now, I usually surprise with visual and video, not text…*"

T2 expressed that:

> "…I use visuals to be a clue to achieve that outcome, I use visuals to concretize, I would put clues and keywords under the visual so that what I want to give explanations is understood correctly, rather than long

explanations. I would aim to attract the attention and interest of children…"

Briefly, when examined teachers' answers, it was concluded that they are using or selecting multimodal representations for only paying attention and telling the subject. However, these representations serve lots of pedagogical purposes ranging from paying attention, triggering curiosity to providing interaction in the classroom environment, supporting creativity, preparing an inquiry based learning environment, awakening different cognitive levels, and etc.

Teachers do not aware of how to design representations in a way that challenges students

Participant teachers were asked how to design a representation which challenges students, lead them to construct causal relationships, and put them into an inquiry process. Teachers pointed out that this process can be realized with models. They indicated that it can be realized by asking a question about the models in written mode. During the interview process, some clues were given to the teachers and they were compelled to think about this issue, but they did not express any opinion. For instance, T3 expressed that:

> "*…Frankly, do the representations I design or choose push students to ask questions? I do not think so. I can say that it is generally simple, I add a text next to a picture. I didn't know how to prepare representations that would put them in a thinking process, maybe it could be done by asking questions…*"

In a same way, T5 told that:

> "*…I can only do this with questions, in writing, not with representation tools, but with materials. I can say that these are not done much with these tools, and I honestly did not think about before how they can be done…*"

Differences between high and low cohesive texts are not recognized by teachers

Teachers were asked about how to write a text with only written mode considering following two distinct ways. The former is about how the text should be manipulated in a way that makes it easier to comprehend. The latter is about how the text should be organized in a way that put readers into attending an inquiry process. Teachers mentioned about just three points which generally focus on form of the text, not content of it. These are about structure of text, genre of text, and paying attention of them such as asking questions, highlihting, underlying some points, and coloring. For example, T2 told that:

> "*…In a story format, the type of writing we choose is important here, it can be a fiction, it can be a question that arouses curiosity, creates a story, and what to do next, this should be chosen as the genre…*"

T3 indicated that:

> "*…I would narrate, I could enact, rather than a straight narrative, the student could feel as if they were reading a story. There would be two or three characters, they would ask questions to each other, the characters would brainstorm, the student would brainstorm that discussion while reading, he would join them, I would start with something that he might be curious about, that he might be interested in, I would start with a question…*"

T4 expressed that:

> "*…First of all, I pay attention to the cognitive level, there should not be very long complex sentences, there should be no phrasing, it should not be written in plain black, there should be colorful texts, at least the titles, underlying can be made, let's emphasize what the child needs to pay attention to, it should not go beyond the concept I want to give…*"

Only one teacher (T1) mentioned about one attribute of high cohesive text. He stated that

> "*… I would talk about the scientific process about the concept and add scientific data…*"

Primitive level of intermodal relations between image-text in multimodal representations is well-known by teachers

Teachers were asked about intermodal relations between image-text in representations by being shown different level of multimodal representations. They were asked how these artefacts differ in terms of instructional purposes serve. Results showed that teachers are capable of naming these texts into some categories regarding purposes. However, they couldn't identify that these purposes are realized by constructing specific types of intermodal relations between image-text. T1 stated that:

> "*…Number three direct students to ask questions, number one can engage students attention, number two can be taught by informing, number four is explanatory, these four representations serve different cognitive levels. There are sentences describing the picture in the text and these provide coherence between the text and the image. Only images are not enough to understand what is explained here, it is necessary to make explanations next to it …*"

T2 expressed that:

> "*...The first is an informative representation that summarizes an event, provides information by summarizing how global warming occurs, the second is showing the stages of the water cycle, the third is a picture that models an experimental process an experiment, and the fourth is a representation that provides an answer to a question by comparing it. By making an explanation under the picture, it can be ensured that the picture and the text form integrity. It can make the job easier if it comes one after the other, has an explanation under the picture, follows a sequence, and is in an order…*"

T5 indicated that:

> "*…I make sure they both refer to each other, I pay attention that the picture reflects the content in the text, or vice versa. I think it is important to*

sequence the two in a harmonious way. The image does not only mean anything to us, it can give some clues, it becomes more meaningful and more accurate with the text, the texts here describe the images more accurately …"

T6 explained that:

"*…Text and images should support each other in harmony, the images expressing the text should not be complicated. It would be more effective if there was a text next to the image…*"

4.1.3 Summary of Preliminary Phase Findings

All these findings mentioned above revealed that ToGs are not qualified at using, selecting, and designing high level of multimodal representations and high cohesion written texts. These data showed that teachers have limited explicit knowledge about intermodal relations in multimodal representations and text coherence attributes in written text.

Interview results also indicated that ToGs have limited knowledge about how to use different types of representations for several pedagogical purposes in the digital or real classroom environment. ToGs do not know how to make a text explicit and how to design a written text which put students into an inquiry process. ToGs have not abililities of designing challengin teaching materials. Moreover, even if they are aware of only written mode is not enough to convey meaning comprehensively, they have not explicit knowledge on how to integrate image mode with written mode in order to transfer meaning in a coherent way.

As a conclusion, since using, selecting, and designing different levels of multimodal represenations -considering intermodal relations and aspects of text chorenece- play critical roles for realizing distinct pedagogical purposes in the classroom, how to equip teachers with these skills remains a real problem to be solved. To handle with this problem, the present study aimed to design a pedagogical model which embeds multimodality into the instructional process.

4.2 Findings of Prototyping Phase

4.2.1 Findings of Micro Cycle 1

4.2.1.1 Findings of Awareness Activities

The researcher distributed six monomodal texts in three different groups and four multimodal texts in four distinct groups to the ToGs as an awareness activity. Then, they were asked them to identify differences between each text in five minutes. After discussions and activities were completed, the researcher (participant researcher) transcribed interviews and analyzed to what extent gifteds' teachers identify distinct metalanguages among texts in activity 1 (monomodal text-text coherence) and activity 2 (multimodal text-intermodal relations).

Statements of ToGs showed that all teachers easily identified aspects of body text, highlighting, and academic vocabulary differences between texts. Three of them recognized differences between text in terms of temporal cohesion and connectives. Two of them perceived scientific process. Just one of them identified headings. No one identified pronouns (Table 4.7).

Table 4. 7 Teachers' perceptions about text coherence

Attributes	T1	T2	T3	T4	T5	T6
Headings				+		
Highlighting	+	+	+	+	+	+
Temporal Cohesion		+	+	+		
Connectives		+	+	+		
Pronouns						
Academic vocabulary	+	+	+	+	+	+
Body Text	+	+	+	+	+	+
Scientific Process	+				+	

At this stage, the researcher secondly investigated to what degree gifteds' teachers can identify differences between multimodal text regarding intermodal relations between image-text. Intermodal relations can be classified into two groups (concurrence-complementarity) in eight themes (decorational, exemplary, representational, expository, comparative, organizational, augmentational, and interpretational).

When the descriptions of the participants were analyzed, results showed that they were capable of identifying decorational, exemplary, and representational relations in concurrence. Two of them also described comparative and organizational relations in complementarity (Table 4.8).

Table 4. 8 Teachers' perception about intermodal relations

Intermodal Relations	T1	T2	T3	T4	T5	T6
Decorational	+	+		+	+	
Exemplary	+	+	+	+		+
Representational	+			+	+	+
Expositional	+					
Comparative		+	+			
Augmentational						
Organizational		+		+		
Interpretational	+					

4.2.1.2 Findings of Awareness Interview Activities

After analyzing the definitions made by the teachers in the awareness activity, the researcher conducted an awareness interview based on the representations of this activity.

When interviews about monomodal written texts were transcribed, data showed that the theme of the body text can be classified into six categories *including definition, descriptive, informative, technical descriptions, and general knowledge about low level cohesion in text*. They described high level cohesion in text as written according to categories of *causality, explanatory, formal, fluent, event sequencing, and progress.* The excerpts from teachers' descriptions as follows:

T1:

> "*General concepts are defined (Text 1). Written according to the causality principle. A more fluent language is used (Text 2).*"

T5:

> *"A description has been made and general information has been given (Text 1). Concept and event sequencing has been made. It is stated how the insulin hormone was discovered over time (Text 2)."*

Participants distinguished low level and high level texts into three categories under the theme of highlighting: *italics, bold, and underlying*. The excerpts from teachers' descriptions as follows:

T2:

> "*Colored. Important places are underlined. Italicized (Text 6). Other text does not include any form of highlighting.*"

T3:

> "*Underlined, bold and colored text were used to emphasize (Text 6).*"

Teachers identified differences between low level and high level texts in two categories in relation to the theme of academic vocabulary: *familiar words and words used in daily lives*. They indicated that high level texts include familiar words that reflect students' daily lives and explanations with parentheses attached. The excerpts from teachers' descriptions as follows:

T6:

> *"Unknown terms and concepts explained in parentheses with familiar words (Text 6)."*

T4:

> "Technical words have been transformed into everyday language (Text 6)."

The descriptions about the theme of connectives are divided into two patterns that are *written step by step and conjunctions.*

T2:

> *"Writing paragraphs step by step and using thematic sentences to bind the paragraphs made it easier to read (Text 4)."*

T3:

> *"Using connectives like 'but' and 'because' provide establishing causal relationships between sentences (Text 4)."*

Two teachers identified the theme of scientific processes by emphasizing categories of *justified claims, research questions, hypothesis, data, and results.*

T1:

> *"Scientists have thought about what functions the pancreas does, and experiments have been carried out by making a claim about this, and as a result it has been concluded that it works in the control of glucose level. They are told in a process in the text (Text 2)."*

T5:

> *"When I compare two texts, the second one includes research questions, and how to test it, and how they report results (Text 6)."*

None of the participants could detect the difference between pronouns.

When interviews about multimodal representations were transcribed, data revealed that teachers described the theme of decorational relation in the categories of *irrelevant, off topic, and no relationship.*

T1:

> *"An unrelated but noticeable image has been added to pay attention. There is no meaningful relation between image-text (Multimodal Text 1)."*

T5:

> *"There is only information about the subject told in text, the text and images do not refer to each other (Multimodal Text 1)."*

Participants generally identified the theme of exemplary relation in the category of *partial attribution*:

T2:

> *"The text mentions thyroxine hormone, thyroid gland, and minerals, and the visual shows only the location of the thyroid gland (Multimodal Text 2)."*

T6:

> *"In the text, it was mentioned that the hormone secreted by the thyroid gland and iodine is required for hormone secretion. The picture only shows the location and shape of thyroid gland (Multimodal Text 2)."*

Teachers identified the theme of representational relation in the category of *reflection*:

T4:

> *"The location and shape of the pancreas are specified. The place and the shape are shown in the picture, the text and the picture reflect each other, as if there is a repetition of meaning (Multimodal Text 3)."*

T6:

> *"The location of the pancreas in the body is stated in the text, and the image expresses the same (Multimodal Text 3)."*

Participants pointed out that image supports text in order to construct rich mental representations in mind when describing expositional relations. They described the theme of exposition relation in the category of *supportive*:

T1:

> "The decrease in the activities of the digestive system is shown as a sleeping stomach, making it easier to visualize this situation in the mind (Multimodal Text 4)."

Teachers (two of them) identified comparative relations between image text as *comparison*:

T2:

> *"This text has been made meaningful by providing a visual and textual comparison of healthy type 1 and type 2 diabetes, and shows in which situations diabetes occurs. It provides us opportunity to compare three situations (Multimodal Text 5)."*

T3:

> *"We can easily compare the differences in healthy, type1 and type 2 diabetes by visual and texts (Multimodal Text 5)."*

Participants (two of them) described the theme of organizational relation in the categories of c*ycle and process*.

T2:

> *"By means of visuals, texts and symbols, the relationship between the hormones and organs involved in the regulation of blood sugar was established and the process was explained (Multimodal Text 6)."*

T4:

> *"Hormone secretion was expressed in a process by indicating the stages sequentially with arrows (Multimodal Text 7)."*

Only one teacher recognized interpretational relations and he stated that this type of multimodal text includes *causality*.

T1:

> *"The relationship between the two hormones working opposite was expressed by the balance in the seesaw and how this balance would be established in the case of hunger and satiety. The reader of this text was asked to establish this causality (Multimodal Text 8)."*

As shown in the quotations and Table 3.15 and 3.16, teachers can mostly identify intermodal relations in the concurrence category, and they can differentiate generally some attributes of text structure in text coherence.

4.2.1.3 Summary of Awareness Activities Findings

At the end of the awareness activities, the researcher reached the following conclusions. The former, it was found that when teachers encounter monomodal texts designed with different parameters of text coherence, they can distinguish a large part of these aspects and name them with different codes. As a result of the interviews conducted about these definitions and names ToGs made, it can be concluded that the participants gained awareness that monomodal texts can be differentiated epistemically and semantically.

Teachers stated that texts written by storytelling, explaining the causes of events with data, emphasizing important points by higlihting and coloring, dividing the subject into parts, translating unknown concepts into everyday language, and using conjunctions to establish relationships between sentences are easier to understand and read fluently. These statements made by teachers clearly revealed that they had gain awareness towards differentiating monomodal texts in terms of text coherence attributes.

The latter, it was concluded that the vast majority of participants gained awareness towards identifying primitive level of intermodal relations such as decorational, exemplary, and representational, -except expositional one. They described decorational one as *irrelevant, off topic, and no relationship*; exemplary relation as *partial attribution*; representational relation as *reflection*; and expositional relation as *supportive*. However, just few ones (one or two of them) gained awareness towards high level multimodal representations by identfying comparative relation as *comparison*, organizational relation as *process or cyclic*, and interpretational relation as *causality*. All these namings and codings reveal high level parallelism with functionalities of aspects of text coherence and intermodal relations.

4.2.1.4 Findings of Design Activities

Activities 3 and 4 were given to teachers as transformed practice in which they apply what they have learned in different contexts. The first one demanded them to apply their learnings about text coherence, the second one asked them to implement their learnings about text coherence and intermodal relations. Thus, a representational challenge was also realized.

Case 1- T1

As compared to representations designed before attending the MpM, T1 started to use different types of intermodal relations in concurrence and complementarity categories (Figure 4.7). While dominant ones are situated in the concurrence category, it seems that he had a tendency towards to design organizational, comparative, and interpretational relations except augmentation. It was observed that he continued to keep his habits in using exemplary relations (Table 4.9).

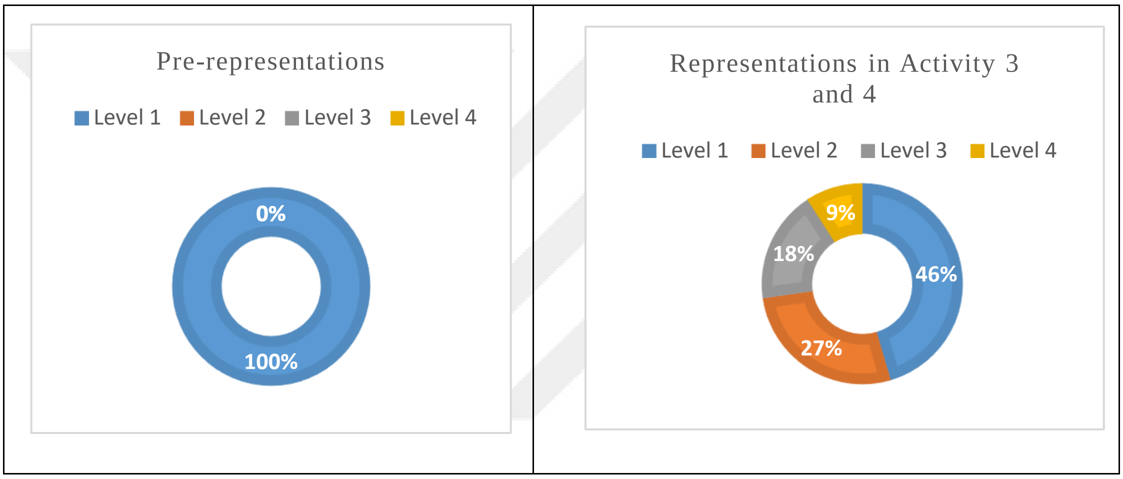


Figure 4. 7 T1's Representations before MpM and in activity 3 and 4

T1 designed eleven representations in telling the subjects of greenhouse gases and global warming. Findings revealed that most of them can be categorized as low level of multimodal representations. A few of them were in the category of high level.

Table 4. 9 Number of intermodal relations designed by T1 in activity 3 and 4

Level 1	Decorational	1
	Exemplary	4
Level 2	Representational	
	Exposition	3
Level 3	Comparative	1
	Organizational	1
Level 4	Augmentation	
	Interpretational	1

An example of each different intermodal relation that the participant constructed in the design activity of this first micro cycle is given in the table below with its explanation (Table 4.10).

Table 4. 10 Intermodal aby T1 in Activity 4

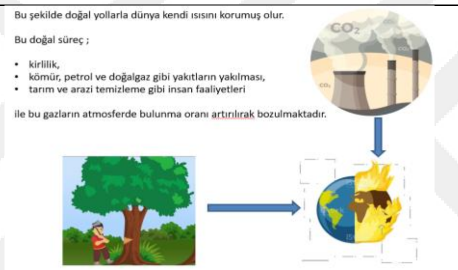
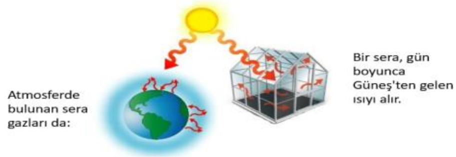
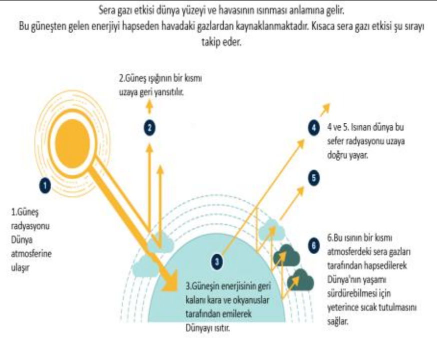
Types of Intermodal Relations	**Sample**	**Explanation**
Decorational		The text refers to greenhouse effect and global warming, the image shows a world under the smokes. There is no meaningful relation, the image or the text does not refer to each other.
Exemplary		The text tells about the reasons of disruption in natural balance like air pollution and deforestation, the image reveals some examples of it.
Exposition		The text refers to carbon level in the atmosphere by years, the image shows this increase with different modes but the same meaning.
Comparative		The text and image together provide readers to understand similarities and differences between greenhouse and greenhouse gases in the atmosphere.

Table 4. 10 Intermodal relations used by T1 in activity 4 (continued)

<table>
<tr>
<td>Organizational</td>
<td>
</td>
<td>The information about the greenhouse effect is distributed among texts and images. For example, while the image shows absorption of gases, the text mentions that absorption leads to increase in ground temperature.</td>
</tr>
<tr>
<td>Interpretational</td>
<td>
</td>
<td>The text and image emerges a question about how the world temperature increases regarding greenhouse gases, and demands readers to make causal relations.</td>
</tr>
</table>

Investigations about text coherence showed that he did not experience any difficulty in applying attributes of text coherence while choosing the proper ones from the available monomodal texts provided by the researcher (Table 4.11). That is, it can be concluded that he is capable of identifying and selecting aspects of high cohesion texts.

Table 4. 11 Text coherence patterns used by T1 in activity 3 and 4

Attributes	Teacher's statements
Headings	Will greenhouse gases warm us?
Highlighting	Some gases in the atmosphere are also called **greenhouse gases** because they capture heat
Temporal Cohesion	1.Solar radiation reaches the Earth's atmosphere 2.Part of sunlight is reflected back into space.
Connectives	Vibrating and shifting gas particles reflect heat…, *so* all these greenhouse gases heat the earth and air.
Pronouns	Greenhouse gases are just like greenhouses, ... Without the effect of greenhouse gases ...
Academic vocabulary	The glass or plastic membranes (walls) of the greenhouse allow photons (sunlight) to pass through.
Body Text	Narrative- argumentative
Scientific Process	He talks about scientists' claims and how they justify those claims.

Case 2- T2

When compared to pre-representations with representations in first micro cycle, it was concluded that the decrease in Level 2 (40%-17%) was reflected in the increase in the third level (20%-29%) (Figure 4.8).

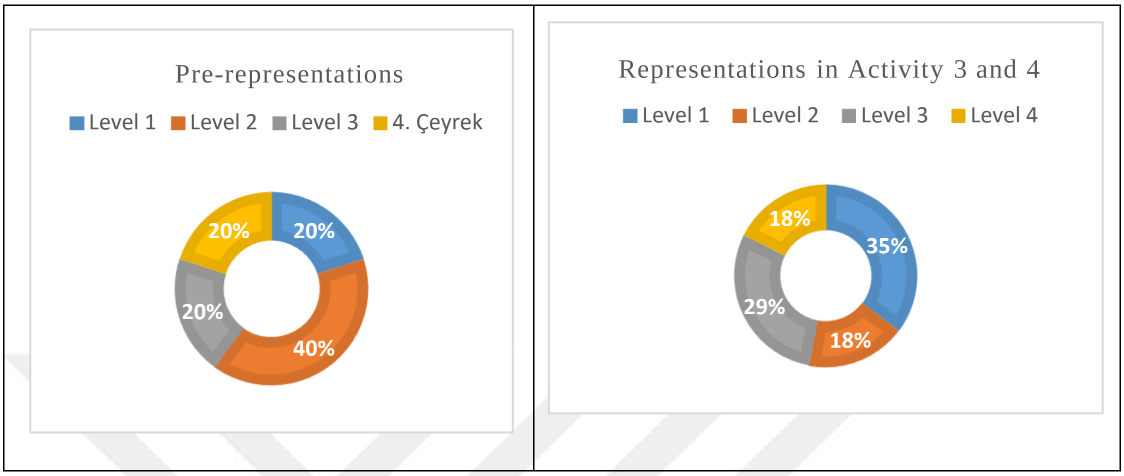


Figure 4. 8 T2's Representations before MpM and in activity 3 and 4

T2 designed seventeen representations in telling the subjects of greenhouse gases and global warming. Findings revealed that she increased the number of designing high level multimodal representations (Table 4.12). These data indicated that when she was provided with available images and texts in order to design representations, she started to construct high level ones. It can be concluded she made progress in selecting and integrating available images and text.

Table 4. 12 Number of intermodal relations designed by T2 in activity 3 and 4

Level 1	Decorational	2
	Exemplary	4
Level 2	Representational	2
	Exposition	1
Level 3	Comparative	3
	Organizational	2
Level 4	Augmentation	
	Interpretational	3

An example of each different intermodal relation that the participant constructed in the design activity of this first micro cycle is given in the table below with its explanation (Table 4.13).

Table 4. 13 Intermodal relations used by T2 in activity 4

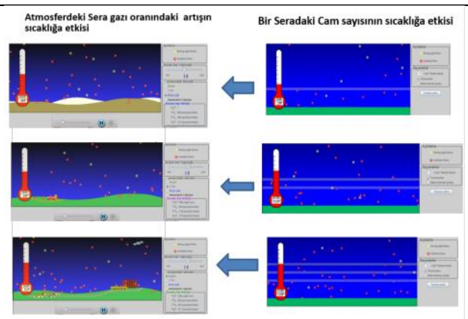
<table>
<tr><th>Types of Intermodal Relations</th><th>Sample</th><th>Explanation</th></tr>
<tr><td>Decorational</td><td>
</td><td>While the text refers to the increasing amount of greenhouse gases, the image shows a sweaty world emoji, there is no meaningful correspondence between them.</td></tr>
<tr><td>Exemplary</td><td>
</td><td>The text tells the increasing rate of greenhouse gases in the atmosphere with the examples of fossil fuel combustion and air pollution, the image gives examples of this situation.</td></tr>
<tr><td>Representational</td><td>
</td><td>The image and the text reflects each other in terms of meaning they convey. While the text tells how photons pass transparent walls of the greenhouse and how the greenhouse absorbs the heat, the image reflects this meaning.</td></tr>
<tr><td>Exposition</td><td>
</td><td>The image mentions the same meaning with the text. While the text refers to an increase in the temperature over years, the image tells the same meaning with graphics.</td></tr>
<tr><td>Comparative</td><td>
</td><td>Representations provide readers to compare the impact of the number of glass in a greenhouse on the temperature with the impact of the rate of greenhouse gases in the atmosphere on the temperature. In this way, readers are enabled to comprehend similariies and differences.</td></tr>
</table>

Table 4. 13 Intermodal relations used by T2 in Activity 4 (continued)

Organizational		The images and texts explain how the world is heated by sharing meaning across them.
Interpretational		The images and text ask readers to construct causal relationships between deforestation and global warming, and melting glaciers and global warming.

She applied features of text coherence appropriately. This result showed that she was good at finding and selecting the ones with high text coherence among the existing texts (Table 4.14).

Table 4. 14 Text coherence patterns used by T2 in activity 3 and 4

Attributes	**Teacher's statements**
Headings	Why is the world warming?
Highlighting	This event is also called **global warming.**
Temporal Cohesion	1.Solar radiation reaches the Earth's atmosphere 2.Part of sunlight is reflected back into space.
Connectives	The glass or plastic walls of the greenhouse allow photons (sunlight) to pass through, *but* these structures also retain some of the heat accumulated inside the building.
Pronouns	Some gases in the atmosphere are called *greenhouse gases* because they capture heat similar to greenhouses. Examples of *greenhouse gases* are water vapor, methane, nitrous oxide and ozone gas along with carbon dioxide.
Academic vocabulary	With human activities such as natural process air pollution, burning fossil fuels, destroying forests, the concentration (rate) of greenhouse gases in the atmosphere is increasing day by day.
Body Text	Narrative-argumentative
Scientific Process	She talks about scientists' claims and how they justify those claims.

Case 3- T3

When she was immersed into a semiotically rich environment, and scaffolded with lots of options regarding available designs, the results showed that there was an increase in the rate of using different intermodal relations (Figure 4.9). However, it was also observed that she continued her old habits considering exemplary and decorational ones. She still dominantly used intermodal relations in concurrence category, besides she had attempts to use organizational and interpretational ones, not comparative and augmentation.

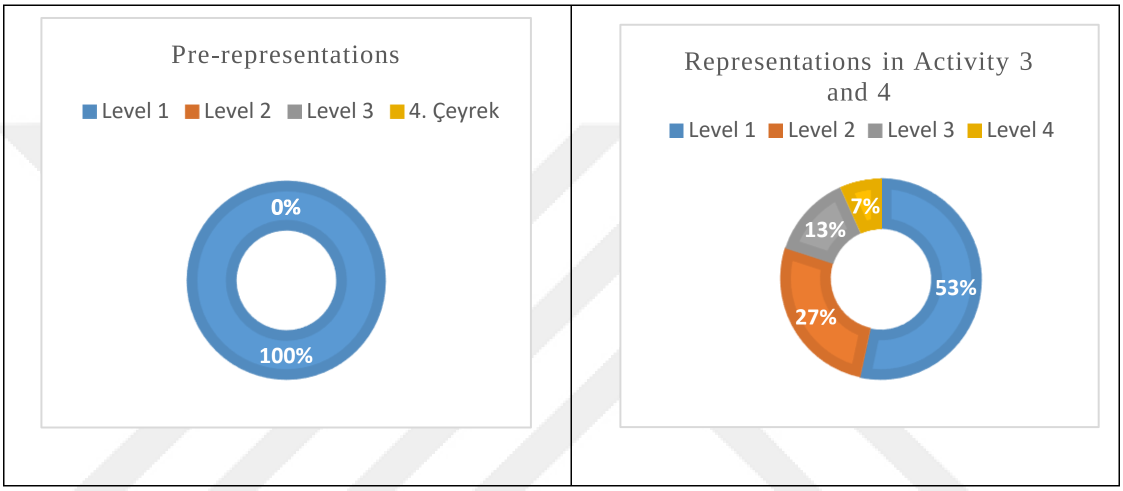


Figure 4. 9 T3's Representations before MpM and in activity 3 and 4

T3 has designed 15 representations describing global warming by selecting and integrating the appropriate ones from the visuals and texts provided to them. She started to use different types of intermodal relations even if most of them are stiuated in low level mechanisms (Table 4.15).

Table 4. 15 Number of intermodal relations designed by T3 in Activity 3 and 4

Level 1	Decorational	2
	Exemplary	6
Level 2	Representational	3
	Exposition	1
Level 3	Comparative	
	Organizational	2
Level 4	Augmentation	
	Interpretational	1

An example of each different intermodal relation that the participant constructed in the design activity of this first micro cycle is given in the table below with its explanation (Table 4.16).

Table 4. 16 Intermodal relations used by T3 in activity 4

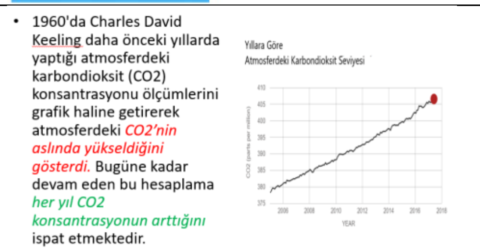
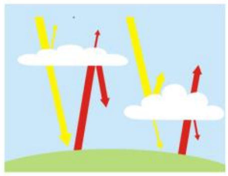
Types of Intermodal Relations	**Sample**	**Explanation**
Decorational		The text refers to greenhouse effect and global warming, the image shows a world under the smokes. There is no meaningful relation, the image or the text does not refer to each other.
Exemplary		The images refer to some examples in the text, such as environmental pollution. The images do not refer to the second paragraph in any way.
Representational		The point in the text (The Earth's atmosphere (gas layer) passes the sun's rays and absorbs some of it.) is reflected by the image.
Exposition		The image mentions the same meaning with the text. While the text refers to an increase in the rate of carbondioxide level over years, the image has the same meaning with graphics.
Organizational		The steps in the image are explained by text in a sequence. The image indicates the points that the text does not mention, or vice versa. In this way, whole meaning is shared.

Table 4. 16 Intermodal relations used by T3 in activity 4 (continued)

Interpretational	• Bulutların yakın ve uzak olması ile küresel ısınma arasında nasıl bir ilişki vardır? 	Image and some tricks (making arrows wide or narrow) in it with text ask readers to construct causal relationships between global warming and clouds close to and far from the earth.

As shown in Table 4.17, she has the capability of using most attributes of text coherence appropriately, except pronouns. The results revealed that she was good at finding and selected most suited ones regarding text coherence.

Table 4. 17 Text coherence patterns used by T3 in activity 3 and 4

Attributes	**Teacher's statements**
Headings	How Do Greenhouses Function?
Highlighting	Since the gases in the atmosphere trap heat similar to the greenhouse, these gases are called **greenhouse gases.**
Temporal Cohesion	1. Greenhouse gases are gases that absorb radiation (radiance) from the sun. 2. These gases get their name from greenhouses.
Connectives	Glass walls trap the heat of the sun, *so* the plants in the greenhouse create an environment that will allow them to grow and develop even in cold nights.
Academic vocabulary	Greenhouse gases are gases that absorb radiation (radiance) from the sun.
Body Text	Argumentative-narrative
Scientific Process	She talks about scientists' claims and how they justify those claims.

Case 4 – T4

In the preliminary stage, the researcher determined in her presentations that T4 usually designs monomodal texts. In the interview, she has also stated that she has only awareness about exemplary and representational relations. At the end of first iteration, data revealed that she can construct different types of intermodal relations, but again generally in concurrence category (Figure 4.10).

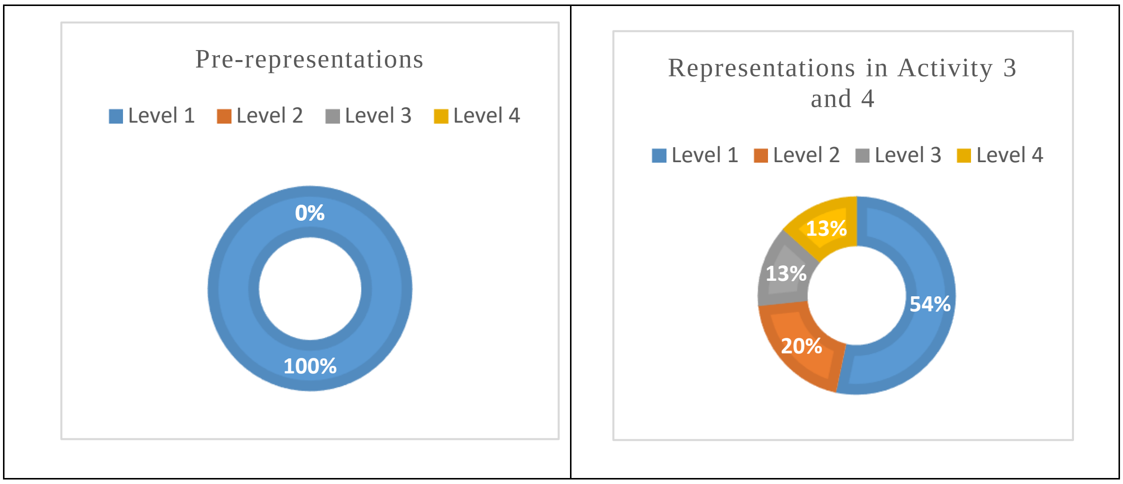


Figure 4. 10 T4's Representations before MpM and in activity 3 and 4

T4 has designed 15 representations describing global warming by selecting and integrating the appropriate ones from the visuals and texts provided to them. She used all types of intermodal relations except representational one (Table 4.18).

Table 4. 18 Number of intermodal relations designed by T4 in activity 3 and 4

Level 1	Decorational	2
	Exemplary	6
Level 2	Representational	
	Exposition	2
Level 3	Comparative	1
	Organizational	1
Level 4	Augmentation	1
	Interpretational	1

An example of each different intermodal relation that the participant constructed in the design activity of this first micro cycle is given in the table below with its explanation (Table 4.19)

Table 4. 19 Intermodal relations used by T4 in activity 4

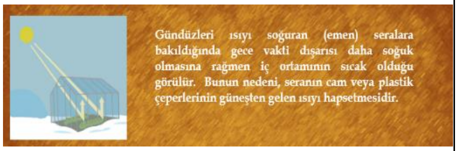
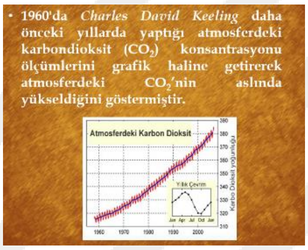
Types of Intermodal Relations	Sample	Explanation
Decorational		While the text mentions that the temperature on the earth's surface has increased due to the increase in CO2, the images do not refer to it.
Exemplary		The image shows only one part of the text, it is an example of it.
Exposition		The image mentions the same meaning with the text. While the text refers to an increase in the rate of carbon dioxide level over years, the image tells the same meaning with graphics.
Comparative		The image and text together enable readers to compare similarities and differences between greenhouse and gases in the atmosphere.
Organizational		The steps in the image are explained by text in a sequence. The image indicates the points that the text does not mention, or vice versa. In this way, the whole meaning is shared.
Augmentation		Cyclic process modelled by arrows (with blue/cold and red/hot tones) augments the meaning of how heat is conserved in a greenhouse in the text.

Table 4. 19 Intermodal relations used by T4 in activity 4 (continued)

Interpretational		Image and text ask readers to construct causal relationships between water vapor and warming of atmosphere.

4.2.1.5 Summary of Design Activities Findings

At the end of the first design activities, findings revealed that all participants gained skills of selecting and integrating proper images and texts from available texts provided by the researcher while designing high cohesion monomodal text and different types of intermodal relations. That is, they were good at finding and selecting the ones with high text coherence among the existing ones. The point should be indicated that participants have designed all types of intermodal relations even if the majority of their representations belongs to the category of primitive level. They gained tendency towards to design high level multimodal representations (rarely augmentation and interpretational ones) and high cohesion texts.

These findings stated that when teachers are provided with available resources that they can compare and select, they gain competence in identifying the difference between them and selecting and combining the appropriate ones. These skills constitute the first two of the basic steps of representational competence skills (gaining awareness, identifying, and selecting) and are expressed as prerequisites for the high abilities of RC skills (designing and evaluating).

4.2.2 Findings of Micro Cycle 2

Teachers were encountered with a more challenging representational activity than previous one in activity 5. They were asked to complete an unfinished infographic about vaccination. The researcher decreased scaffolding level and provided questioning based feedback to the teachers' designs. The researcher did not enable teachers with images and texts, and asked them to find appropriate ones themselves.

4.2.2.1 Findings of Design Activities

Case 1- T1

The new representational challenge has resulted in decrease in first two levels of intermodal mechanisms, and has led to increase in last two levels of intermodal relations as compared to the previous activity (Figure 4.11)

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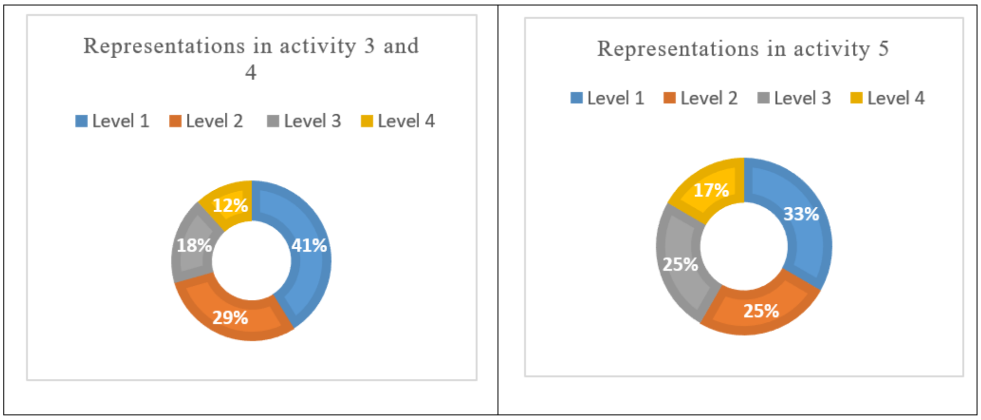


Figure 4. 11 T1's Representations in Activity 3 and 4 and in Activity 5

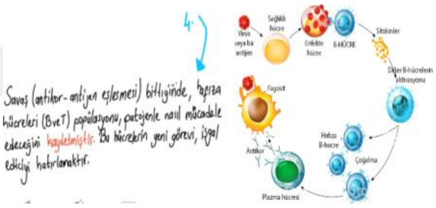
T1 designed twelve multimodal representations while completing infographic given. He constructed augmentation representation differed from the previous activity (Table 4.20).

Table 4. 20 Number of intermodal relations designed by T1 in activity 5

Level 1	Decorational	1
	Exemplary	3
Level 2	Representational	
	Exposition	3
Level 3	Comparative	1
	Organizational	2
Level 4	Augmentation	2
	Interpretational	

An example of each different intermodal relation that the participant constructed in the activity of 5 this first micro cycle is given in the table below with its explanation (Table 4.21)

Table 4. 21 Intermodal relations used by T1 in activity 5

Types of Intermodal Relations	Sample	Explanation
Decorational		The text refers to change in virus gene, the image does not refer to it meaningfully, only decorate the situation.
Exemplary		The image only reflects some part of the text: stimulation of antibody production by weakened viruses.
Exposition		The image re-express the same meaning in the text with symbols or signs.
Organizational		How to combat the pathogen again is described as a process. Images and text share meaning among themselves to tell the process.
Augmentation		Antibody-antigen matching is modelled with key-lock. The text also refers to specific matching between virus and antibody.

Case 2- T2

The new representational challenge prompted T2 to engage in less Level 1 relations while encouraging more Level 2 relations. While there was an increase in the use of level 2 representations, no change was observed in Level 3 and 4 (Figure 4.12). Although she has the opportunity of designing augmentation relations, the researcher could not investigate any type of this relation.

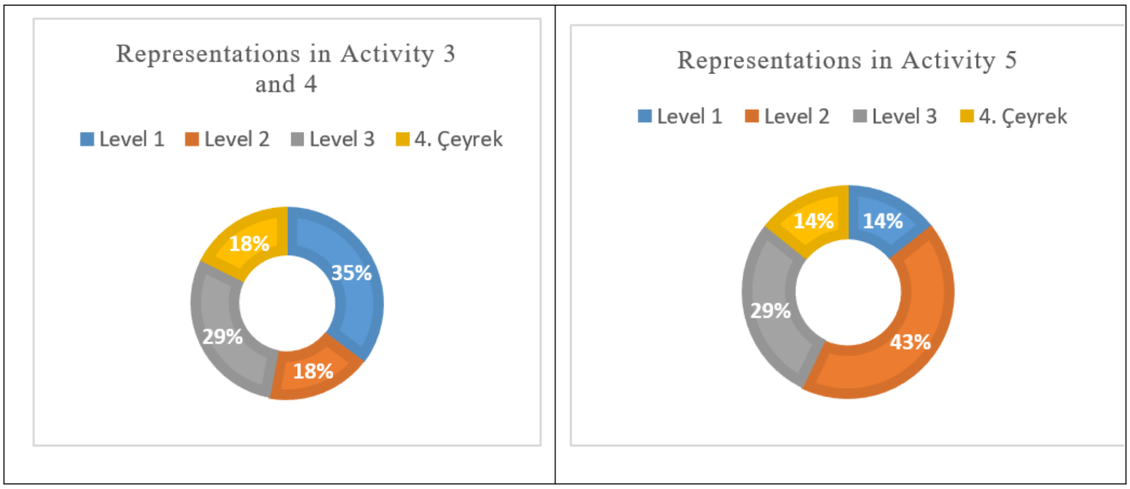


Figure 4. 12 T2's representations in activity 3 and 4 and in activity 5

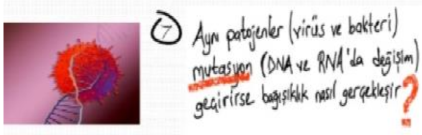
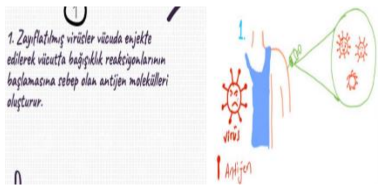
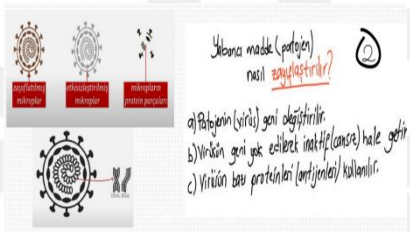
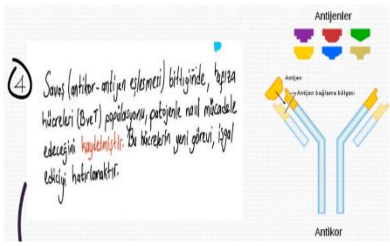
T2 designed seven representations in order to complete the infographic. She generally constructed upper level relation except augmentation one (Table 4.22).

Table 4. 22 Number of intermodal relations designed by T2 in Activity 5

Level 1	Decorational	1
	Exemplary	
Level 2	Representational	
	Exposition	3
Level 3	Comparative	1
	Organizational	1
Level 4	Augmentation	
	Interpretational	1

An example of each different intermodal relation that the participant constructed in the activity of 5 this first micro cycle is given in the table below with its explanation (Table 4.23).

Table 4. 23 Intermodal relations Used by T2 in activity 5

Types of Intermodal Relations	Sample	Explanation
Decorational		While the text asks about how mutation occurs, the image has no reference to this meaning.
Exposition		Weakened viruses are viewed as emojis in the same generality. The image and the text reflects the same meaning, but with different semiotic sources.
Comparative		The text and image enables readers to compare different situations, but it should be stated that this representation is superficially comparative since the images do not have an exact capability of explaining weakened process.
Organizational		The process of recognizing virus and destroying it explained in the text is visualized with the images.
Interpretational		Recording the information about specific antigens by T-cells explained in the text and antibody matching with specific antigen not others stated in image, demands readers to make causal relationships.

Case 3 – T3

In the new representational challenge, there appears to be a noticeable decrease in Level 1 relations in representations and an increase in Level 2 relationships.

Moreover, there also appears to be a slight increase in the use of level 3 and 4 relations (Figure 4.13).

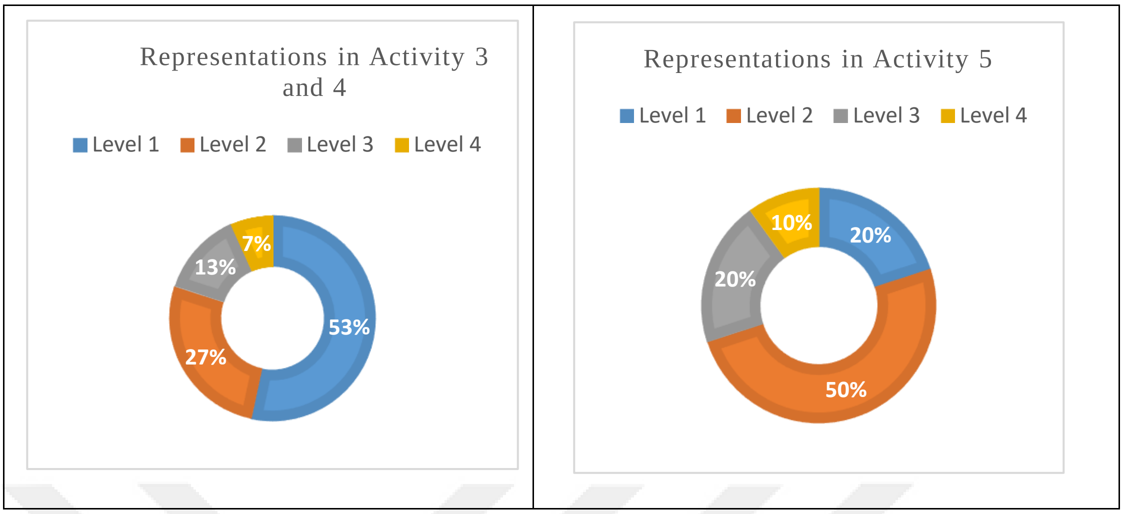


Figure 4. 13 T3's representations in activity 3 and 4 and in activity 5

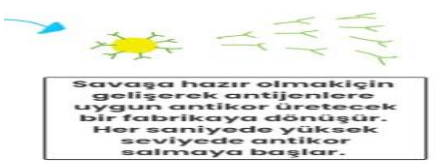
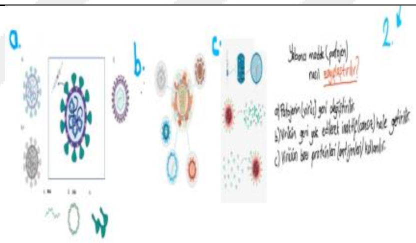
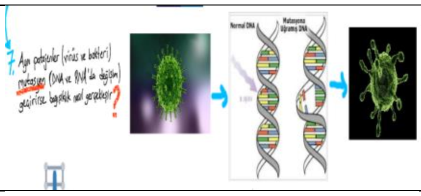
T3 designed ten representations in order to complete the infographic. She constructed all types of intermodal relation except exemplary and interpretational one (Table 4.24).

Table 4. 24 Number of intermodal relations Designed by T3 in activity 5

Level 1	Decorational	2
	Exemplary	
Level 2	Representational	3
	Exposition	2
Level 3	Comparative	1
	Organizational	1
Level 4	Augmentation	1
	Interpretational	

An example of each different intermodal relation that the participant constructed in the activity of 5 this first micro cycle is given in the table below with its explanation (Table 4.25).

Table 4. 25 Intermodal relations used by T3 in activity 5

Types of Intermodal Relations	Sample	Explanation
Decorational		The image decorates the meaning in the text with an antibody which scans viruses.
Representational		There is an exact correspondence between image and text. While the text mentions transferring of antigens by immune cells, the image reflects it.
Exposition		Weakened viruses are viewed as emojis in the same generality. The image and the text reflects the same meaning, but with different semiotic sources.
Comparative		The text and images enable readers to compare different situations: (1) changing the gene of the virus, (2) inactivating the virus, (3) using antigens of virus.
Organizational		Images and text together explain the process of mutation in a simple way.
Augmentation		The key-lock symbolizing in the image is stated as a targeted antigen in the text.

Case 4 – T4

Data revealed that intermodal relations designed by T4 evolved from decorational, exemplary to mostly representational, exposition, organizational and augmentation (Figure 4.14). Besides, she still experienced difficulties in designing interpretational relations.

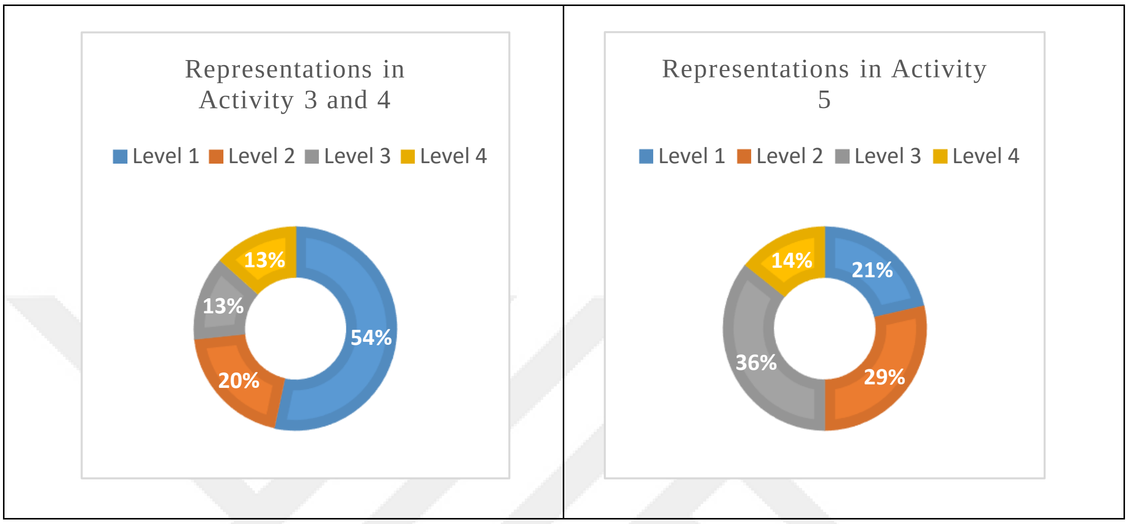


Figure 4. 14 T4's Representations in activity 3 and 4 and in activity 5

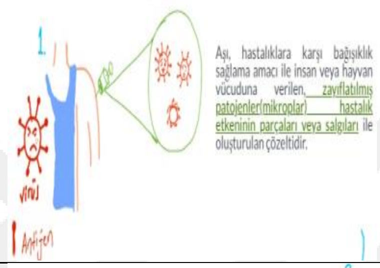
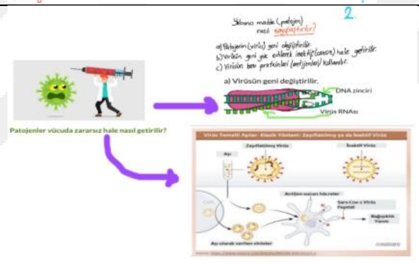
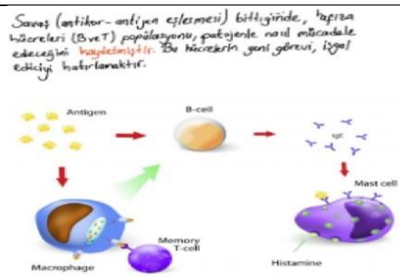
T4 designed fourteen representations in order to complete the infographic. She constructed all types of intermodal relations except exemplary and interpretational one (Table 4.26).

Table 4. 26 Number of intermodal relations designed by T4 in activity 5

Level 1	Decorational	3
	Exemplary	
Level 2	Representational	2
	Exposition	2
Level 3	Comparative	2
	Organizational	3
Level 4	Augmentation	2
	Interpretational	

An example of each different intermodal relation that the participant constructed in the activity of 5 this first micro cycle is given in the table below with its explanation (Table 4.27).

Table 4. 27 Intermodal relations used by T4 in activity 5

Types of Intermodal Relations	Sample	Explanation
Decorational		While the text mentions how pathogens are inactivated, the image refers to a virus who is scared from a vaccine.
Representational		The text and image reflect the same meaning of each other.
Exposition		Weakened viruses are viewed as emojis in the same generality. The image and the text reflects the same meaning, but with different semiotic sources.
Comparative		The situations of (1) changing the gene of the virus, (2) inactivating the virus, (3) using antigens of the virus can be compared with different images in the representation.
Organizational		The recording of how the population of memory cells will combat pathogens is described as a process.
Augmentation		The combination of antibodies and antigens is described in the visual by analogy with the key and lock, and in the article it is expressed with the expression of harmony.

4.2.2.2 Summary of Design Activity

In this step, although the researcher gave participants only half of the available resources as opposed to the previous step (all resources were provided) and guestioning based feedback instead of explanatory feedback unlike the previous step, the results showed that their designs were evolved from Level 1 and 2 to Level 3 and 4, and from low cohesion texts to high cohesion texts as compared to previous design activity. Data clearly revealed that there was a noticeable decrease in using Level 1 representations, increase in Level 2, and slight increase in Level 3 and Level 4 multimodal texts. However, it was clear that even if teachers have many opportunities to design comparative, organizational, augmentation, and interpretational relations to fulfill half completed infographic, they did not used these. Findings also showed that teachers had difficulties in addings scientific process (research questions, hypothesis, results) to the text, and converting scientific academic vocabulary to daily language.

All these findings took into consideration, it can be concluded that representational design skills of ToGs have slightly increased during the process, and when compared to previous design activity.

4.2.3 Findings of Micro Cycle 3

In this cycle, participants were again put through a transformed practice process in a new and more difficult representational challenge with extended available designs (Table 3.31). In activity 6, researchers aimed to increase representational challenge and decrease scaffolding level. To do this, the researcher provided seven questions with only three images. Other than these, no support or clue was provided. They were asked to design their external representations by answering given questions, and apply creatively. The researcher also asked teachers to evaluate their external representations with respect to the criteria on text coherence and intermodal relations unlike the previous activity.

4.2.3.1 Findings of Design Activity

Case 1- T1

Data showed that T1 decreased the use of low level intermodal mechanisms according to previous activity (58%-37%), and increased the design of high level mechanisms (42%-63%) (Figure 4.15). However, it cannot be said that some ones (e.g organizational one) reflect the intermodal relation he intended to, it needs to be improved. Despite this evolvement, T1 continued to use decorational and exemplary ones even if he has opportunity to use comparative and augmentation ones. For instance, while answering the question of how Pascal principle works, he can design an augmentation mechanism in order to model Pascal principle, but he did not. Or, even if he had the opportunity to use comparative ones to explain the question of why the blood pressure is measured at the level of heart, he did not construct this relation.

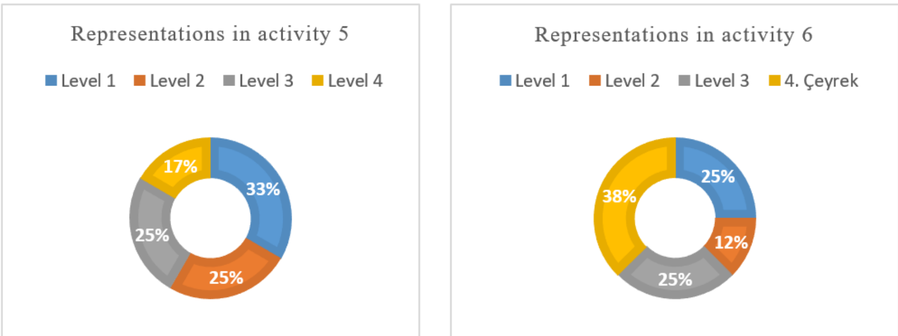


Figure 4. 15 T1's representations in activity 5 and in activity 6

T1 designed eight multimodal representations in order to answer the seven questions in the task. It was found that the number high level of intermodal relations was more than the low level (Table 4.28). He designed interpratational and organizational ones correctly.

Table 4. 28 Number of intermodal relations designed by T4 in Activity 5

Level 1	Decorational	1
	Exemplary	1
Level 2	Representational	1
	Exposition	
Level 3	Comparative	
	Organizational	1
Level 4	Augmentation	
	Interpretational	3

An example of each different intermodal relation that the participant constructed in the activity of 6 this first micro cycle is given in the table below with its explanation (Table 4.29).

Table 4. 29 Intermodal relations used by T1 in activity 6

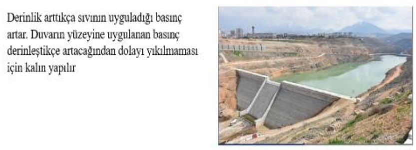
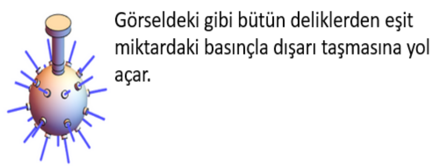
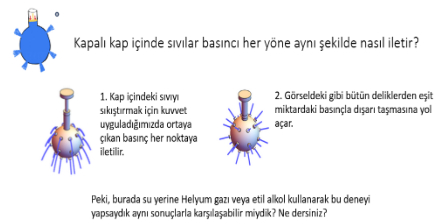
Intermodal Relations and Teachers' Statements	**Sample**	**Explanation**
Decorational Statement: I wanted to give examples of usage areas of Pascal principle with images. However, the images do not show exactly the examples in the text.		The images do not refer to examples of hydraulic systems mentioned in the text, only decorate the text.
Exemplary Statement: I showed with a realistic picture that the lower part of the dam wall was thick. There is exemplary relation.		The image shows the lower part of the dam walls is thickly built as an example.
Representational Statement: I paid attention to the fact that the text and the image reflect each other.		The text mentions an equal amount of liquid coming out of the holes, the image reflects it.

Table 4. 29 Intermodal relations used by T1 in activity 6 (continued)

<table>
<tr>
<td>Organizational

Statement: I wanted to show as a process that liquids transmit pressure with the same force in all directions. I tried to make it organizational.</td>
<td>
</td>
<td>How fluids transmit pressure in all directions is described in a sequence.</td>
</tr>
<tr>
<td>Interpretational

Statement: I tried to explain why blood pressure is measured at heart level by establishing a causal link with the city water supply, and I wanted the reader to establish this relationship.</td>
<td>
</td>
<td>The text and image demand readers to make causal relationships between depth of water and why blood pressure is measured at heart level.</td>
</tr>
</table>

Case 2 – T2

When compared to previous activity, the rate of low level of intermodal relations was reduced in the current activity (57%-31%). Also, the percentage of high level relations has increased (43%-69%) (Figure 4.16). T2 seems representational competent at the end of this activity. The vast majority of multimodal representations she designed reflect high level intermodal relations.

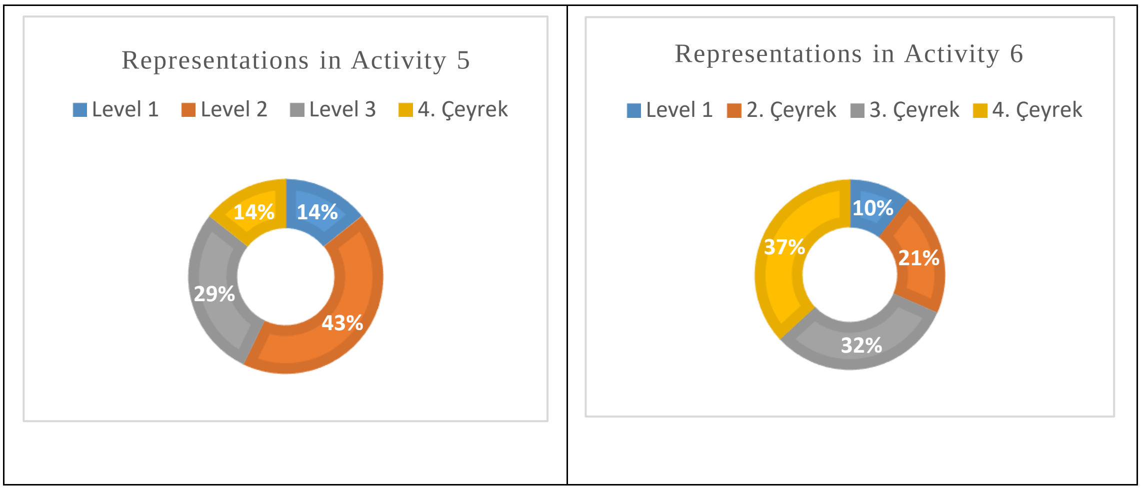


Figure 4. 16 T2's representations in activity 5 and in activity 6

T2 designed nineteen multimodal representations in order to answer the seven questions in the task. It was found that the number high level of intermodal relations was more than the low level (Table 4.30). She designed all types of intermodal relations except representational one.

Table 4. 30 Number of intermodal relations designed by T2 in activity 6

Level 1	Decorational	1
	Exemplary	1
Level 2	Representational	
	Exposition	4
Level 3	Comparative	3
	Organizational	3
Level 4	Augmentation	4
	Interpretational	3

An example of each different intermodal relation that the participant constructed in the activity of 6 this first micro cycle is given in the table below with its explanation (Table 4.31).

Table 4. 31 Intermodal relations used by T2 in activity 6

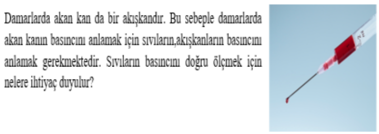
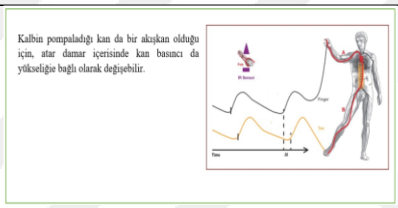
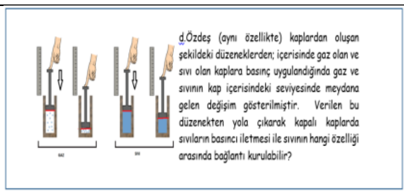
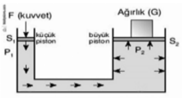
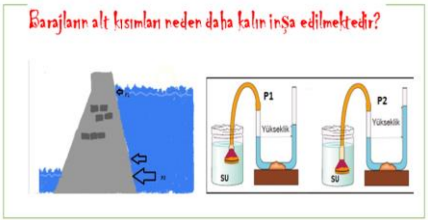
Intermodal Relations and Teachers' Statements	**Sample**	**Explanation**
Decorational Statement: I wanted to express the fluidity with an image so I tried to exemplary.		While the text mentions fluidity and its relation between pressure, the images show a syringe.
Representational Statement: I paid attention to show with image that the applied force is transmitted exactly in all directions, as stated in the text.		The image reflects the meaning in the text (When the mouth of a closed container is opened slightly and pressure is applied, the lid is observed to move upwards).
Exposition Statement: I also tried express with image the statement in the text that the pressure in the artery changes depending on the height.		The image re-express the meaning in the text with graphics.
Comparative Statement: I wanted them to be able to make a comparison by giving the gas and liquid state, showing the granular state.		Two different situations are described in the representation in order to provide readers to understand similarities and differences between them.
Organizational Statement: I tried to express the working principle of hydraulic lift in an organizational process.		The working principle of hydraulic lift is explained in a sequence. The image and text share meaning mutually.

Table 4. 31 Intermodal relations used by T2 in activity 6 (continued)

Augmentation Statement: I tried to re-state the expression of “Pressure in the intended magnitude and direction can be obtained by changing the location of the place where pressure impacts” with an image.	 Pascal prensibine göre basıncın etki ettiği yüzeyin yeri (konumu) ve büyüklüğü değiştirilerek istenilen yönde ve büyüklükte basınç kuvvetleri elde edilebilir.Hidrolik liftte de farklı yüzeye sahip yüzeylerden yararlanılır.	The working principle of hydraulic lift is modelled with communicating vessels.
Interpretational Statement: I wanted the reader to understand why the lower parts of the dams were built in bold by establishing a causal relationship between the two visuals and texts.		The answer to the question of why the lower part of the dam walls are built thicker is asked to solve with another image by making causal relationships.

Case 3 – T3

As shown in Figure 3.31 and Table 3.35, the rate of low level of intermodal relations was reduced in the current activity (70%-22%). Also, the percentage of high level relations were increased (30%-78%) (Figure 4.17). T3 seems representational competent at the end of this activity. However, her comparative relations were not exactly comparative, it was close to it because meaning is not distributed between image and text equally.

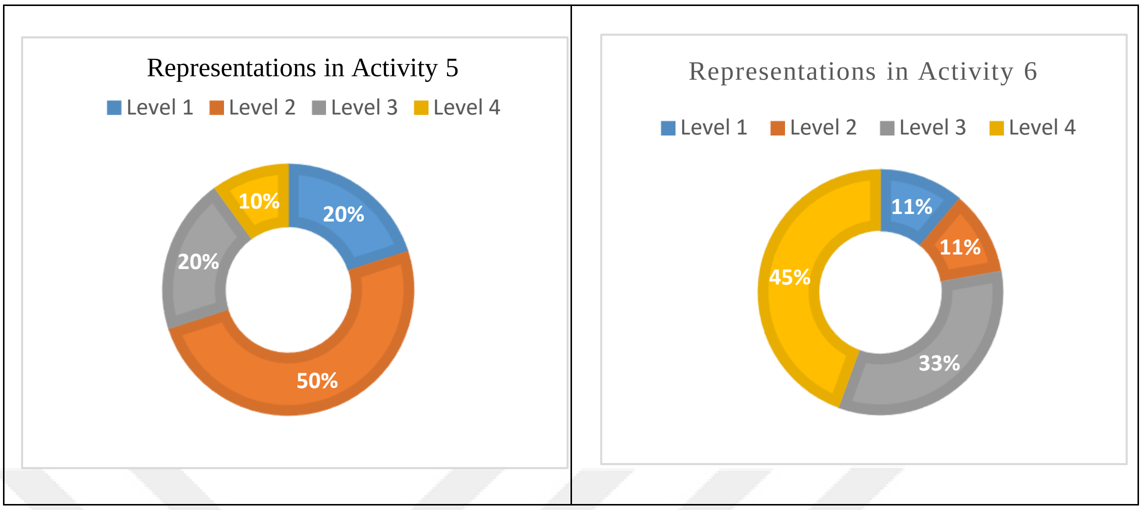


Figure 4. 17 T3's representations in activity 5 and in activity 6

T3 designed nine multimodal representations in order to answer the seven questions in the task. It was found that the number high level of intermodal relations was more than the low level (Table 4.32). She designed well organized multimodal representations in both Level 3 and 4. An example of each different intermodal relation that the participant constructed in the activity of 6 this first micro cycle is given in the table below with its explanation (Table 4.33).

Table 4. 32 Number of intermodal relations designed by T2 in activity 6

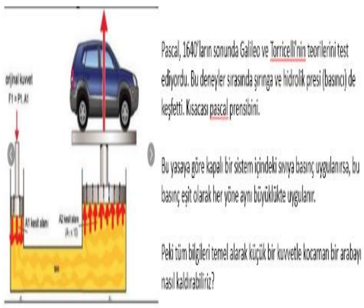
Level 1	Decorational	
	Exemplary	1
Level 2	Representational	1
	Exposition	
Level 3	Comparative	1
	Organizational	2
Level 4	Augmentation	2
	Interpretational	2

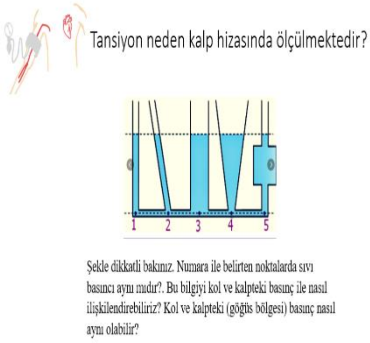
Table 4. 33 Intermodal relations used by T3 in activity 6

Intermodal Relations and Teachers' Statements	**Sample**	**Explanation**
Exemplary Statement: I wanted to show an example of the city water supply mentioned in the text		The image shows an example of city water supply, it does not mention that low pressure water can be increased to the intended height by compressing with air.
Representational Statement: I wanted to show what is expressed in the text in the same way as the image.		The text tells that if the depth is the same, the fluid pressure is the same for every point at that depth, the image conveys the same meaning.
Comparative Statement: I made such a design so that they could recognize the similarities between the two situations. I constructed a comparative relation.		The reader compares two situations, and tries to find similarities and differences between them.
Organizational Statement: I tried to tell the system of hydraulic pressure in an organizational way.		The image and texts together state how the hydraulic system works.

Table 4. 33 Intermodal relations used by T3 in activity 6 (continued)

<table>
<tr><td>Augmentation

Statement:I focused on modeling Pascal's principle with a closed container. However, I tried to make it easy for learners to visualize the process in their mind by showing the number of arrows on both sides of the container in different numbers.</td><td></td><td>The working principle of hydraulic lift is modelled with communicating vessels. The number and direction of arrows in the image also augment the meaning in the text.</td></tr>
<tr><td>Interpretational

Statement: I demanded readers to construct causal relationships between why is blood pressure measured at heart level and communicating vessels.</td><td></td><td>The answer to the question of why blood pressure is measured at heart level is asked to solve with another image by making a causal relationship.</td></tr>
</table>

Case 4- T4

Findings showed that there was a slight difference between the rate of high level and low level of intermodal relations. While the rate of using level 4 relations has increased (14%-25%), the rate of designing level 3 relations has decreased (36%-25%) (Figure 4.18). When investigated totally, it appears that there was no change in the rate of high level and low level of intermodal mechanisms (50%-50%).

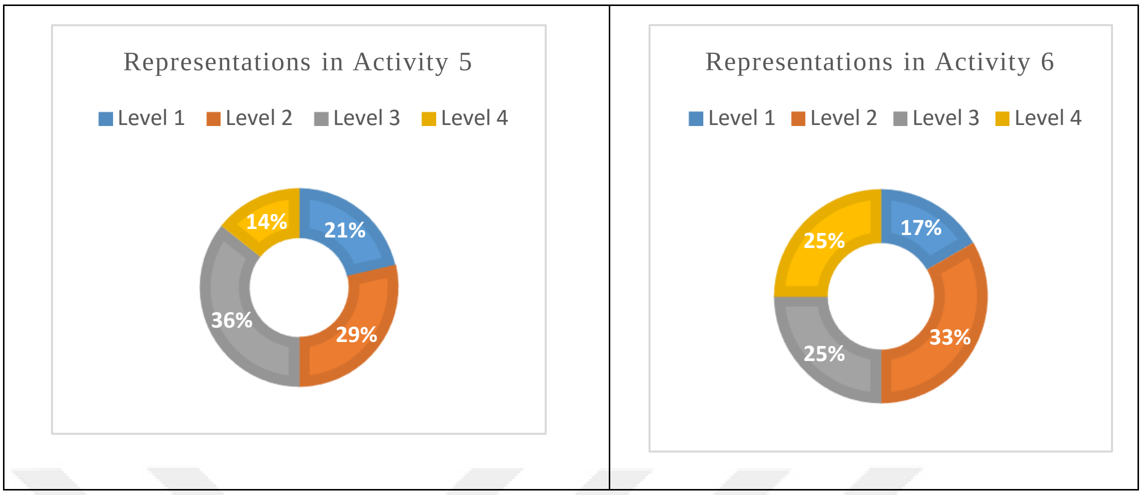


Figure 4. 18 T4's representations in activity 5 and in activity 6

T4 designed twelve multimodal representations in order to answer the seven questions in the task. It was found that the number high level of intermodal relations equals to the low level (Table 4.34). Even if she constructed high level ones in diverse ways except augmentation one, she continued to use low level ones. An example of each different intermodal relation that the participant constructed in the activity 6 this first micro cycle is given in the table below with its explanation (Table 4.35).

Table 4. 34 Number of intermodal relations designed by T4 in activity 6

Level 1	Decorational	1
	Exemplary	1
Level 2	Representational	3
	Exposition	1
Level 3	Comparative	1
	Organizational	2
Level 4	Augmentation	
	Interpretational	3

Table 4. 35 Intermodal relations Used by T4 in activity 6

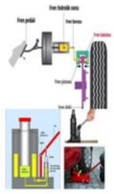
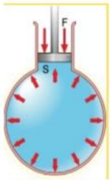
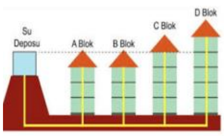
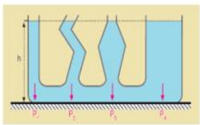
Intermodal Relations and Teachers' Statements	**Sample**	**Explanation**
Decorational Statement: I visualized the shark and fish man as examples.	 Barajların alt kısımları neden daha kalın inşa edilmektedir? Baraj duvarlarının derine indikçe daha kalın olmasının nedeni basınçtır. Barajın derinleştiği kısımlarda su kuvveti fazla olduğundan dolayı basınç fazla olur. Bu durum ince duvarları yıkabilir. Bu nedenle baraj duvarlarında derine inildikçe duvarlar daha kalın olacak şekilde yapılır.	While the text mentions that there is less pressure on the fish-man than on the shark, the image shows a man above the shark.
Exemplary Statement: I gave examples about where pascal principle is used in daily lives.	 Pascal ilkesinden yararlanılarak; bileşik kaplar, su cendereleri, sıkıştırma sistemleri (hidrolik frenler, hidrolik presler), taşıma sistemleri (hidrolik liftler, vinçler), tulumbalar, berber koltukları ve hatta lunaparktaki atlıkarıncalar gibi birçok araç yapıldığını biliyor muydunuz?	The image shows some examples in the text.
Representational Statement: I put in an image that mirrors the text exactly, thus reinforcing the meaning.	 Örneğin üzerinde delikler olan içi su solu bir balona herhangi bir noktadan basınç uygulandığında su bütün deliklerden aynı hızla akar.	The text tells that when pressure is applied from any point to a water-filled balloon, water flows at the same speed from every point, the image conveys the same meaning.
Exposition Statement: Just like the previous one, I put in an image that mirrors the text.	 Sıvıya bir noktadan uygulanan basınç, sıvının temas ettiği her noktaya sadece kuvvet doğrultusunda değil bütün doğrultularda aynen iletir.	It is expressed again with arrow symbols showing the same magnitude and different direction, that the pressure is transmitted in the same magnitude in all directions
Comparative Statement: I provided two images that describe text. In this way, readers can make comparison and comperehend similarities and differences.	 Su depolarından apartmanlara su iletimi birleştirilmiş kaplar prensibi kullanılarak yapılmaktadır.	The images and the text demand readers to compare and understand similarities between city water supply and communicating vessels.

Table 4. 35 Intermodal relations used by T4 in activity 6 (continued)

Organizational Statement: I tried to explain hydraulic pressure system in a process with image and text.		The image and texts together state how the hydraulic system works by sharing meaning.
Interpretational Statement: I tried to design interpretational relation in which reader is asked to make causal relation between given image and the question.		The answer to the question of why the lower part of the dam walls are built thicker is asked to solve with another image by making causal relationships.

4.2.3.2 Summary of Design Activity Findings

At the end of design activity of micro cycle 3, although scaffolding level was decreased and teachers were enabled with questioning based feedback, design skills of participants improved as compared to previous micro cycle. The number and diversity of designed high level multimodal representations have increased. Findings revealed that teachers developed abilities of selecting and then combining appropriate images and texts by finding on their own from any available resources in the digital and real learning environment. Apart from these, some teachers (e.g T1 and T4) did not design augmentation relation despite having this opportunity. Moreover, some teachers have tried to construct comparative relations, but their design did not reflect exactly attributes of this relation type.

Briefly, it was concluded that the participant teachers improved upper level representational skill of designing in this micro cycle together with the ability of selecting.

4.2.3.3 Findings of Evaluation Activity

The researcher asked teachers to evaluate their multimodal representations in terms of intermodal relations. First, they were asked to determine which type of intermodal relations their design belong, and then they were asked to explain why. Data showed that although T1, T2, and T4 designed decorational, they evaluated them as exemplary. As well as, T4 evaluated augmentation relation as exposition one. Apart from these exceptions, findings revealed that teachers gained ability of evaluating their own representations (Table 4.36).

Table 4. 36 Evaluation findings of participants' representations in activity 6

	T1	T2	T3	T4	T5	T6
Decorational	+				+	+
Exemplary	+		+		+	+
Representational	+	+	+	+		+
Exposition		+			+	
Comparative		+	+	+	+	+
Organizational	+	+	+	+	+	+
Augmentation			+		+	
Interpretational	+	+	+	+		+

Teachers who designed decorational relations explained this type of relation with following statements. For instance T5 expressed that:

> *"The image I used in the representation does not refer to the text, so it is decorational. I designed this artefact in order to pay attention of student at the beginning of lesson."*

Teachers who designed exemplary relations explained this type of relation with following statements. For instance T1 stated that:

"I showed with a realistic picture that the lower part of the dam wall was thick. There is exemplary relation." (See Table 4.29)

Teachers who designed representational relations explained this type of relation with following statements. For instance T3 indicated that:

"I wanted to show what is expressed in the text in the same way as the image." (See Table 4.33)

Teachers who designed exposition relations explained this type of relation with following statements. For instance T2 pointed out that:

"I also tried to express with another mode (the graphic) the statement in the text that the pressure in the artery changes depending on the height." (See Table 4.31)

Teachers who designed comparative relations explained this type of relation with following statements. For instance T4 stated that:

"I provided two images that describe text. In this way, readers can make comparison and comperehend similarities and differences." (See Table 4.35)

Teachers who designed organizational relations explained this type of relation with following statements. For instance T2 told that:

"I tried to express the working principle of hydraulic lift in an organizational process." (See Table 4.31)

Teachers who designed augmentation relations explained this type of relation with following statements. For instance T2 indicated that:

"I focused on modeling Pascal's principle with a closed container. However, I tried to make it easy for learners to visualize the process in their mind by showing the number of arrows on both sides of the container in different numbers." (See Table 4.33)

Teachers who designed interpretational relations explained this type of relation with following statements. For instance T3 explained that:

"I demanded readers to construct causal relationships between why is blood pressure measured at heart level and communicating vessels." (See Table 4.33)

Briefly, findings revealed that teachers (four of them) had difficulties in evaluating exposition and augmentation relations. Half of the participants also evaluated their decorational designs as exemplary. One of them (T2) also assessed her augmentational design as exposition. Apart from these, it can be concluded that teachers improved higher level representational competence skills of evaluating in this micro cycle.

4.2.4 Findings of Micro Cycle 4

In this cycle, participants were put through the most difficult transformed practice process in a new and difficult representational challenge. The researcher only determined the subjects on which the participants would design their multimodal representations. They designed their external representations, apply creatively, and then evaluated their representations in terms of intermodal relations and text coherence attributes.

4.2.4.1 Findings of Design Activity

Case 1 – T1

At the end of activity 7, data revealed that T1 can be called as representationally competent since he can not only designing a high level of intermodal mechanisms, he can evaluate his representations according to the criteria of intermodal relations. Although he sometimes used a low level of intermodal mechanisms, he also explained the reason why to use them. At the end of micro cycle 4, he seems representationally competent regarding applying attributes of text coherence (Table 4.37).

Table 4. 37 Text coherence attributes used by T1 in activity 7

Attributes	Teacher's statements
Headings	How does electrophoresis work?
Highlighting	**Artificial selection** describes the process by which humans *consciously* and *purposefully* select certain characteristics of an organism (living being) and raise them in a controlled manner.
Temporal Cohesion	1. The gene whose desired characteristic is determined… 2. In the DNA of a living thing that does not have the desired property…
Connectives	The DNA molecule is electrically negatively charged, *so* when an electric current is applied, the DNA fragments move towards the positive pole of the gel.
Pronouns	An organism (living being)
Academic vocabulary	The genetic modification (manipulation)
Body Text	Narrative-argumentative
Scientific Process	He talks about the scientists' claims and how they justfiy those claims.

T1 designed thirteen multimodal representations while telling the subject of genetically modified foods. It was found that the number high level of intermodal relations are more than the low level (Table 4.38). He designed all types of intermodal relations.

Table 4. 38 Number of intermodal relations designed by T4 in activity 6

Level 1	Decorational	1
	Exemplary	1
Level 2	Representational	1
	Exposition	1
Level 3	Comparative	2
	Organizational	2
Level 4	Augmentation	2
	Interpretational	3

As compared to the previous activity, he increased the use of Level 3 and 4 representation types, and he decreased the use of Level 1 representations (Figure 4.19).

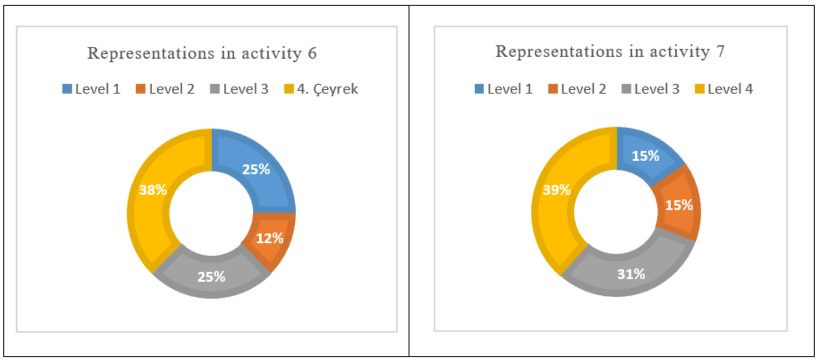


Figure 4. 19 T1's representations in activity 6 and in activity 7

An example of each different intermodal relation that the participant constructed in the activity 7 is given in the table below with its explanation (Table 4.39).

Table 4. 39 Intermodal relations used by T1 in activity 7

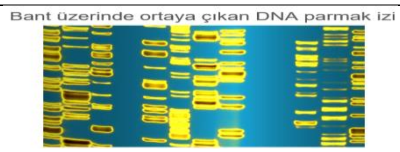
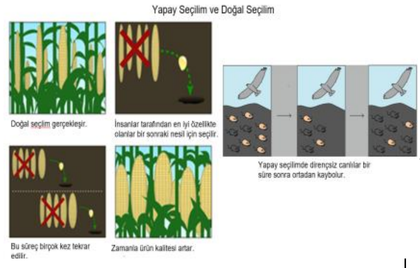
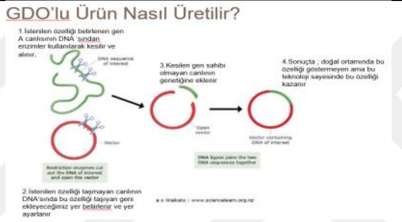
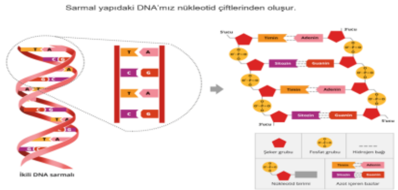
Intermodal Relations and Teachers' Statements	Sample	Explanation
Decorational Statement: I used these images in order to engage students attention, the text or image does not refer to each other.		While the text tells how does gmo affects us, the image shows some decorated examples of gmo.
Exemplary Statement: I tried to give some examples of artificial selection.		The images are examples of the text.
Representational Statement: I wrote as a text what is described in the image.		The text mentions that dna fingerprint emerging on the tape, the image reflects the same meaning.

Table 4. 39 Intermodal relations used by T1 in activity 7 (continued)

Exposition Statement: I told with graphic mode what is in the text.		The image restates the meaning in the text by pie chart.
Comparative Statement: I aimed to present artificial and natural selection together with text and visuals, and then compare them and determine their differences.		The images and the text ask readers to compare and understand differences between natural selection and artificial selection.
Organizational Statement: I tried to tell the process of producing GMO product in an organizational way by distributing meaning between images and texts.		The images and the texts explain how genetically modified products are produced in a sequence.
Augmentation Statement: I tried to show the model of DNA and nucleotid pairs.		The image augments the meaning in the text by modelling DNA helix and nucleotide.
Interpretational Statement: I demanded student to make causal relationship between mendel corssing and artificial selection.		The image and the text ask reader to make causal relationship between mendel cross and artificial selection.

Case 2 – T2

As shown in Figure 4.20 and Table 4.42, in the new activity, She can be accepted as representationally competent if two points are ignored. The researcher could not examine whether she identified exposition and exemplary relation since she did not design this type of intermodal relation in this activity. Her representations and statements on her designs also indicated that she has awareness and design skills. At the end of micro cycle 4, she also seems representationally competent regarding applying attributes of text coherence (Table 4.40).

Table 4. 40 Text coherence attributes used by T2 in activity 7

Attributes	Teacher's statements
Headings	Biotechnology: In **Which** Fields and **Why?**
Highlighting	The process of transferring specific gene sequences of specific length is called ***gene transfer***.
Temporal Cohesion	1.Bacteriophage transfers its genetic material to the bacteria… 2. Copied genetic material with new bacteriophages…
Connectives	Extracellular DNA taken from a bacterium and organism is taken up by another bacterium, *so* new (recombinant) bacteria are formed by transferring genetic material.
Pronouns	A cytoplasmic bridge is established between two bacteria with different characteristics. Two bacteria exchange genes between themselves
Academic vocabulary	Conjugation (combination)
Body Text	Narrative-argumentative
Scientific Process	She talks about the scientists' claims and how they justfiy those claims.

T2 designed twelve multimodal representations while telling the subject of genetically modified foods and gene transefering. It was found that the number high level of intermodal relations are more than the low level (4.41).

Table 4. 41 Number of intermodal relations designed by T4 in activity 6

Level 1	Decorational	1
	Exemplary	
Level 2	Representational	1
	Exposition	
Level 3	Comparative	3
	Organizational	3
Level 4	Augmentation	2
	Interpretational	2

As compared to the previous activity, she increased the use of Level 3 representation types, and she decreased the use of Level 1 and 2 representations (Figure 4.20).

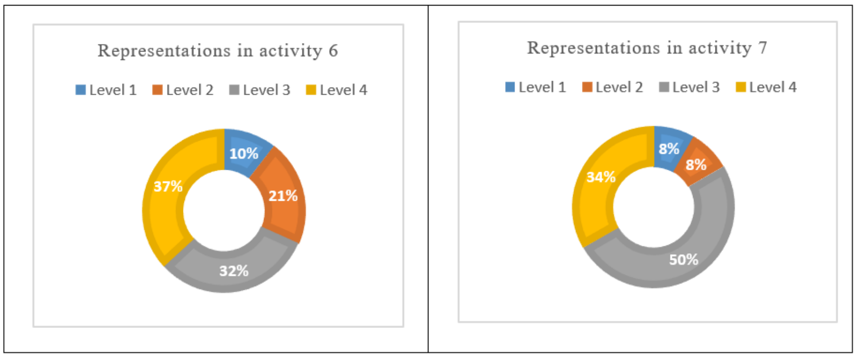


Figure 4. 20 T2’s representations in activity 6 and in activity 7

An example of each different intermodal relation that the participant constructed in the activity 7 is given in the table below with its explanation (Table 4.42).

Table 4. 42 Intermodal relations used by T2 in activity 7

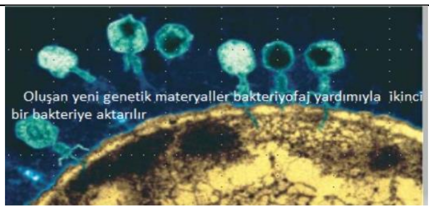
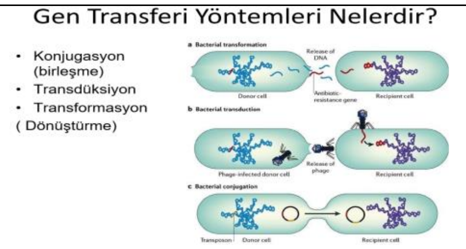
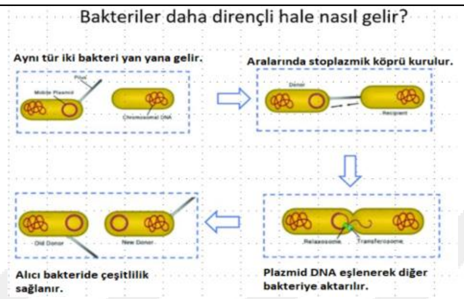
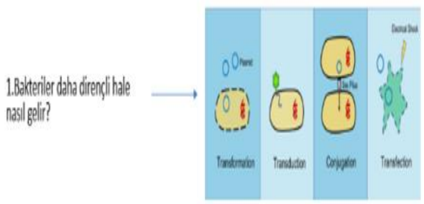
Intermodal Relations and Teachers’ Statements	Sample	Explanation
Decorational Statement: I used such an image at the beginning of the topic to attract students' attention, it has no semantically complete connection with the text.		While the text mentions results of changes in an organism’s genetics, the image does not refer to it.
Representational Statement: I aimed to exact correspondance between image and text semantically. The image tells what is in the text in parallel ways.		The text states that the new genetic material formed is transferred to a new bacterium by bacteriophage; the image conveys the same meaning.

Table 4. 42 Intermodal relations used by T2 in activity 7 (continued)

Comparative Statement: I presented methods of gene transfering together in order to ask students to compare its similarities and differences.		The images and texts provide readers to compare methods of gene transferring.
Organizational Statement: I showed the process of how bacteria become more resistant. I shared the meaning between images and texts.		The images and texts explains that how bacteria become more resistant in a sequence.
Augmentation Statement: I found this image, and I thought that the image of scissor can augment the maening provided by text: plasmid cut by enzyme.		The meaning of enzyme is augmented with a scissor model.
Interpretational Statement: At the end of the subject, I considered that students make causal relationship between the images and how bacteria become more resistant.		At the end of all this learning, students are asked how bacteria become more resistant by showing them different gene transferring methods.

Case 3 – T3

As stated in findings of micro cycle 3, she was seen as representationally competent despite lacking some attributes. In the current activity, data revealed that she handled with these difficulties. Findings of micro cycle 4 also verified that she can be accepted as representationally competent in terms of of designing skills if two points are ignored. The researcher could not examine whether she capables of designing exemplary and representational relations, since she did not design. She also seems representationally competent regarding applying attributes of text coherence (Table 4.43).

Table 4. 43 Text coherence attributes used by T3 in activity 7

Attributes	Teachers' Statements
Headings	What Is Recombinant Technology And How Is Dna Cloning Done?
Highlighting	The method for determining who a DNA sample belongs to is called ***DNA fingerprinting***.
Temporal Cohesion	1. An egg cell whose nuclei has been removed ... 2. The new cell that is formed is forced to divide ...
Connectives	It is the transfer of a particular DNA region from an organism to a structure such as a self-replicating plasmid, *so that* the transferred DNA region can reproduce by means of the plasmid.
Pronouns	After five years of extensive health and environmental testing, *Calgene's Flavr Savr tomato* became the first US food product approved by the U.S. Department for commercial production. *Flavr Savr tomatoes*, inhibit the production of a natural tomato protein,
Academic vocabulary	Somatik hücre (vücut hücresi)/ implant (yerleştirme)
Body Text	Narrative-argumentative
Scientific Process	She talks about the scientists' claims and how they justfiy those claims.

T3 designed twelve multimodal representations while telling the subject of biotechnology. It was found that the number high level of intermodal relations are more than the low level (4.44).

As compared to the previous activity, she increased the use of Level 3 representation types, and she decreased the use of Level 1 representation (Figure 4.21).

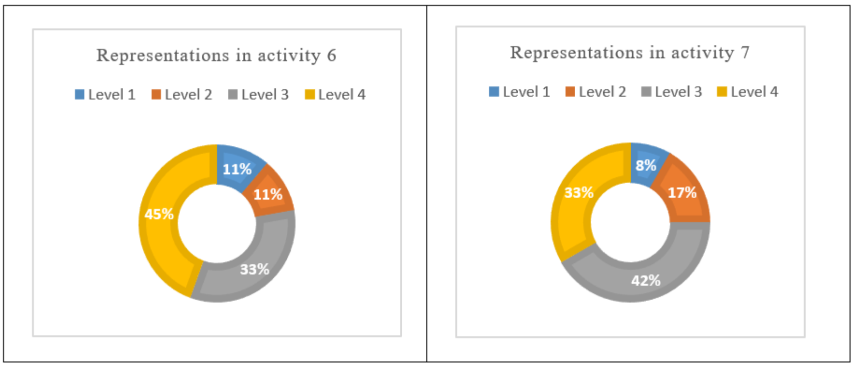


Figure 4. 21 T3's representations in activity 6 and in activity 7

Table 4. 44 Number of intermodal relations designed by T4 in activity 6

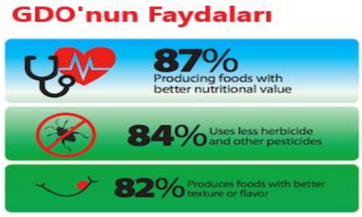
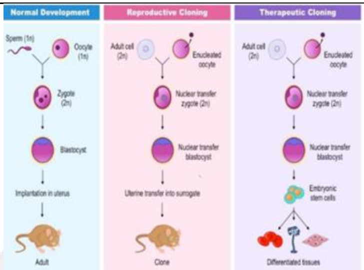
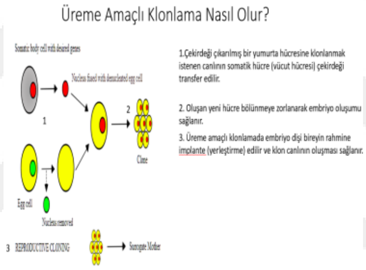
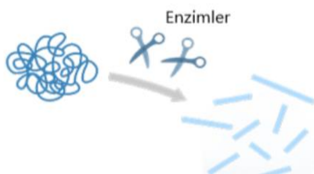
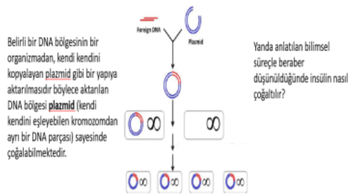
Level 1	Decorational	1
	Exemplary	
Level 2	Representational	
	Exposition	2
Level 3	Comparative	2
	Organizational	3
Level 4	Augmentation	2
	Interpretational	2

An example of each different intermodal relation that the participant constructed in the activity 7 is given in the table below with its explanation (Table 4.45).

Table 4. 45 Intermodal relations used by T3 in activity 7

Types of Intermodal Relations	Sample	Explanation
Decorational Statement: I tried to show what biotechnology is about with an image. There is no exact correspondence between image and text. May be, I could not use the image like that.		The text mentions biotechnology, the image does not refer to it.

Table 4. 45 Intermodal relations used by T3 in activity 7 (continued)

Exposition Statement: I wanted to express the benefits of GMO with an infographic which includes some symbols to re-state what the text is about in the same generality.		The images re-state the meaning in the text with signs.
Comparative Statement: I tried to present three types of cloning, and asked them to understand each by making comparisons.		The images and texts enable readers to compare and comprehend differences and similarities between cloning types and normal development.
Organizational Statement: I aimed to tell the proces of reproductive cloning in an organizational way by distributing meaning between images and texts.		The images and texts explain how does reproductive cloning occurs.
Augmentation Statement: I tried to expand the meaning of enzymes by comparing them to scissors.		The meaning of enzyme is augmented with a scissor model.
Interpretational Statement: First, I presented how re-production occurs in a process. And then, I asked students to make causal relationships between this and insulin production.		The texts and images demand readers to understand the causal relationship between insulin production and the process of conjugation.

Case 4 – T4

Based on this data and her statements, it can be concluded that she is representationally competent if one point is ignored. That is, the researcher couldn't examine whether she is able to design exposition relation since she did not construct in this cycle. She also seems representationally competent regarding applying attributes of text coherence (Table 4.46).

Table 4. 46 Text coherence attributes used by T4 in activity 7

Attributes	Teachers' Statements
Headings	How Do We Treat Diseases With Genes?
Highlighting	**Biotechnology** is the techniques and processes used to understand and change the functions found in human, plant and animal cells.
Temporal Cohesion	a. The idea of treating diseases by manipulating people's genes… b. Although the first gene therapy drug was launched in China…
Connectives	This is the evolutionary mechanism that works by having a higher chance of survival and reproduction compared to other individuals who do not have the favorable characteristics, and *as a result*, they can transfer their genes to new generations.
Pronouns	*Gene therapy* is the use of segments of DNA to cure or prevent disease. *Gene therapy* may be a promising treatment option for some genetic conditions.
Academic vocabulary	*Organisms (living things)*
Body Text	Narrative-argumentative
Scientific Process	She talks about the scientists' claims and how they justfiy those claims.

T3 designed twelve multimodal representations while telling the subject of biotechnology. It was found that the number high level of intermodal relations are more than the low level (Table 4.47).

Table 4. 47 Number of intermodal relations designed by T4 in activity 6

Level 1	Decorational	1
	Exemplary	1
Level 2	Representational	1
	Exposition	
Level 3	Comparative	2
	Organizational	4
Level 4	Augmentation	2
	Interpretational	3

Data revealed that there wasnoticeable increase in the use of high level intermodal relations (Level 3 and 4) (50%-79%), and decrease in the use of low level (Level 1 and Level 2)(50%-21%) when compared to previous activity (Figure 4.22).

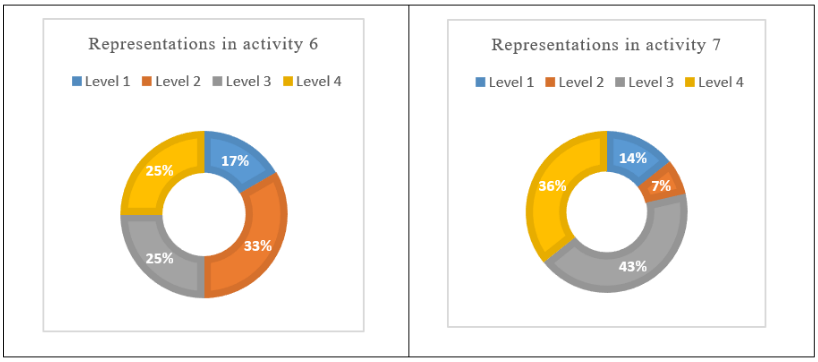


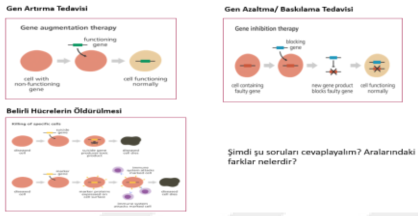
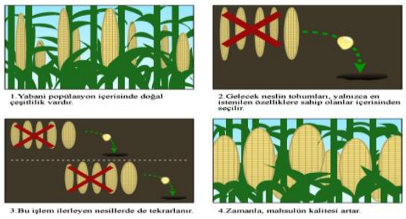
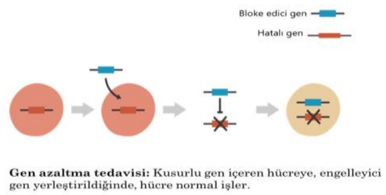
Figure 4. 22 T4's representations in activity 6 and in activity 7

An example of each different intermodal relation that the participant constructed in the activity 7 is given in the table below with its explanation (Table 4.48).

Table 4. 48 Intermodal relations used by T4 in activity 7

Intermodal Relations and Teachers' Statements	Sample	Explanation
Decorational Statement: I tried to explain how penicillin is produced in a process. The representation has organizational relations.		While the images and texts tell how insulin is produced in a sequence, the images only decorate the meaning in the text.
Exemplary Statement: In order to attract student attention, I presented some examples with images which I mentioned in the text.		Images include examples of what is expressed in the text.

Table 4. 48 Intermodal relations used by T4 in activity 7 (continued)

Representational Statement: I tried to construct exact correspondance between images and texts.		The image reflects the meaning in the text which states that the conscious selection of certain characteristics of an organism and their controlled production. For instance, if you choose the characteristic of flowers, broccoli is cultivated.
Comparative Statement: I provided three distinct situations to students to understand how they differ.		The images and the texts provide readers to compare gene augmentation therapy, gene inhibition therapy, and killing of specific cells.
Organizational Statement: I presented natural selection as a process.		The process of natural selection is told in a sequence with images and texts.
Augmentation Statement: I aimed to present gene inhibation therapy by simplifying with signs and symbols.		Gene inhibition therapy is modelled and augmented by stimulating the genes with some signs, like blocking gene and non-functioning gene.
Interpretational Statement: Together with images and texts, I tried to tell student how natural selection occurs by making causal relationships between two distinct situation.		The images and texts demand readers to understand how artificial selection occurs by making causal relationships in both two situations.

4.2.4.2 Summary of Design Activity Findings

At the end of design activity of micro cycle 4, design skills of ToGs improved as compared to previous micro cycle. The number and diversity of designed high level multimodal representations have increased. Findings revealed that teachers improved abilities of selecting and then integrating appropriate images and texts by finding on their own from any available resources in the digital and real learning environment. Participant teachers designed almost all types of multimodal representations considering the elements of intermodal relations and text coherence. Hence, they can be called as representationally competent in terms of selecting (identifying) and designing skills.

4.2.4.3 Findings of Evaluation Activity

The researcher asked teachers to evaluate their multimodal representations in terms of intermodal relations. First, they were asked to determine which type of intermodal relations their design belong, and then they were asked to explain why. While some of them have experienced difficulties in identifying decorational with exemplary, and exposition with augmentation in micro cycle 3, they were able to evaluate and explain why the intermodal relation they designed fell into that type of relation in the new cycle. That is, as compared to the previous micro cycle, findings revealed that ToGs improved representational competency skill of evaluating (Table 4.49).

Table 4. 49 Evaluation findings of participants' representations in activity 7

	T1	T2	T3	T4	T5	T6
Decorational	+	+	+	+	+	+
Exemplary	+			+	+	+
Representational	+	+		+	+	+
Exposition	+		+		+	
Comparative	+	+	+	+	+	+
Organizational	+	+	+		+	+
Augmentation	+	+	+	+	+	+
Interpretational	+	+	+	+	+	+

Teachers who designed decorational relations explained this type of relation with following statements. For instance T1 expressed that:

> *"I used these images in order to engage students attention, the text or image does not refer to each other."* (See Table 4.39)

Teachers who designed exemplary relations explained this type of relation with following statements. For instance T4 stated that:

> *"I presented some examples with images which I mentioned in the text."* (See Table 4.48)

Teachers who designed representational relations explained this type of relation with following statements. For instance T2 indicated that:

> *"I aimed to construct exact correspondance between image and text semantically. The image tells what is in the text in parallel ways."* (See Table 4.42)

Teachers who designed exposition relations explained this type of relation with following statements. For instance T3 pointed out that:

> *"I wanted to express the benefits of GMO with an infographic which includes some symbols to re-state what the text is about in the same generality."* (See Table 4.45)

Teachers who designed comparative relations explained this type of relation with following statements. For instance T2 stated that:

> *"I presented methods of gene transfering together in order to ask students to compare its similarities and differences."* (See Table 4.42)

Teachers who designed organizational relations explained this type of relation with following statements. For instance T3 told that:

> *"I aimed to tell the proces of reproductive cloning in an organizational way by distributing meaning between images and texts."* (See Table 4.45)

Teachers who designed augmentation relations explained this type of relation with following statements. For instance T4 indicated that:

> *"I tried to expand the meaning of enzymes by comparing them to scissors."* (See Table 4.48)

Teachers who designed interpretational relations explained this type of relation with following statements. For instance T1 explained that:

> *"I demanded student to make causal relationship between mendel corssing and artificial selection."* (See Table 4.39)

Briefly, findings regarding evaluation activity showed that teachers are capable of evaluating their own multimodal representations. They have gained the ability to easily explain the relation types with its reasons. Thus, it can be concluded that teachers improved higher level representational competence skills of evaluating in this micro cycle as compared to the previous micro cycle.

4.2.5 Findings of Micro Cycle 5

Micro cycle 5 was conducted as a verification study whether they are representationally competent in terms of evaluation skills, since participant teachers evaluated only their own multimodal representations until now. Hence, the researcher provided an assessment matrix to the teachers, and asked them to evaluate any peer's multimodal artefacts.

4.2.5.1 Findings of Evaluation Activity

Evaluation of participants about intermodal relations and text coherence and their statements about representations are given below with tables. These data revealed that ToGs have capabilities of identifying intermodal relations and features of text coherence. Findings indicated that they were not only capable of evaluating peers' texts, but also criticizing to what extent the representation correspondence to the intermodal relations their peer referred to. Moreover, they suggested to their mates on what types of relations and text attributes they should use.

Case 1 – T1

T1 analyzed all types of intermodal relations and aspects of text coherence designed by his peer. Besides, he advised peer how to improve his/her multimodal representation. For example, he stated that:

> "*Representational has been used as an intermodal relation. You can strengthen your representation by designing comparative relation. You can select two of them, and focus on similarities and differences.*" (See Table 4.48)

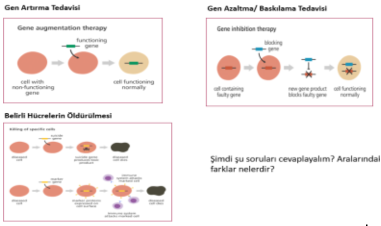
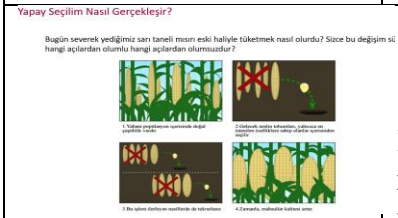
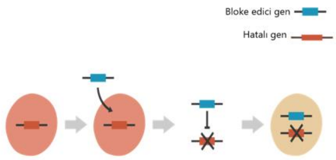
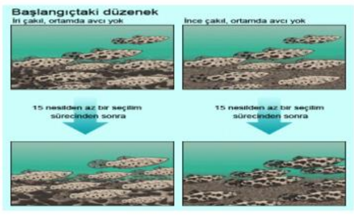
He also criticized his friend’s representations to what degree his/her design reflects intermodal relations s/he referred to. In addition to these, he also stated in his evaluations that there may be more than one intermodal relation in a multimodal representation. For instance he expressed that:

> *“Interpretational has been used as an intermodal relation. It also consists of comparative, but the interpretational seems more dominant.”*
>
> *“Comparison has been used as an intermodal relation. It also includes augmentation.”* (See Table 4.50)

Table 4. 50 Multimodal representations analyzed by T1

Representation	Intermodal Relations	Text Coherence
	Decorational has been used as an intermodal relation. Examples could be presented as a starting point. Or exposition could be done. It is poor/**fair**/good in meeting the intermodal relations I mentioned above.	An informative title was used in terms of text coherence.
	Exemplary has been used as an intermodal relation. It is poor/**fair**/good in meeting the intermodal relations I mentioned above.	The content/body text is informative and authoritative, highlighting was made as bolding.
	Representational has been used as an intermodal relation. You can strengthen your representation by designing comparative relation. It is **poor**/fair/good in meeting the intermodal relations I mentioned above.	The content/body text is informative, is made explanatory with examples.

Table 4. 50 Multimodal representations analyzed by T1 (continued)

	Comparison has been used as an intermodal relation. It also includes augmentation. It is poor/fair/**good** in meeting the intermodal relations I mentioned above.	The title and body text is informative. Academic vocabulary is scaffolded with daily language.
	Organizational has been used as an intermodal relation. It is poor/fair/**good** in meeting the intermodal relations I mentioned above.	It includes heading as a question, the body text is informative, and is also made explanatory with examples.
 **Gen azaltma tedavisi:** Kusurlu gen içeren hücreye, engelleyici gen yerleştirildiğinde, hücre normal işler.	Augmentation has been used as an intermodal relation. Gene reduction therapy is modeled with new icons. It also includes exposition. It is poor/fair/**good** in meeting the intermodal relations I mentioned above.	The content/body text is informative.
 Doğal seçilim süreci	Interpretational has been used as an intermodal relation. It also consists of comparative, but the interpretational seems more dominant.	Title is informative, content persuasive, is also made explanatory with examples.

Case 2 – T2

T2 have abilities of evaluating multimodal representations in terms of intermodal relation and elements of text coherence. She criticized peer's multimodal text to what extent his/her representation corresponds to intermodal relation s/he referred to. For example, she pointed out that:

*"It is poor/**fair**/good in meeting the intermodal relations I mentioned above. The representation seems organizational, but not distributing meaning in the text to the image, and asking students to establish a relationship between this process and how insulin is reproduced, so it is interpretational."*

She also claimed that one representation can include more than one intermodal relation:

"The representation is organizational, but it has been accepted as augmentational because of the analogy of the enzyme to scissors."

Table 4. 51 Multimodal representations analyzed by T2

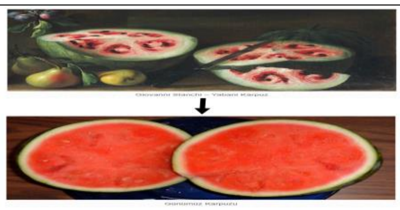
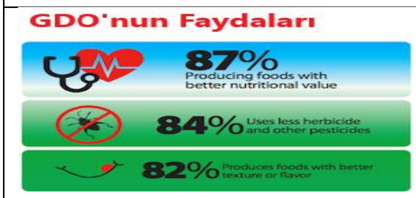
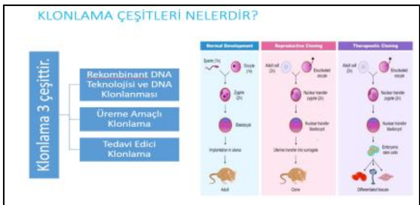
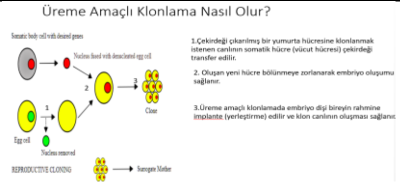
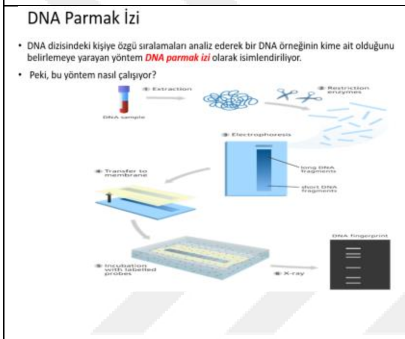
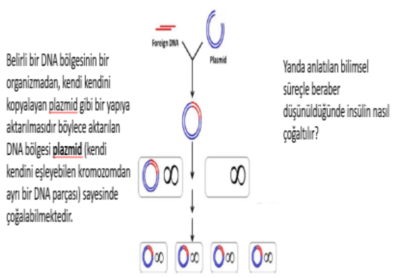
Representation	Intermodal Relations	Text coherence
	-Decorational has been used as an intermodal relation. -It is poor/fair/**good** in meeting the intermodal relations I mentioned above.	-An informative title was used. -The title can be made as questioning. Ex. What is Biotechnology?
	-Exemplary has been used as an intermodal relation. -It is poor/**fair**/good in meeting the intermodal relations I mentioned above.	An informative title and content was used.
	-Representational has been used as an intermodal relation. -It is poor/fair/**good** in meeting the intermodal relations I mentioned above.	Informative content was used.
	Exposition has been used as an intermodal relation. It is poor/fair/**good** in meeting the intermodal relations I mentioned above.	An informative title and informative body text was used.

Table 4. 51 Multimodal representations analyzed by T2 (continued)

	Comparative has been used as an intermodal relation. It is poor/fair/**good** in meeting the intermodal relations I mentioned above.	The content is informative.
	Organizational has been used as an intermodal relation. It is poor/fair/**good** in meeting the intermodal relations I mentioned above.	Headings as questioning, invites the reader to the text. Scientific language supported by daily language.
	-The representation is organizational, but it has been accepted as augmentational because of the analogy of the enzyme to scissors. -It is poor/**fair**/good in meeting the intermodal relations I mentioned above.	-The title and body text is informative. Highlighting was made as bolding and italics. -The title can be made as questioning.: How are DNA fingerprints obtained?
	-The representation seems organizational, but not distributing meaning in the text to the image, and asking students to establish a relationship between this process and how insulin is reproduced. -It is poor/**fair**/good in meeting the intermodal relations I mentioned above.	The title and body text is informative. Highlighting was made as bolding and italics Headings as questioning, invites reader to the text.

Case 3 – T3

T3 evaluated peer's multimodal representations regarding intermodal relations and aspects of text coherence. She also criticized that some representations did not exactly refer to the relation type the designer intended to construct. For example, she indicated that:

> *"It is **poor**/fair/good in meeting the intermodal relations I mentioned above. Organizational has been used as an intermodal relation but the text and the content do not reflect each other exactly."*

She also noticed that a multimodal representation can involve more than one intermodal relation:

> *"Augmentation has been used as an intermodal relation. It also includes exposition relations. Gene and plasmid are expressed in the same sense but in another mode. Intermodal relations are intertwined."*

> *"Interpretational has been used as an intermodal relation. It also consists of comparatives."*

Table 4. 52 Multimodal representations analyzed by T3

<table>
<tr><th>Representation</th><th>Intermodal Relations</th><th>Text coherence</th></tr>
<tr><td>
</td><td>-Decorational has been used as an intermodal relation. In addition, the question and the image do not fully refer to each other.
-It is poor/fair/good in meeting the intermodal relations I mentioned above.</td><td>The content/body text can be made explanatory with examples.

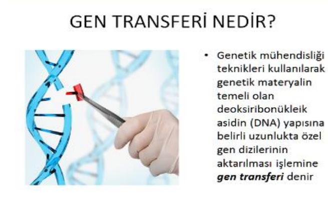
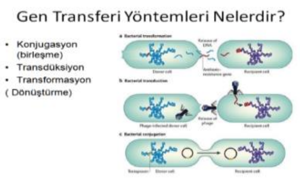
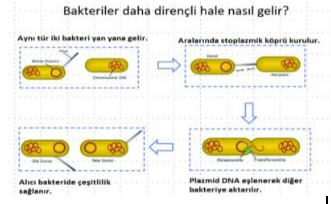
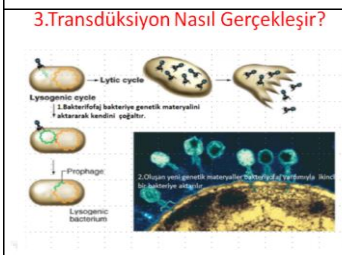
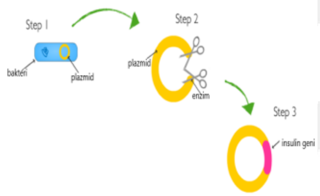
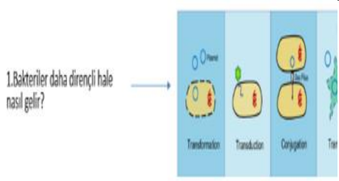
It includes a heading as a question.</td></tr>
<tr><td>
</td><td>-Decorational has been used as an intermodal relation. We can say that it can be important to draw attention. Organizational can be made.
-It is poor/fair/good in meeting the intermodal relations I mentioned above.</td><td>It includes a heading as a question. Highlighting was made as bolding. The content/body text is informative and authoritative.</td></tr>
<tr><td>
</td><td>Comparative has been used as an intermodal relation.
It is poor/fair/good in meeting the intermodal relations I mentioned above.</td><td>It includes a heading as a question. Highlighting was made as bolding. Text is informative and authoritative.</td></tr>
</table>

Table 4. 52 Multimodal representations analyzed by T3 (continued)

	Organizational has been used as an intermodal relation. It is poor/fair/**good** in meeting the intermodal relations I mentioned above.	It includes a heading as a question. The content/body text is informative and authoritative
	Organizational has been used as an intermodal relation but the text and the content do not reflect each other exactly. It is **poor**/fair/good in meeting the intermodal relations I mentioned above.	It includes a heading as a question. The content/body text is informative and authoritative. Can talk about the scientific process and qualitative and quantitative data.
	-Augmentation has been used as an intermodal relation. -It also includes exposition relations. Gene and plasmid are expressed in the same sense but in another mode. Intermodal relations are intertwined. -It is poor/fair/**good** in meeting the intermodal relations I mentioned above.	
	Interpretational has been used as an intermodal relation. It also consists of comparatives. It is poor/**fair**/good in meeting the intermodal relations I mentioned above.	It includes a heading as a question.

Case 4 – T4

T4 are capable of evaluating multimodal representations in terms of intermodal relation and elements of text coherence. She also realized that a multimodal representation can include more than one intermodal relation:

"Organizational and augmentation have been used as intermodal relations. They are interwined."

"Comparative and organizational have been used intermodal relations."

Table 4. 53 Multimodal representations analyzed by T4

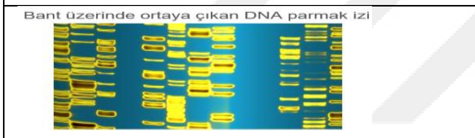
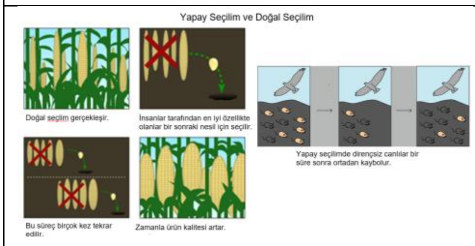
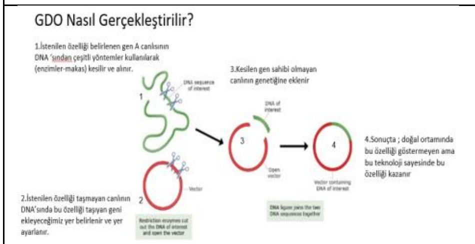
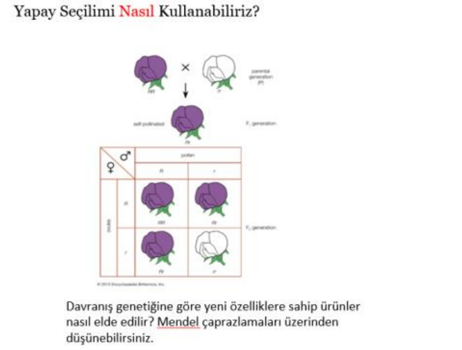
Representation	Intermodal Relations	Text coherence
	Decorational has been used as an intermodal relation. It is poor/fair/**good** in meeting the intermodal relations I mentioned above.	It includes heading as question.
	Exemplary has been used as an intermodal relation. It is poor/**fair**/good in meeting the intermodal relations I mentioned above.	
	Representational has been used as an intermodal relation. It is poor/fair/**good** in meeting the intermodal relations I mentioned above.	Explanations with examples can be added.
	Comparative and organizational have been used intermodal relations. It is poor/fair/**good** in meeting the intermodal relations I mentioned above.	It involves informative heading and content.
	Organizational and augmentation have been used as intermodal relations. They are interwined. It is poor/fair/**good** in meeting the intermodal relations I mentioned above.	It includes question as heading and informative content.

Table 4. 53 Multimodal representations analyzed by T4 (continued)

	Interpretational has been used as intermodal relation. It was asked to establish a causal link between Mendelian cross and artificial selection. It is poor/fair/**good** in meeting the intermodal relations I mentioned above.	It includes question as heading and highlighting with coloring.

4.3 Findings of Evaluation Phase

Evaluation process in a design based research is conducted through research. Evaluation of micro cycles are realized in order to refine the model and to follow the development of the participants' skills as a result of the intervention applied during and after the process. As a result of the data obtained from these evaluations, conclusions are drawn about the design principles of the intervention model and the model itself.

4.3.1 Findings on Evaluation of Micro Cycles 1 and 2

When investigating all cases individually as stated in the findings part, and examining all designed representations totally (Figure 4.23), the tendency of teachers to use different types of intermodal relations was improved. Data also showed that the number of high levels of intermodal relations used by participants have increased (Table 4.54).

Table 4. 54 Number of different levels of representations in each activity

	Pre-representations	**Activity 3 and 4**	**Activity 5**
Level 1	16	34	10
Level 2	3	16	15
Level 3	2	13	18
Level 4	1	10	9
Total	23	73	52

Data also revealed that they had no difficulties in applying parameters of text coherence, except exactly embedding scientific process into the text and transforming scientific vocabulary to daily language. However, it is still too early to indicate that they are representationally competent since they constructed low levels of intermodal mechanisms in activity 3 and 4 despite all available text and images were provided by researchers. Likewise, although half of the infographic was given by the researcher, it was seen that they maintained their habit of designing level 1 and level 2 relations in activity 5.

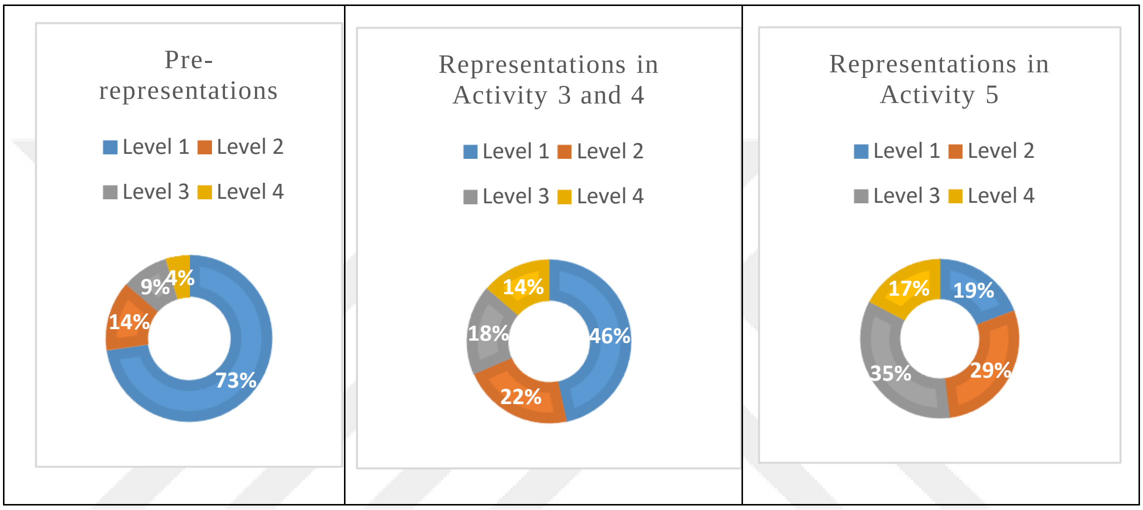


Figure 4. 23 Total change in intermodal relations used by all teachers during the process

Other reasons why they are not accepted as representationally competent can be indicated as follows. The former, teachers experienced difficulties in designing comparative, organizational, augmentation, and interpretational relations. That is, they were not capable of using high levels of intermodal relations effectively. The latter is that they did not take advantage of using appropriate intermodal relations although having this opportunity provided by topic. For instance, while the given topic mentions two issues which have similarities and differences, teachers did not use comparative relations. As another example, whereas the topic mentions a process, teachers did not realize it, and they do not use organizational relations. The same issues were determined in interviews with them over their multimodal representation. Some quotations are given below.

T2 stated that:

> *"Even though I wanted to make it interpretational, it wasn't like that, it just seems to be a decorative relationship. I was careful about organizing, but in order to be complete, I had to break it up a bit and present it in conjunction with pictures and texts."*

T3 told that:

> *"The gene is changed but I think they are not the correct visual, I gave the three items differently and made them compare them to each other, but it is not exactly comparative, I think I had to add the extra texts as well, it is comparative but not complete, I wanted to see and compare the situations a b c but I could not provide exactly that with the images and the text."*

T4 indicated that:

> *"Actually, there are organizational, there are comparisons of two situations. I tried to provide them, but as I said, I could provide this with better images, it was not possible."*

Briefly, teachers can be able to identify these intermodal relations through discussions and sometimes it was seen that they still cannot apply these intermodal relations because they do not realize them at all. Nevertheless, in the light of all this data, it can be argued that the participants are increasingly skilled in establishing higher-level intermodal relations. This shows that MpM can be effective in making participants to be representationally competent. However, some refinements and improvements are also needed. Hence, the researcher decided to make some refinements on the model by discussing with the experts and participant teachers.

Discussions made with the experts and participant teachers revealed that four basic refinements should be made about the model and its applying process. Suggested refinements and additions are about representational challenges with scaffolding level, self assessment, medium of application, and overt instruction.

- **Representational Challenge**

Experts and participant teachers proposed that increased representational challenge with decreased scaffolding can be effective in improving teachers' representational competence, since data provided by researchers give some clues about this inclination. The statements made by experts and participants are given below.

Expert 1 stated that:

> *"Comparing the state of giving all texts and images with the state of giving half, more improvements have been observed in the second. Accordingly, it may be appropriate to carry out activities from easy to difficult. Scaffolding level can be decreased."*

Expert 2 told that:

> *"As the scaffolding level decreases and the representational challenge increases, there seems to be an increase in their competency, it may be good to focus on these aspects of the model."*

Suna indicated that:

> *"In fact, I can say that I work more flexibly at the points you leave us."*

Zeynep said that:

> *"I think it's more and more important that we just do these things on our own, I think the more I strain, the more productive I can be."*

As a conclusion, the researcher made refinement regarding the model by designing actitivities in which representational challenge is improved step by step in a progress.

- **Self Assessment**

Making self assessment may be a crucial factor for the process of critical framing in which teachers can reflect on their designing. In this context, Experts suggested that self-assessment should be added to the part of critical framing in the model.

Expert 3 pointed out that:

> *“They can improve their competencies by evaluating their designs and analyzing them. In this way, they can gain a critical eye towards their designs. I think such an arrangement can be made, I can say that self-assessment will work here and it can eliminate its shortcomings.”*

Expert 2 expressed that:

> *“Self assessment process can provide teachers to improve their representational competency skills of evaluating. If they explain what type of intermodal relation constructed with its reasons, their abilities can develop.”*

As a result, The researcher decided to make improvements on the model by adding self-assessment activities while designing the next activities.

- **Medium of Application**

Since each participant has different qualifications on using different digital platforms while designing their representations, most of them suggested that leaving the participants flexible in selecting the medium may be beneficial in terms of constructing better designs.

T1 stated that:

> *“If there was another program, it would be more effective if the activities were carried out in more flexible applications. The reason for such a design is the limitations of applications, so I think it might be better to leave it flexible.”*

T3 indicated that:

> *“The program we used is actually helpful, but I thought I would be more effective if I used other applications, or if I had a pen, paper, or tablet, I could be more creative in making these designs.”*

T4:

> *"I faced some difficulties in designing intermodal relations between text and images, as it is a program that I am not used to, in this respect, participants can be freed to use any application."*

As a consequence, the researcher left teachers free to choose applications to design when conducting next activities.

- **Overt Instruction**

Participants indicated that the part of overt instruction in the model should be enriched apart from the videos and feedback given by the teacher, since it is too hard to comprehend high levels of intermodal relations and construct high cohesion text in terms of argumentative sstructure of it. For instance T1 told that:

> *"Something like this could be added. The explanations in the videos were instructive, but if such explanations were given as text, I would have looked in front of me. I experienced the lack of this, it could be more effective if the subjects described were given as text."*

T3 also said that:

> *"The videos are prepared very well, we can benefit from them if there is a written document in front of us, it is very difficult to find it from the video, the return could be easier, it would be nice if there was a full text with lots of examples."*

Consequently, the researcher decided to present available designs with different mediums such as handbook and videos for the next activities.

4.3.2 Findings of Individual Progress of Participants During Micro Cycles 1 and 2

In this part, individual progress of participant teachers during micro cycle 1 and 2 are given below with pie graphics.

Case 1 – T1

Data revealed that T1 lacked abilities of designing high level multimodal representations before attending to the MpM. T1 started to design different levels of representations in micro cycle 1, while vast majority of them were classified into concurence category (Figure 4.24). He increased and diversified the use of high level ones (from 0% to 27%). He gained tendency towards to design high level ones except augmentation one at the end of micro cycle 1. Analysis of his representations in micro cycle 2 showed that he improved the skill of designing advanced level multimodal texts (from 27% to 42%) as compared to the previous micro cycle. Moreover, he began to use primitive level multimodal texts less often when telling a subject topic (from 73% to 58%).

These parameters clearly revealed that during these micro-cycles, the ability to select existing advanced multimodal texts and design these ones regarding intermodal relations and text coherence has improved, although not at the desired level.

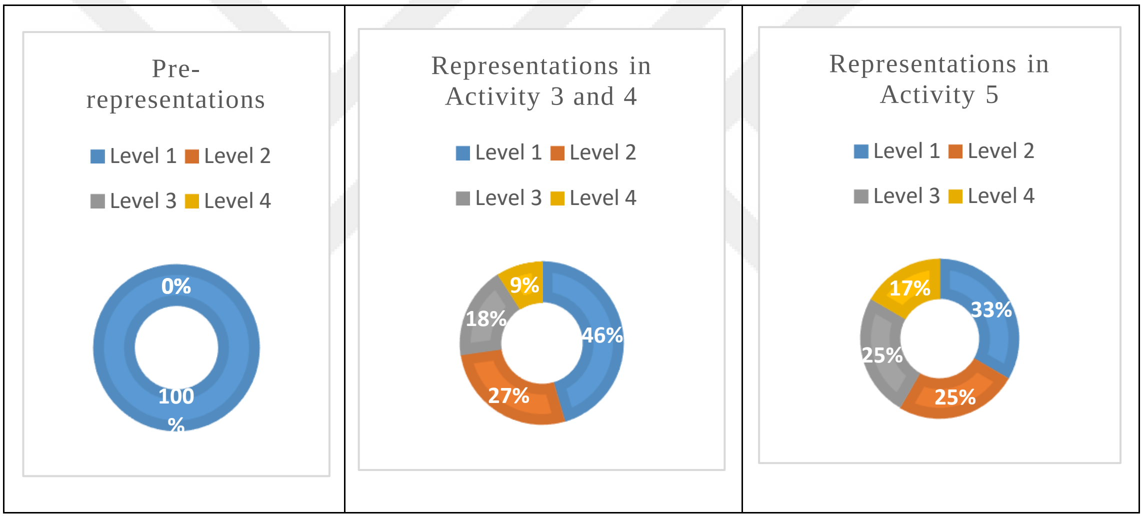


Figure 4. 24 Intermodal relations levels designed by T1 in different activities

Case 2 –T2

Findings showed that T2 had not representational competence skills of selecting and designing multimodal representations in both low level and high level ones before attending to the MpM even if she used exposition and organizational one. This is because she had not awareness about these relations when she was asked about how and for which purpose to design these in the pre-interview. At the end of the micro cycle 1, she was able to design different types of intermodal relations. She increased the use of high level ones (from 29% to 47%), and also decreased the use of low level ones (from 71% to 53%) (Figure 4.25). Analysis of her designs in micro cycle 2 revealed that there was a slight decrease in the use of high level ones (from 47% to 43%), and also there was a noticeable increase in Level 2 relation types, and decrease in Level 1 relation types.

All findings took into consideration, it can be concluded that T2's representational competence skills of selecting and designing advanced level multimodal representations have improved throughout the micro cycle 1 and 2.

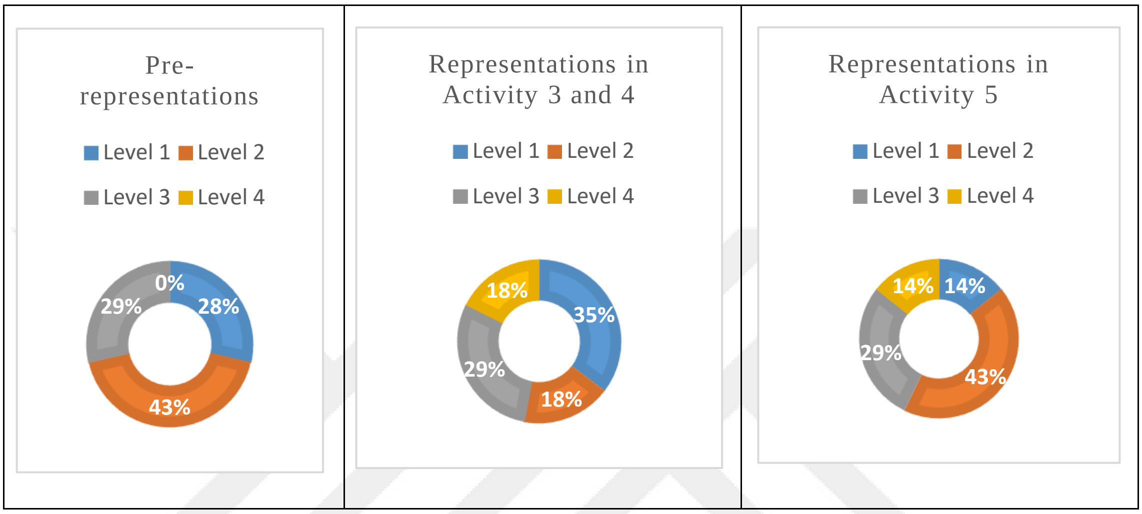


Figure 4. 25 Intermodal relations levels designed by T2 in different activities

Case 3 – T3

Before attending to the MpM, T3 had no awareness about how to design multimodal representations in different levels considering intermodal relations and elements of text coherence. At the end of awareness, recognize, and design activities of micro cycle 1, she improved skills of first selecting, and then integrating appropriate images and text in order to construct diverse multimodal artefacts. She increased the use of advanced level ones (from 0% to 20%), and Level 2 relations (from 0% to 27%). At the end of recognize and design activities of micro cycle 2, findings showed that there was a slight increase in the design of high level ones (from 20% to 30%), and noticeable increase in the design of Level 2 (from 27% to 50%) (Figure 4.26).

The following conclusion can be drawn from these data, T3 has improved the abilities of selecting appropriate multimodal representations and designing them during the micro cycle 1 and 2.

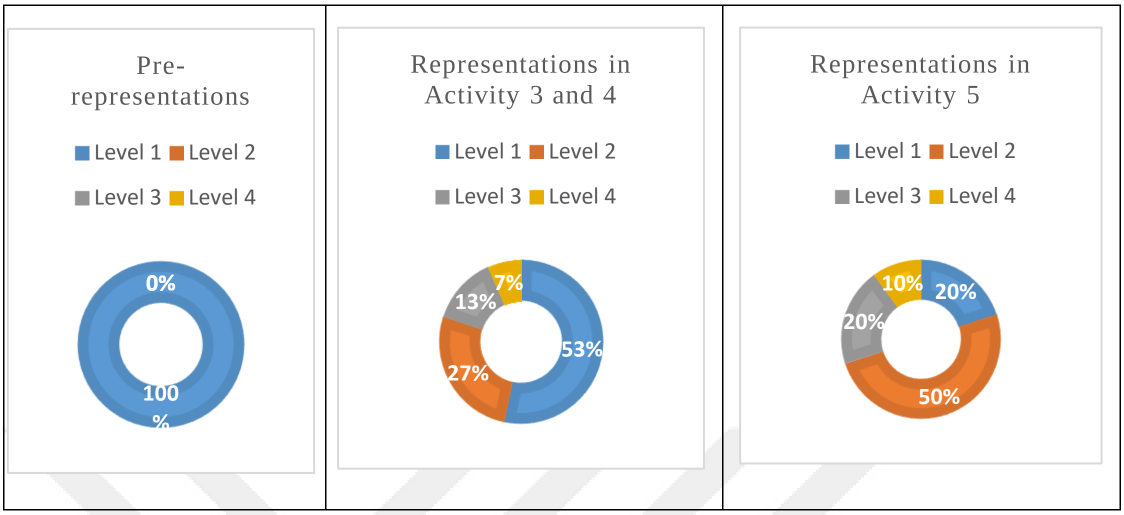


Figure 4. 26 Intermodal relations levels designed by T3 in different activities

Case 4 – T4

In the preliminary stage, the researcher found that T4 was only capable of designing Level 1 multimodal representations that belong to the category of exemplary. At the end of micro cycle 1, she started to design different types of intermodal mechanisms including low and high level ones even if vast majority of her designs was situated into low category (57% low level- 43% high level). Data of micro cycle 2 revealed that she increased the use of advanced level of multimodal representations (from 28% to 50%), and the design of Level 2 relation types (from 15% to 29%). Moreover, she decreased the design of Level 1 intermodal mechanisms (from 57% to 21%) (Figure 4.27).

These findings indicated that T4 improved representational competence skills of selecting and designing multimodal representations during the micro cycle 1 and 2.

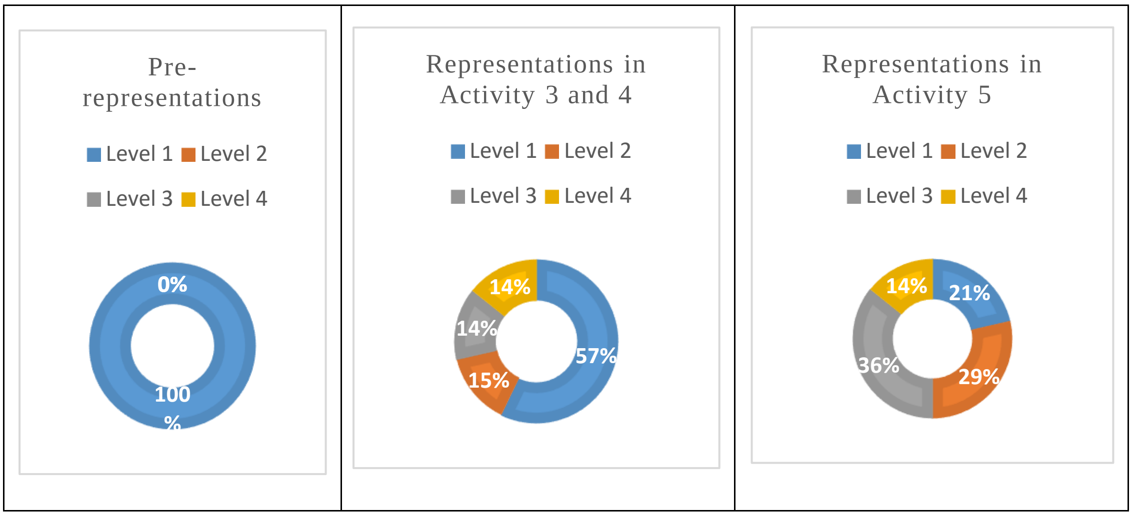


Figure 4. 27 Intermodal relations levels designed by T4 in different activities

4.3.3 Findings on Evaluation of Micro Cycles 3 and 4

As seen in Figure 4.28, making refinements and applying them to the model impacted the use of high level and low level of intermodal relations. Although representations of case five highly affect the rates, the rate and number of high level ones increased (52%-66%-68%; 27-33-40), the rate and number of low level ones decreased (48%-36%-32%; 25-19-19).

Table 4. 55 Number of different levels of representations in each activity

	Activity 5	Activity 6	Activity 7
Level 1	10	9	12
Level 2	15	10	7
Level 3	18	16	22
Level 4	9	17	18
Total	52	52	59

At this point, it is clear that the rates and the number of multimodal representations do not exactly refer to that participants became representationally competent. Hence, the researcher also investigated the statement made by participants during self-assessment. Findings revealed that they were not only designing different types of intermodal relations and applying aspects of text coherence, but also they were able to identify types of intermodal mechanisms and text coherence elements they established. Since designing also includes selecting appropriate modes, participants can be accepted as representationally competent who selects, designs, and evaluates multimodal representations.

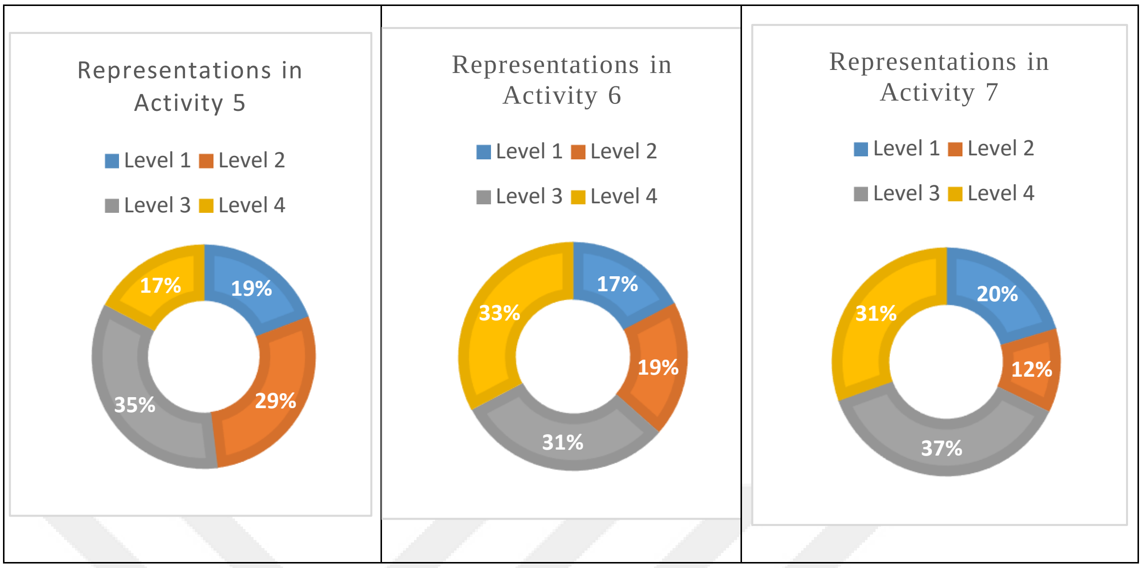


Figure 4. 28 Total change in intermodal relations used by all teachers after micro cycles 3 and 4

Discussions made with experts and participant teachers showed that two important points should also be emphasized in order to make the model more comprehensive. The former, interaction between participants should be realized. In this way, the pedagogical environment can be enriched and overt instruction can be strengthened because participants have the opportunity to view new types of multimodal representations as available designs. For instance,

T2 stated that:

> *"For example, I was curious about what other friends have done, I would like to see their representations, as there are a few more resources, you learn more from friends, or a resource in that sense."*

T3 also pointed out that:

> *"I wonder what others have done too, seeing their representations can help me learn, and I would have seen more resources about these relationships."*

The latter point indicated by the experts is that it was not sufficient for the participants to evaluate their own representations. Hence, they need to assess peer's representation in different contexts. In this way, it is exactly determined whether they are competent or not as representationally. This also strengthens the critical framing part.

For example, Expert 3 told that:

> *"In the previous process they only analyzed their own representation, this is an important point to see if they made a conscious choice. Another point is that the participants did not design some intermodal relationships, you can not identify whether they are identifying these intermodal relations or not. Therefore, analyzing other people's representations will give us complete information. Peer evaluation can be added."*

Based on the micro evaluation 2, the researcher made refinements on the model again by adding a presentation part in which participants present their design to the peers. In this way, researchers aim to improve interaction between participants. Also, peer evaluation was added to enrich transformed practice and critical framing parts.

4.3.4 Findings of Individual Progress of Participants During Micro Cycles 3 and 4

In this part, individual progress of participant teachers during micro cycle 3 and 4 are given below with pie graphics.

Case 1 – T1

When tracing developmental progress of T1 in designing multimodal representations regarding intermodal relations and text coherence aspects, findings revealed that the rate of using and designing advanced level representations has increased (42%-63%-70%), and parallel to this conclusion the percentage of using and designing primitive level reprsentations has decreased (58%-37%-30%) (Figure 4.29). Moreover, findings of his interpretations to his designs indicated that he was able to evaluate multimodal artefacts in terms of relation types and elements of cohesive texts.

All these findings made it clear that T1 became representationally competent one, since he was able to use, select, and evaluate different levels of multimodal representations. He improved competency skills throughout the micro cycle 3 and 4.

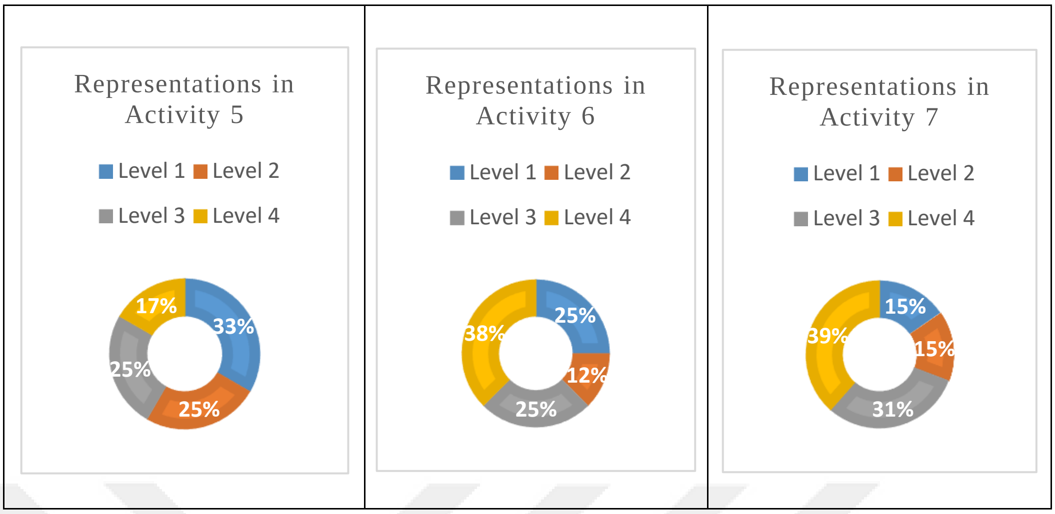


Figure 4. 29 Intermodal relations levels designed by T1 in different activities

Case 2 – T2

Developmental trends of T2 in terms of representational competence skills are clearly seen in findings. She became more talented than the previous micro cycles in using and designing high level multimodal representations. She has increased the rate of using and designing advanced level texts during the micro cycle 3 and 4 (43%-69%-84%). On the other hand, she has decreased the percentage of using and designing of low level ones (57%-31%-16%) (Figure 4.30). Apart from these, data also showed that she was able to evaluate their own multimodal representations accurately regarding intermodal relations and elements of text cohesion.

As a result, at the end of micro cycle 4, it can be concluded that she developed abilities of representational competence during these processes.

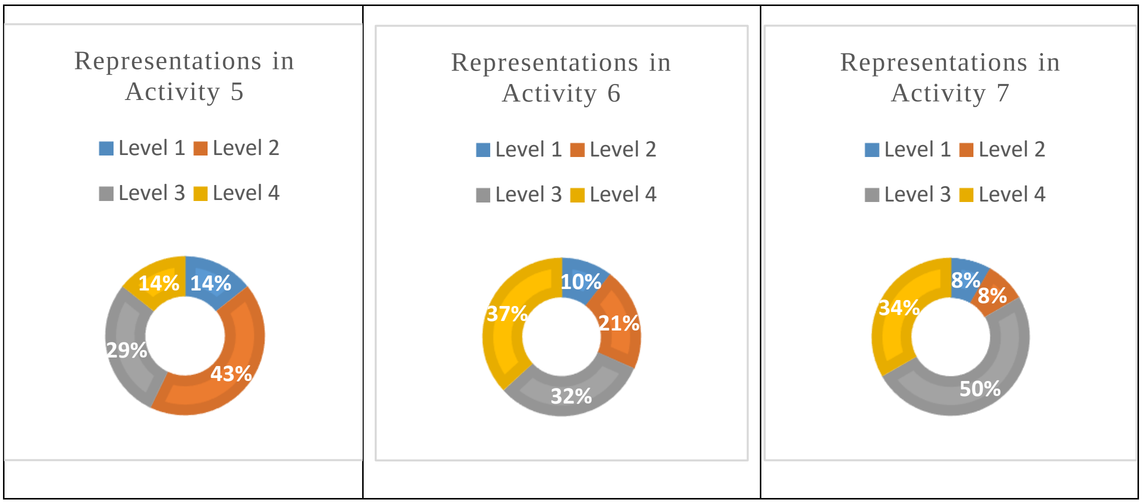


Figure 4. 30 Intermodal relations levels designed by T2 in different activities

Case 3 – T3

As shown in Figure 4.31, T3 performed an increasing tendency towards the use and design of advanced level multimodal represenations even if there was a slight difference between the findings of micro cycle 3 and micro cycle 4. These results stated that T3 became representationally competent at the end of activity 6. She has increased the use and design of high level ones noticeably (from 30% to 78%), and has also decreased the use and design of low level ones (from 70% to 22%). Apart from these, her statements showed that she was able to evaluate her own multimodal texts accurately according to the pre-determined criteria.

As a conclusion, all these findings indicated that T3 improved the skills of selecting, designing, and evaluating different levels of multimodal representations properly during the micro cycle 3 and 4.

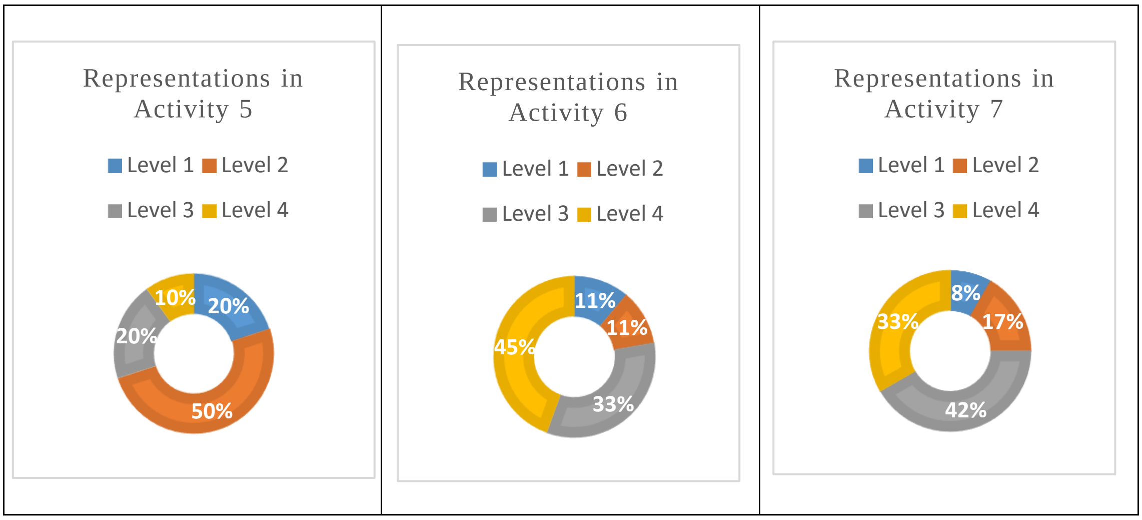


Figure 4. 31 Intermodal relations levels designed by T3 in different activities

Case 4 – T4

Analysis results of T4's representations at the end of each micro cycle showed that she improved the use and design of advanced level multimodal representations. Although there was no change in the rate of low level and high level ones between micro cycle 2 and 3, there was a noticeable change between micro cycle 3 and 4. The percentage of designing of high level ones has increased from 50% to 79%, and the rate of low level ones has decreased from 50% to 21% (Figure 4.32). Besides, her interpretations about her multimodal texts revealed that she was able to assess these various types of texts accurately.

Briefly, all these findings indicated that T3 improved the skills of selecting, designing, and evaluating different levels of multimodal representations properly during the micro cycle 3 and 4.

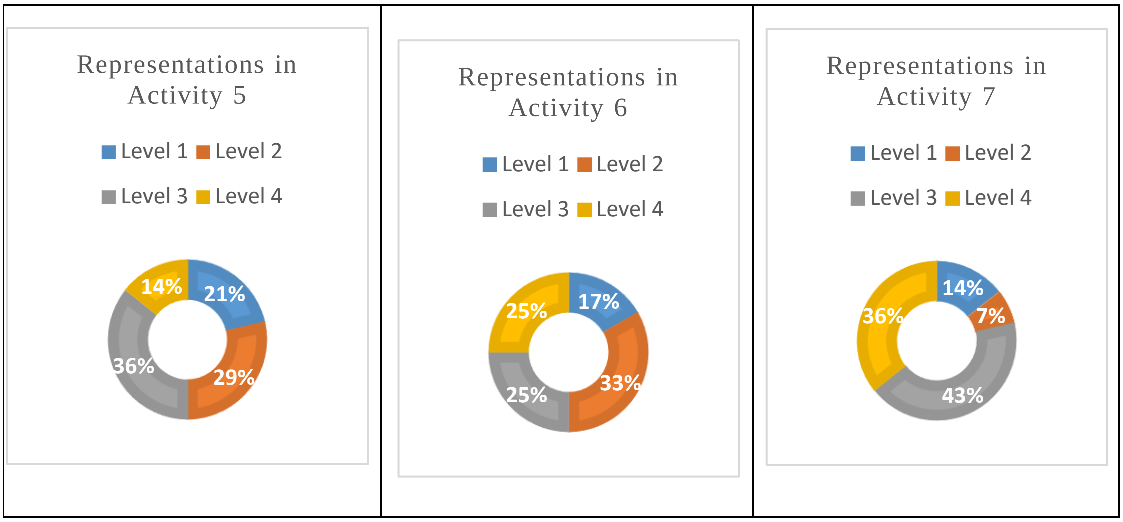


Figure 4. 32 Intermodal relations levels designed by T4 in different activities

4.3.5 Findings on Evaluation of Micro Cycle 5

Analysis of participants about intermodal relations and text coherence and their statements about representations revealed that they have capabilities of identifying intermodal relations and features of text coherence. Findings indicated that they were not only analyzing, but also criticizing to what extent the representation correspondence to the intermodal relations referred to. Moreover, they suggested their mates on what types of relations and text attributes to use. Statements made by them to the questions in the interview also showed parallelism when compared to their representations they design and analysis they made. These parameters seem that they have also gained analytical skills and critical perspectives towards what types of intermodal mechanisms and text coherence attributes are designed in any representation. These are clear signs of their representational competence skills. Thus, all these data showed that there is no need for a new revision.

4.4 Findings of Post Interviews

Interviews were done with all participants at the end of the study. The aim of the interviews was to reveal difficulties that ToGs are encountered in this process and their views and perceptions about the MpM, and how they recognize opportunities of the MpM to the education of gifteds.

4.4.1 Findings of Participants' Views and Perceptions on Model and Teaching Process

4.4.1.1 Difficulties Experienced by ToGs

In this context, when participants were asked about what difficulties they experienced during the process, findings showed that the difficulties experienced were about the designing process. According to the qualitative data, the theme of -difficulties encountered in the design process- can be classified into four categories: *(1) designing text coherence, (2) designing intermodal relations-finding available designs, (3) with which source to start the design, (4) difficulties in using digital tools.*

- **Text Coherence**

All participants in this study indicated that they had some challenges while realizing text coherence. These challenges can be coded as *integrating scientific process to the text, transforming scientific knowledge to daily language, and detailing with explanations*.

For instance, T4 told that:

> *"Sometimes it was difficult to put qualitative quantitative data into the text, it was easy to find texts containing direct information, but it was really difficult for me to put the texts that include the hypothesis research question and the data while I was explaining the process to the students. I thought a lot, it is difficult to reach and present scientific sources. Frankly, using persuasive language is difficult compared to descriptive language."*

She stated that it was difficult to reach and find such texts as the reason for her inability to construct highly cohesive texts. This can be considered as an indication that such texts are scarce in educational environments, so teachers should have the skills to design such texts in order to enrich educational settings.

T1 also mentioned the same difficulties as T4:

> *"It was difficult for me to embed the scientific process into the text, to write that process, and to write it in a language that the student could understand."*

T2 expressed her difficulties regarding this issue as follows:

> *"I had difficulties in bringing scientific language closer to everyday language, it was really difficult to make explanations with examples from everyday life in parentheses. Because it was difficult to think and express the concept in the language of the student, and in that respect, it challenged me."*

They stated that they did not know how to translate the scientific language into the language that the student would understand, as the reason for not being able to translate the scientific language into the everyday language. Hence, it can be drawn that teachers do not have a rich vocabulary.

T3 identified difficulties she had in this way:

> *"I had difficulty in giving the scientific process, especially in this process, it was difficult for me to add qualitative and quantitative data, I also had difficulties in translating the scientific language into everyday language, it is really difficult to express it in the language of the students. It is difficult to access the data, it is difficult to find it on the internet and trust it, and it is also difficult to reach the article and transfer it to the students' level."*

All these findings regarding text coherence showed that the most difficult and challenging parts of constructing text coherence was about embedding scientific processes into the text and transforming scientific language into daily language because of the following reasons: difficulties in accessing scientific data; in embedding them into the text; in bringing this language closer to the daily language of the student.

- **Intermodal Relations**

Participants generally admitted that augmentation and interpretational one are more challenging than the others, they indicated that designing these ones require more time, more effort, and more research and investigation. For example, T4 stated that:

> *"I had difficulties in designing augmentation and interpretational one. I needed more attention and concentration."*

T3 pointed out that:

> *"Augmentetaiton was also difficult, hard to model something really, this is actually a very high-level scientific process, it is difficult to create visuals and text to describe it, it requires a lot of research and have a good content knowledge."*

T5 also indicated that:

> *"I struggled with the augmentation relations because it is a really difficult process to simulate and model closest to the subject told."*

T2 told that:

> *"I have worked hard with the interpretation one, again, to design augmentation because it is very difficult to find images in this area, I have something in my mind, yes, I say it is interpretational, but since I cannot design as in mind, I tend to those who are ready, but there is also not what I want."*

All these findings with regard to intermodal relations revealed that the most difficult and challenging parts of designing process was to construct augmentation and interpretational representations because of the following reasons: requires more time, effort, and research; high-level of cognitive skills; reaching proper resources.

- **Starting Point**

When participants were asked about which one (image-text) made it easier for you to start designing intermodal relations. The answers differ. Two of them stated that text is a main factor for designing, the rest claimed that starting from an image is more functional than text.

T1 advocated to start with text, because he indicated that:

> *"I do not start with the visual, the text that matters. That's why I choose the way to edit the semantic relationships by adding images based on the text and the content of the text. It is easier to start with the text, the priority is the text, the main element is the text."*

T2 also supported the idea of starting with text, she claimed that:

> *"I usually start from the text, mostly from the text. The reason for this is that we reach the easiest text while sharing something scientific, which affects my starting from the text, we transfer more information with the text, we use the most text, so it is easier to create the text and then go to the visual."*

T3 is advocator of designing intermodal relations by starting with image, she mentioned that:

> *"I guess to start with the image. Finding images is more enjoyable, it is easier to match the text with the image, maybe because it is more concrete, maybe it is more understandable."*

T4 also advocated this idea:

> *"In general, I first choose the images and then construct a relation with the text. If I look at it, I establish these relationships based on the image, it is easier and more functional for me to start with the visual."*

Advocaters of the former one claimed that starting with text to designing is easier than the image due to these following reasons: text is main component of meaning making process; easy access to written text; widespread use of this mode.

Advocaters of the latter explain their choices based on following reasons: image is more enjoyable, concrete, functional, and understandable than written text.

- **Use of Digital Tools**

Participants in this study told that they had some challenges while using digital tools. These challenges can be coded as *not getting used to digital tools* and *lack of equipped instruments*. For instance,

T1 stated the following about the problems he had with digital tools used for design:

> *"I had difficulties in accustomating to using digital tools when designing, if there was another program, it would be more effective if the activities were carried out in more flexible programs, I know you free us to use other apps as well, however all apps have some limitations. I could design my representations more effectively with a tablet and pen, I know it is an issue about budget."*

T1 also indicated same points like that:

> *"If it was a tablet and a pen, I would have less difficulty doing these designs. I claimed this, but tablet use also includes some challenging points. It also requires some abilities and familiarity to use them."*

T3 also emphasized this point:

> *"Digital tools have actually become very helpful to design, but I would like to draw, I thought I would be more effective if there was a tablet and a pen. You gave detailed information about how to use digital tools, told us about their features, we asked you whenever we wanted, we were even released to use other tools we know, but I still felt such a need while designing."*

T4 pointed out that:

> *"I liked digital tools, but there are minor deficiencies, I tried to fix them with other programs. In the subject on how the vaccine works? I used the mobile phone on the one hand and the computer on the other hand, I tried*

to handle the two together, but if it was a tablet, I could be more comfortable in the drawings."

As a result, the interview findings about difficulties showed that digital tools have limitations to realize the ideal design in mind, and sometimes it requires abilities of drawing even if they have proper materials such as tablet and pen.

4.4.1.2 Participants' Views and Perceptions on Teaching Process

When transcribed participants answers to the questions of what is your views about teaching process of MpM and which purposes do it serve, their answers can be classified into six categories under the theme of contributions of MpM to teaching and learning process: *(1) aim, (2) motivation, (3) teaching process, (4) learning products, (5) changes in perception, (6) selection and design.*

- **Aim**

All participants in this study indicated that the model, the teaching process and intermodal relations designed could serve some crucial purposes in the classroom environment. These purposes can be coded as *interaction, questioning, motivation, discussion, thinking skills, classroom management, creativity-individuality, and presenting challenges for gifteds.* For instance T1 said:

> *"Through these intermodal relations, if our aim in the classroom is to make explanations, we can use an organizational relation; or if our aim is to create discussion environment, we can use comparative and interpretational one. I think this increasingly difficult process and different intermodal relations increase interactivity and questioning, which gets attention of student and motivates them."*

The statements made by T1 revealed that he gained awareness that different intermodal relations serve various pedagogical purposes in educational settings.

T1 also indicated that:

> *"Challenging representations can be designed for gifteds, texts that students can produce ideas can be designed instead of higher-level information, comparisons can be made with higher-level intermodal*

relations, and they can be asked to make inferences in this way, an argumentative text can be given even without visuals, that is, a text describing the scientific process."

These quotations have shown that the texts designed by paying attention to these criteria are very helpful in meeting the instructional needs of gifted students.

In parallel with T1, T2 told:

> *"In fact, the model and intermodal relations we learned contribute to improve students' thinking skills, giving a critical image-text pair (that is high level ones) can improve their critical thinking skills, and provide a good understanding of the concept we want to teach. It increases interest and motivation, and contributes to their questioning and critical skills, from the modes we choose for designs to the relations between them. In the text we have designed, if it is open to interpretation, it will make students active, this will really serve our purpose, in terms of revealing creativity and their own difference."*

T2 told about opportunities of multimodal representations to education of gifted as follows:

> *"Presenting questionable and interpretative representations to gifteds will reveal individuality even more at this point because we observe individuality more clearly in these students. Therefore, if the text is designed in such a way that the student can participate and present his / her own opinion, if it is in a way to ask questions, this will be supportive in revealing his own difference."*

The explanations of T2 clearly showed that multimodal texts designed at higher levels are important for gifted students as they will reveal their individual differences and enable them to think critically.

T4 mentioned:

> *"Decorative intermodal relations can be used to attract attention. It can be used comparative and interpretation for questioning, the model and*

intermodal relations I learned seemed very important for making the course interactive, both for timing and for classroom management. With these, I can increase their motivation by drawing attention, there is a moment to become aware of some issues, but I think this is also beneficial for those at the same time, I think that causal structures, procedural expressions and comparative structures will create a discussion environment and include them in the class, as they will push students to think differently. If I tell a subject, maybe one or two people will participate and express their opinion, but with such a presentation, the narration will activate more people. Maybe they will raise questions in their minds and create new topics for discussion. I also think it will prevent misunderstanding."

All these statements made by T4 indicated that she realized that texts at different levels and at different cohesion levels can be used for different instructional purposes in the classroom.

While T4 is mentioning about meeting the needs of gifted, she focused on creativity and presenting challenges for them as follows:

"First of all, our students are curious tudents, we are in a world where they can easily access the texts they will read, but they do not have the number of resources that will make their own inference and interpretation to produce new ideas, they have ready-made information packages, we are really lacking in this respect, yes I read it, it is in the magazine. I have read, they also have dissatisfaction, so presenting such texts actually satisfies the inquiry and creativity side of them."

All in all, views of ToG revealed that designing multimodal representations considering intermodal relations serves several purposes ranging from increasing interactivity, motivation, independence, and interest to provide valauble instructional sources to gifteds to make their own inference and interpretation to produce new ideas, and also to reveal their individual differences and creativity.

- **Motivation**

Practitioners stated that the model, the way it is conducted, and the content motivate them to participate in the research. Reasons of motivation can be coded as: *pointing to the real need, wondering what will happen at the end of the research, involvement in an inquiry process, and the ways the content is constructed and presented.* T3 said:

> *"The videos are prepared very well. When I said text, I had a lot of different things in my mind. Right now, I can look at it from a very different perspective, this motivated me the most, and learning new things motivated me a lot. I got more excited in each video because it was telling something new, something new. I talked about this in my doctoral course. As a teaching approach, I transferred my knowledge about text design to them."*

T1 told:

> *"Seeing that it will fill a real gap in education has motivated me a lot, I wanted to support, I want to see the result, I wonder what will happen in the process, I saw that potential in this study."*

T2 said:

> *"Questioning whether the text and images I use correspond to the meaning that I want to give, this issue motivated me a lot because I had never thought that a relationship could be established between text and images for different purposes and different ways."*

Views has shown that the teaching process has motivated ToGs to participate, as it indicates a real need in gifted education.

- **Teaching process**

Views of participants regarding the teaching process can be classified into three codes: *sequence of teaching process, the way the activities are conducted, and willingness to use this process as a way of teaching*. For instance, T2 told:

"The activities were well connected and progressed gradually, the answer you gave in the previous activity emerges in the other activity. While doing the next activity, it made me realize my shortcomings in the previous activity and complete it by myself, so I realized my shortcomings myself, looking back with the explanations the next week, what I had done in the previous week came to my mind and I made the connection more clearly, as a method, it enabled me to move forward by questioning. I saw the difference between what was supposed to be and what I did myself, and I started using it in the presentations I prepared.

I would like to carry this teaching process to my class, because the child encounters with the teaching material at first and then the child tries to do the same thing with different strategies, adds creativity to it, it is a very suitable method for what we are trying to do, and I would like to use it because I believe it will support creativity in this aspect."

T2 claimed that the teaching process is well organized, as it enables the learning process to take place within the cycles of awareness, recognition, design and evaluation by recognizing and correcting its own shortcomings. She stated that such a teaching process would improve the creativity of gifted students as it would offer the opportunity to solve problems in different contexts, she was willing to apply this teaching process in her own classroom environment.

T4 said:

"After doing the assignment, the video came, that is, we learned after making some inferences ourselves, we constantly had the opportunity to compare what we did with what it was supposed to be, which was very good, I think it was useful. I think this is a correct approach and sequencing, I would like to use it as my own teaching method, it was very useful, and I would do it like this."

T4, like T2, stated that she wanted to carry this teaching process to her own classroom environment for similar reasons.

T5 stated:

> *"I like that you manage the process in this way, the process progresses with increasing difficulty, over time all the work is left to us and we evaluate the representations of our friends when we reach the level of analysis. If you had given it in the beginning, we would have had a hard time going step by step, reducing the cognitive load and allowing us to progress, going piece by piece and then letting us assemble the pieces helped us learn more."*

Teachers' views depicted that all wanted to adapt this process into their teaching process, since the method enables: well organized activities, moving forward by questioning, to students to encounter challenging teaching material, well designed teaching and learning process, a progress with increasing difficulty.

4.4.1.3 Participants Views on Opportunities of the MpM to the Education of Gifteds

- Learning products

Participants stated that the model, the way it was conducted, and the content would impact learning products of students. Elements of these impacts can be coded as: *meaning making, design of learning products, creativity, interest, and questioning*. T2 told:

> *"The more we present our texts with different modes and semantic relationships, the more effective the students' internalizing them, questioning them or transforming them into products. I think preparing the texts consciously in this way will provide them with a subconscious way of learning, we will be able to see them in the learning products, because the students are very careful, focusing on a small place in the visual that you do not care about, they can say what it is, create a misconception, think and design as a whole, the student will be able to reflect on the product as much as they can understand. Richness in the text leads to richness in the product."*

T2 stated that since gifted students are careful and have the ability to be aware of details, designing the texts according to the aspects they have learned would increase the diversity and richness of the learning products coming from gifted students.

T1 said:

> *"Since it will be easier for students who are exposed to well designed multimodal representations to make sense, I think that their design will be better than the first group, unimodal, and their design will also be multimodal. If you think of two presentations, one is random and one is prepared according to these rules, the first group will definitely experience distraction, difficulty in interpretation processes, if we do it in accordance with these rules, interest will increase, class management will become easier, the text will be better understood."*

T1 simply made a comparison and expressed that the learning products of gifted students exposed to multimodal texts would be like this.

T3 stated:

> *"These texts can now help them more consciously select the representations in any teaching source that construct the meaning."*

T4 mentioned:

> *"I think these multimodal text will affect learning products a lot, because I think about the assignments I gave without thinking about them before, they were doing the same and sending what I did, neither their creativity nor their expressing with their own sentences, I think if they are prepared with these intermodal relations, their answers will vary and change, they will add their own interpretations and express them with their own sentences. I think their own ideas will emerge and they will continue on with it."*

Briefly, teachers indicated that designing multimodal representations considering intermodal relations and text coherence would impact students' learning products in a positive ways. These components can affect the diversity, richness and creativity in learning products.

- **Perception**

All participants indicated that the process they experienced changed perceptions towards to select, to use, and to design multimodal representations regarding intermodal relations and text coherence. These changes can be called as: *self-criticism, perspective, awareness, selection and design of multimodal representations, and criteria for designing*. For example, T4 said:

> *"As far as I saw in the process, I noticed that my perspective on the texts had changed, I did not have much information about what you were telling. Actually, now I started to look at texts from this point of view when I was examining them or while designing text. I realized that I was looking at how harmonious the texts are, even if it is not related to the lesson. I'm thinking about how the text used scientific language, or the image reflects the meaning in the text, or just include some examples. I have these questions in my mind, I started to look critically, I now pay attention to this in my own works."*

T4 pointed out that this whole process gave him a critical point of view towards scientific texts.

She also stated about her designing process and selection of available design as follows:

> *"First I look at the subject, I determine the concepts related to the subject, then I find the images and construct text coherence, then I design the intermodal relations between the text and the image."*

T2 told:

> *"While I was presenting something in the lesson, I started to criticize myself for whether there is a connection between them and whether these modes reflect the related process. You put it here but I made a self-criticism that it was decorative and I could make it stronger, put a classic picture next to*

it without dwelling on how I can make it more meaningful, but I did it without questioning whether the relationship between it will give the meaning I want to give. Actually, when I looked at it, I realized that it was also in a cognitive order, before that I was doing the following when I was preparing a text, I was taking a picture on the subject and putting it there."

T2, like T4, indicated that this teaching process and being exposed to these types of multimodal texts gave him a critical point of view towards scientific texts.

She also pointed about her designing process and selection of available design as follows:

"After determining the concept and putting it in focus, I determine the image and text that I can use, I pay attention to the coherency between them, then I use organizationally if it is a process mentioned in the article, I pay attention to create a clear text for the interpretation of the students, I pay attention to choose the relation with which the concept to be conveyed is more appropriate."

Mustafa mentioned:

"We knew that the title was important, I knew the content was important, but it made me realize how it could be such questioning and informative. Frankly, I can say that I learned the coherency between the title and the content, the content and the image better, I was not looking at it from this perspective."

He also indicated about her designing process and selection of available design as follows:

"First, I look at the whole subject, then I look at the concepts used here, then I decide which intermodal relation I will establish according to these, I use organizational if there is a need to describe a process here, now I look at the whole subject and then look at the intermodal relation that it makes sense to present."

T1 made the following statements:

"I pay attention to principles of multimodality while designing, I do it by considering intermodal relations between the text and the image, I determine them according to the cognitive level of the student, I try to complicate intermodal relations according to the cognitive level. I try to design according to the content of the subject. If there is a process, for example, photosynthesis here I use organizationally, I can make an analogical explanation with an expression so that the same thing can be remembered more. It can be all of them, my focus here is on my purpose in the classroom and which of the subject's content is suitable for doing."

T3 pointed out that:

"While choosing and designing the representations, I pay attention to the text cohesion features and the relationship of the image with them. I determine which intermodal relation I will use according to the subject, there may be an interpretational relation on this subject, I think that there is comparative here. If it is a question, my goal is to use higher level intermodal relation, if I want to develop high level skills, if my purpose is more to reinforce, I establish an exemplary relation."

They claimed that they first looked at the whole subject, then paid attention to what concepts and processes were in it, and then started to think about how this concept and process would be designed according to which intermodal relations and for which purposes (discussion, explanation, problem solving, and etc.) in the classroom.

Briefly, findings about teachers' views on MpM and its teaching process revealed that both of them served specific aims in classroom environment, motivated them to participate in teaching process, had a well organized teaching process, impacts learning products of learners, changed perceptions of them while selecting, using, and designing multimodal representations.

4.5 Final Product

4.5.1 Revisions of Design Principles at the End of Micro Cycles 1 and 2

Based on the evaluation, some additions and refinements were realized in design principles. Three of them have been revised and a design principle added according to data obtained in micro cycles 1 and 2, and suggestions of experts and participant teachers. Self assessment point has been added in order to improve teachers' representational competency skills of evaluation. Moreover, the researcher decided to increase the level of representational challenge step by step in each activity, decreasing scaffolding level, and enriching available sources in order to develop teachers' representational skills of selecting and designing. They are shown in the table with rationales. (Table 4.56)

Table 4. 56 New design principles at the end of micro evaluation 1

Initial DP	**Revised DP**	**Rationale**
At the end, designers' learning products (multimodal representations) should be assessed by the teacher who is an epistemic authority according to multimodal assessment rubrics.	Designers should make self assessment of their multimodal representations with respect to the criteria of intermodal relations and text coherence, and then teacher should assess and give progressive feedbacks to the representations of students'	Making self assessment may be a crucial factor for the process of critical framing in which teachers can reflect on their designing. Teachers should support explicit discussion about multimodal representations and help students to evaluate the usefulness of particular representational forms.
Designers require to encounter representational challenges, which elicit their causal accounts of phenomena.	Designers need to face increasingly difficult representational challenges, the level of scaffolding provided by teachers needs to decrease in parallel with increasing difficulty.	Representaitonal challenge with decreased scaffolding can be effective in improving teachers' representational competency since data provided by researcher give some clues about this inclination.
Teachers should present designed multimodal texts by harmonizing and organizing available designs.	Teachers should present designed multimodal texts in different mediums, such as video and handbook in order to enrich pedagogic environment.	Overt instruction in model should be enriched apart from the videos and feedbacks given by teacher since it si too hard to comprehend high level of intermodal relations.
	Added DP	Rationale
	Designers should be free to choose the applications in which they design multimodal representations.	Since each participant has different qualifications on using different digital problems while designing their representations, most of them suggested that leaving the participants flexible in selecting the medium may be beneficial in terms of constructing better designs.

4.5.2 Revisions of Design Principles at the End of Micro Cycles 3 and 4

Based on the findings regarding evaluation of micro cycles 3 and 4, one design principle has been revised and a new added. Peer assesment issue has been added in order to improve participants' representational competence skill of evaluation. Interaction between teachers was provided in order to improve teachers' representational competence skill of selecting and designing. These refienements are shown in Table 4.57 with rationales.

Table 4. 57 New design principles at the end of micro evaluation 2

Revised DP	Final DP	Rationale
External representations of students should first be evaluated themselves considering intermodal relations, and then evaluated by the teacher according to the criteria of multimodal analysis.	Evaluation of external representations should be realized in three following steps: self assessment, peer assessment, and assessment by epistemic authority.	Making self assessment and peer assessment is a crucial factor for the process of critical framing and to understand whether participants are representationally competent or not.
	Added DP	
	Multimodal learning environment should provide some opportunities for interactions of designers.	In this way, learners could help each other in order to overcome problems in such interactions.

4.5.3 Final Design Principles

Theoretical Design Principles

1. Teaching and learning in the classroom is a multimodal experience and a design.
2. "Learning", consequently, is defined as an increased capacity to use signs (modes/representations) and engage them meaningfully in different situations.

3. Learning is a design, and it includes internal and external design of representations.
4. The multimodal texts and artifacts that designers make can be seen as one kind of sign of learning, a material trace of semiosis.
5. Multimodal learning environment requires representational competent teacher.
6. Multimodal texts have manipulable characteristics, they provide designers to attend text in different entry points.
7. Teachers are active designers of their teaching materials and learning products.
8. Students are active designers of their learning products.

Practical Design Principles

1. Designers should be situated and immersed into a semiotically/multimodally rich classroom environment.
2. Teachers should present designed multimodal texts in different mediums, such as video and handbook in order to enrich pedagogic environment.
3. The teacher should design multimodal texts and to organize student activities, dialogues, and discussions as a mediator and negotiator in order to enhance (a) comprehending fundamental and functional semiotic forms of various typess of modes, (b) understanding conceptual structures of the modes, and (c) awareness of the potentials enabled by the different structures of representations.
4. Teachers should encourage explicit discussion about the appropriateness of particular multimodal representational forms.
5. Tasks should be involved for the transformation, transduction, and re-representation of concepts and ideas from one mode to another.

6. Designers need to face increasingly difficult representational challenges, the level of scaffolding provided by teachers needs to decrease in parallel with increasing difficulty.
7. Multimodal learning environment enable designers to design their conceptual understanding by using multiple modes.
8. Designers should be free to choose the applications in which they design multimodal representations.
9. Multimodal learning environment should provide some opportunities for interactions of designers during implementation.
10. Evaluation of external representations should be realized in three following steps: self assessment, peer assessment, and assessment by epistemic authority.

4.5.4 Final Model (The MpM)

DPE was enriched with participants' representations and handbook on intermodal realtions and text coherence. Teaching metalanguage was extended through live instruction on discussion about designs of participants, representational challenge which increases sequentially, and decreasing scaffolding step by step. Critical framing was enriched with self assesment. Transformed practice was extended through interaction activities and peer assessment (se Figure 4.33).

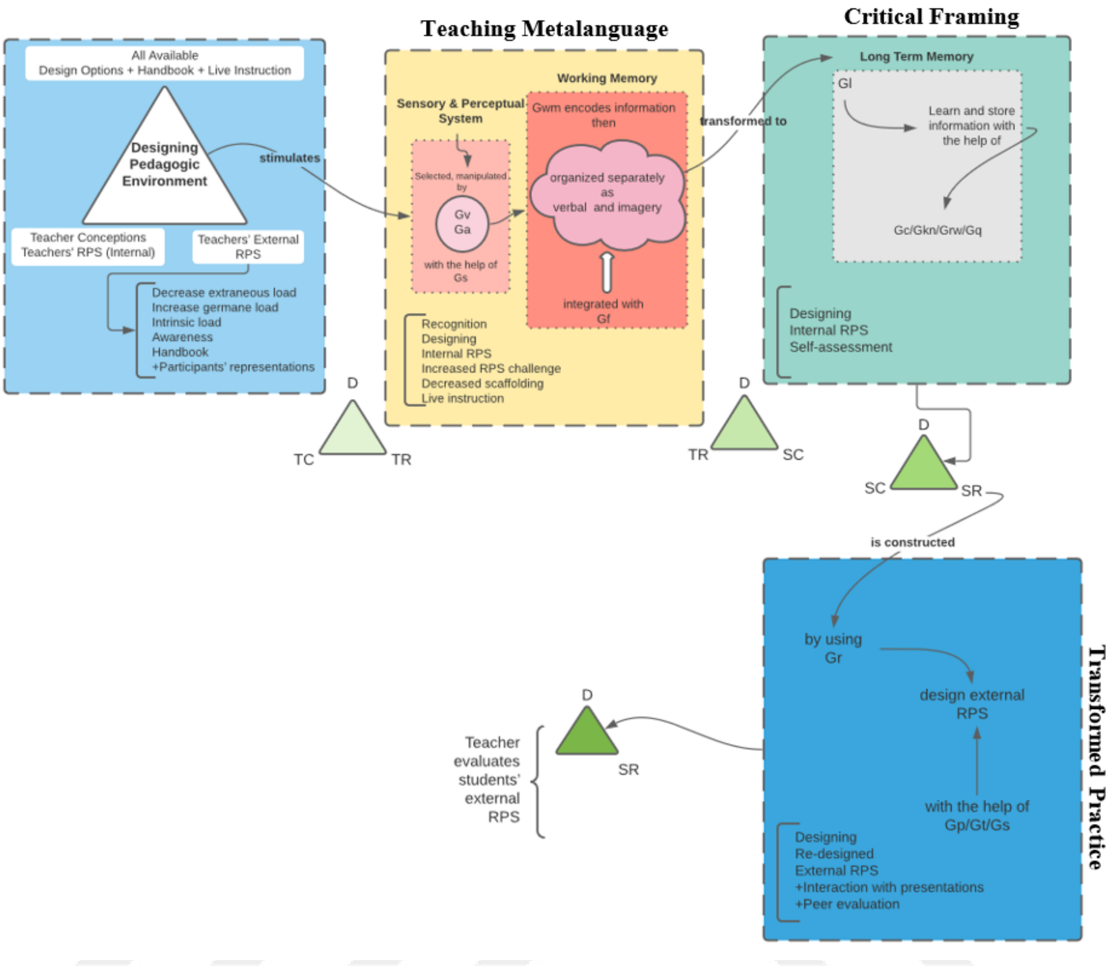


Figure 4. 33 Final model of the MpM

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5
RESULTS AND DISCUSSION

The teaching and learning needs of gifted students arise in three realms. The former is about the content. While preparing the content, three parameters should take into considerations: how the content engages them, how the content presents knowledge deeply beyond the prescribed curriculum, and how the content provides students with opportunities to think on complex ideas (Taber, 2007, 2016; VanTassel-Baska & Wood, 2009). The latter is about process and product which refers to teaching methods and its activities. That is, intellectually challenged activities which aim to develop gifteds' higher order thinking skills should be embedded in differentiated teaching methods. In-depth discussions should be involved in this process in order to encourage students to be in charge of their learning (VanTassel-Baska & Stambaugh, 2006). The last is about a learning environment which encourages investigations, questioning, discussion, and student independence (VanTassel-Baska & Hubbard, 2016).

All these requirements mentioned above reveal that applying these principles can only be realized by an effective teacher who has experiences about differentiated teaching methods regarding these issues. However, studies showed that teachers of gifted were not qualified at coping with these concerns even if they are aware of designing a learning environment which prompts students to use higher order thinking skills (Chan, 2011; Reis, 2009). Moreover, they are stuck to use traditional teaching methods such as textbook-based, teacher centered and examination oriented teaching (Yuen, 2004). Students' views on teachers of gifted also indicated that teachers lack the ability of conducting a proper teaching method which proposes a sufficient level of challenge and presenting the subject in depth (Mammodow, 2019). Hence, there is a consensus between scholars that a differentiated pedagogy should be designed in order to equip them with abilities of: (1) applying differentiated teaching methods that improve higher order thinking skills, and engage gifted students' attention and curiosity (2) designing challenging teaching materials that promote Bloom's high level cognitive skills (analyse, synthesis, evaluate), (3) guiding and scaffolding students to gain independence and autonomy in their learning (Coleman, 2014; Dilekli, 2017; Housond, 2016; Miedijensky, 2018; Renzulli, 2011; Stott & Hobden, 2016; VanTassel-Baska, 2011). Here, many scholars have proposed some models (School-wide Enrichment Model, Integrated Curriculum Model, Autonomous Learner Model) to account for what should be done. All these models offer in common that differentiation applications should be applied considering acceleration and enrichment. Acceleration is about compacting curriculum with respect to the learning pace of gifted. Enrichment is generally about enabling students with greater depth and breadth in subject specific area with more diverse educational experiences. These models frankly explain *what of* (principles) questions on teaching of gifted. Hence, it is apparent that investigations on differentiated teaching should be extended and transformed towards *how of*.

Here, the investigation process led the researcher to ponder on how the cognitive system of gifteds works, how learning occurs, how the teaching should be, and finally how to equip teachers of gifted with the answers of previous first three questions (*how of questions*). At this point, within the perspectives of these models' principles (differentiating by enrichment, autonomy in learning, improving thinking skills, designing challenging teaching materials, and etc.), and findings about the how of questions, researcher designed the MpM for teachers of gifted. Before designing this model, needs analysis was realized through interviews, literature reviews, and document analysis. After problems and needs were defined, the researcher looked for possible solutions, and then determined theoretical and practical principles of the model, its learning and teaching process, and its activity types under the new pedagogical model.

In this chapter, the findings obtained in the study are discussed and the results are given. The discussion was carried out under two main but embedded titles. In the first of these titles, since the study is an educational design research conducted *through intervention* (McKenney & Reeves, 2012), the findings obtained for the development of Multimodal Pedagogical Model are discussed. In the second title, the impact of the model on ToGs' RC is discussed. That is, the main aim in the present study is to determine design principles of the model and design this model together with its activities in line with theoretical and practical design principles by applying the teaching process in different micro cycles. These micro cycles provided researchers with revising and evolving design principles and model. The second aim is to investigate the impact of the model on participants' representational competence level during and after the intervention. While discussing the model and its principles, representational competence level of teachers is discussed under the same headings as well.

5.1 Discussion on MpM

In order for teachers to acquire the desired skills mentioned above, appropriate instructional activities and teaching processes must be carried out. At this point, the researcher has claimed that the MpM with pre-determined design principles offer an effective approach. Findings briefly revealed that the model has become solid after it was iterated through five micro cycles. This inference was made by looking at findings that teachers became representational competent. Evolvements and refinements of the model and its design principles, and its impacts on RC of ToGs are discussed below.

5.1.1 Discussion on Micro Cycles 1 and 2

Each micro cycle was designed by the researcher considering the steps of teaching process (DPE-TM-CF-TP) and related design principles with these steps. For each cycles, in DPE, the researcher designed teaching process which includes: (1) lots of intentionally constructed multimodal representations and monomodal cohesive texts in order to immerse teachers into semiotically rich environment (DP1, DP2), (2) discussion and dialog oriented activities (DP3, DP4) which also present challenging tasks (DP6), that provide teachers with transforming of concepts and ideas from one mode to another (DP5, DP7), (3) information about the judgment criteria (DP8). Within the TM process, DPE is put into practice in different contexts. For each cycles, TM offered a challenging task which prompts discussion on available designs. Moreover, researchers made explicit instruction regarding the form and function of modes, patterns of text coherence and intermodal relations between modes. In TP, teachers were encouraged to design their own learning products within the same context by applying appropriately and within the different context by applying creatively. At the end of the activities, researcher evaluated their external representations, and gave feedbacks them in order to re-design. Feedbacks can be accepted as a component of TM, and re-designing can be accepted as an activity for TP in the perspective of applying appropriately.

At the end of both micro cycles, teachers' external representations were analyzed and interviews were made with them about their designs and their views on the the model. Findings revealed that teachers did not experience any difficulties in applying parameters of text coherence except embedding scientific process into the text and transforming scientific vocabulary to daily language while choosing from the available ones presented by the researcher.

Results also indicated that teachers gained slight tendency towards to select high level multimodal representations from available ones and to orchestrate different modes considering the appropriateness of subject and their aims in the teaching process. Even if teachers' views on their external representations showed that they were aware of intermodal relations and had intention to design these relations, it has seen that they maintain their habit of designing low level intermodal relations. Briefly, findings in the first micro cycles indicated that teachers were good at identifying and then selecting patterns of text coherence and high level multimodal representations, however they had difficulties in designing these on their own. They improved their representational competence skills of selecting, using, and designing. Two inferences can be made in here. The former, applying rules of text coherence in representations is easier than designing intermodal relations in these texts according to teachers. The latter, some refinements are required to improve the model and its principles. Those were determined by making interviews with participants and experts, and reviewing literature on the points they mentioned.

At the end of the micro cycle 1 and 3, findings showed that teachers gained abilities of identifying, describing and being aware of intermodal relations and text coherence patterns, but they were not good at design, a similar result was reported by Tolpanen, Rantaiinitty and Aksella (2016). They found that lessons on multimodal writing helped students to understand the importance of multimodal writing and increased the use of multimodal representations by them, however it was not sufficient for students to fully grasp in what ways different modes should be integrated.

Based on the interviews with the participants and experts and the data obtained, the necessity of making additions and revisions in the design principles of the model emerged. As a result of the data collected and interviews, revisions were made under four main headings. The former is that the challenge should be presented and improved step by step in a sequence, and some studies in the literature have emphasized that this can positively affect RC (Hubber & Tytler, 2017; Tytler et al., 2013b). Hubber and Tytler (2017) designed a lesson on Astronomy for eight grade students based on a sequence of representational challenges, the results indicated that students started to design more detailed and subject focused multimodal representations. As a result, the previous design principle was revised as below:

> *'Designers need to face increasingly difficult representational challenges, the level of scaffolding provided by teachers needs to decrease in parallel with increasing difficulty.'*

The latter issue is the emphasis that the self-assessment will contribute to improvement in RC. In the first iteration, since the teacher is the epistemic authority, the assessment provided by him was thought to be useful and sufficient. However, participants and experts thought self-assessment could be effective. Literature review also showed that this point may be important (Andersen & Munksby, 2018; Tolpanen, Rantainitty, & Aksela, 2016; Kohl & Finkelstein, 2005; Tippett, 2016). In line with participants' and experts' views, Kohl and Finkelstein (2005) found that students' self-assessment on the representations they designed while solving physics problems improved students' RC. Hence, the previous design principle was revised as below:

'Students should make self assessment of their multimodal representations with respect to the criteria of intermodal relations and text coherence, and then teacher should assess and give progressive feedbacks to the representations of students'

Another point emphasized in the findings is the subject of flexibility in the use of digital applications that enable students to design representations. Although the application tools were introduced to the participants, it was seen that this guidance did not provide them to use it effectively, so teachers should be lef flexible in using digital tools. And it was stated by the teachers that this flexibility would facilitate them in designing better representations. For instance, Ahmet stated that:

"I'm dealing with photoshop a little bit, could we design it with the tool we wanted and send it to you? Maybe we could use slightly different applications, so I think it might be better to be flexible about using apps."

Thus, a new design principle was added like that:

'Designers should be free to choose the applications in which they design multimodal representations.'

The latest change is that a handbook is needed because explicit instruction with multimedia tools such as video and animation creates difficulties in accessing available designs provided by the researcher. For instance, Zeynep stated that

"The videos and animations are prepared very well, thank you, if there is a written document in front of us, we can benefit from it, it is very difficult to find among the videos, so the return could be easier, it would be nice if it was a full text."

This situation showed that the learning styles of experienced teachers should be taken into consideration, so DPE should be enriched in terms of available designs. Hence, the previous design principle was revised as below:

'Teachers should present designed multimodal representations in different mediums, such as video, animation, and handbook in order to enrich the pedagogic environment.'

5.1.2 Discussion on Micro Cycles 3 and 4

DPE was strengthened, differentiated or enriched with: (1) presenting intentionally constructed multimodal representations in different ways such as handbooks (DP1, DP2) (Tippett, 2011), (2) presenting a sequence of representational challenge (DP6) (Hubber & Tytler, 2017; Tytler et al., 2013), (3) self assessment (DP8) (Andersen & Munksby, 2018; Kohl & Finkelstein, 2005; Tolpanen et al., 2016; Tippett, 2016) in these micro cycles. TM was enriched with live instruction and handbook additionally to available designs and feedback provided by the researcher. CF was extended by providing teachers with assessing their designs. TP was elaborated by eliminating applying appropriately, only focusing on applying creatively. TP was also differentiated by presenting tasks where the difficulty increases and the scaffolding decreases.

At the end of the micro cycles 3 and 4, teachers' external representations were analyzed and interview was made with them about their designs and their views on the model. Findings revealed that teachers did not experience difficulties in applying attributes of text coherence, but still they stated that the most difficult ones are transforming scientific language to daily language and embedding scientific process into the text. Results also indicated that while the rate of high level multimodal representations design increased, the rate of low level of them decreased. However, it is apparent that the increasing rate did not exactly refer to that they became representationally competent. Statements on their design should also be examined to understand why they used these types of intermodal relations. Their statements indicated that they were not only having abilities of designing different types of intermodal relations, but also they were able to identify types of intermodal mechanisms they established, and for what purposes they designed. They reported that their designs were generally about subject-concept specific and teaching purpose oriented. All these parameters indicated that teachers became representational competent. That is, they were equipped with the skills of identifying, describing, selecting or constructing, translating, assessing, and explaining multimodal representations appropriateness for a specific purpose.

In the light of the data obtained at the end of these cycles, it has been shown that the teachers are representationally competent. However, experts stated that it is necessary to apply these activities in other contexts again in order to be able to claim this inference accurately. Moreover, they were told that students should be able to not only make recommendations and criticize how well their own representations meet the claimed competencies, but also they should be able to assess other multimodal representations designed by peers. Furthermore, participants stated that interactions between participants can be improved because you learn better with your peers. Quotations can be found in the evaluation part of micro cycle 3 and 4.

In the light of all these views, the new literature review has been conducted and has been found that interaction will increase number of multimodal representation they are exposed to. That is, new representations will provide diversity in available designs, enable them to learn from each other, and increase dialogue and interaction will improve representation competencies (Danish & Phelps, 2011; Gebre & Polman, 2016; McDermott & Hand, 2013, 2016; Oz & Memis, 2018). As stated in the study of Danish and Phelps (2011), encouraging students to make peer assessment and to give feeedback to their peers while designing multimodal representations improved their representational competence skills. As interaction increased, students began to criticize each other's representations more, which resulted in better representations. In similar vein, Gebre and Polman (2016) pointed out that providing students with peer feedback while designing infographic based science news reporting enabled them to construct well-organized multimodal representations. Thus, one principle was revised again, and also a new design principle was added.

The revised principle is that:

'Evaluation of multimodal representations should be realized in three following steps: self-assessment, peer-assessment, and assessment by teacher.'

Added principle is that:

'Multimodal learning environment should provide some opportunities for interactions of designers during implementation.'

5.1.3 Discussion on Micro Cycle 5

The new iteration includes one micro cycle. DPE in this cycle: (1) was extended with many of well organized teacher curated multimodal representations in order to situate them into semiotically rich environment (DP1, DP2), (2) interaction was improved by encouraging peer to peer dialog instead of just teacher-student oriented (DP3, DP4, DP9), (3) was elaborated with peer-assessment (DP10) (Danish & Phelps, 2011; Gebre & Polman, 2016; McDermott & Hand, 2013, 2016; Oz & Memis, 2018). TM was enriched with feedback provided by peers. In CF, teachers were appointed to the role of assessing peers' artefacts. In TP, teachers were exposed to the most challenging task, they both assessed peers' representations, and enlightened their friends on how to improve these texts regarding intermodal relations and text coherence.

At the end of the micro cycle 5, analysis of participants about intermodal relations and text coherence, and their statements on peers' text were analyzed. Results indicated that teachers were not only able to identify and analyze adequacy of multimodal representations, but also able to criticize to what extent the representation reflects the intermodal relations and patterns of text coherence pointed. Moreover, they can advise their peers on what kind of relations and attributes they should use. Briefly, these parameters showed that teachers can be called as representational competent from now on.

All these findings indicated that participant teachers improved representational competence skills of being aware of, selecting, using, designing, and evaluating during and after the intervention.

5.1.4 Discussion on Overall Findings

5.1.4.1 Discussion on Teaching Process

The MpM and its design principles revealed as a result of all these micro cycles have expanded, detailed, and differentiated some approaches that express the aspects of the learning and teaching process with multimodal representations.

The DeFT (Ainsworth, 2006), which is among these studies, focused on what should be considered in learning with multiple representations and put forward some theoretical principles regarding this learning style. For example, the framework offers suggestions on which points should be considered while designing such as involving guidance on the number, mode, and sequences of representation. While all these contain information about what to do, there is no guidance on how to do it. On the contrary to the DeFT, the MpM explains *the parameters of how* to do it with practical principles and activities related to these principles. For example, the MpM explains the ways of increasing challenge, decraesing scaffolding, how intrinsic load on working memory can be decreased or increased, how awareness activities can be conducted, how design, self or peer assessment activities can be conducted. The MpM not only interests in number, mode, and sequences of representation, but also focuses on functions of modes and how these functions are realized through intermodal relations and text coherence.

Likewise, IF-SO proposed by Waldrip, Prain, and Carolan (2010) revealed what pedagogical principles of learning with multimodal representations, but it just emphasizes teachers. On the contrary, the MpM emphasizes all designers (teachers and students) since it accepts them all as active designers of their learning process. In a similar vein, Prain and Tytler (2012) suggested RCA which aims to explain how learning is enhanced with representations regarding the three dimensions of meaning: meaning-making as a semiotic process, meaning making at the epistemic level, and meaning making as an epistemological activity. Unlike RCA, the MpM also paid attention to cognitively explain how meaning is formed and how learning can be strengthened with the theoretical framework of Cattell-

Horn Carroll Cognitive Theories Based Multimodal Generative Learning Theory. The MpM also clarifies what types of meanings occur via intermodal relations, and how epistemic tools (modes) should be coordinated and designed in realizing different levels of epistemic activities. Thus, the model expanded and detailed RCA and provided guidance on how to make these meaning making activities in RCA.

The 'how of pedagogy', which was put forward by the New London Group (1996) and later developed under the title of 'Design by Learning' by Cope and Kalantzis (2000, 2015), assert principles about how teaching and its process should take place, and focuses on aspects of this environment.

Under the perspective but beyond all these studies, the MpM emphasizes the importance of expressing how the human mind works for an effective pedagogy. It focuses on how the information is encoded, how the data will stimulate the sensory and perceptual system, how the data is organized, associated and integrated in the working memory. It aims to explain how learning occurs with modes according to CHC-Based Multimodal Generative Learning Approach. In the light of cognitive load theory, which is an important part of this theoretical framework, the model tries to state how the intermodal interactions can be increased or decreased according to the student's level, and how the load on the working memory can be increased or decreased according to the student's level. It is thought that this perspective can contribute to researchers and teachers while designing the learning and teaching process. In parallel with other studies mentioned before, learning and teaching have been described as a 'design-designing' which refers to transformation of available multimodal representations to the new ones. The design processes that take place at each step of the model is explained with trialogue of Robert (1996, p.414). The trialogue tries to explain interactions between the elements of (D-TC-TR-SC-SR). Different from the IF-SO framework, the MpM added a new trialogue (D-SR-(TA-Teacher assessment, SA-Self assessment, PA-Peer assessment)) in order to improve interactions and interaction types in the learning environment.

5.1.4.2 Discussion on Learning with Multimodal Representations

In the context of the design concept, how learning takes place with multimodal representations is re-expressed with the ARDE (Awareness-Recognition-Design-Evaluation) framework. Unlike DeFT, IF-SO, and RCA, ARDE aims to increase awareness by exposing learners to well-organized representations by discussing the form and functions of multimodal representations, how they share meaning, whether they complement or constrain each other, and accounts for in which ways they complement or constrain each other. The recognition part is parallel to the tasks part of the DeFT and the form and functions part of IF-SO. The principles of what should be done in the DeFT are taken into account, and an extension was provided on how to do it, but unlike IF-SO, an explicit instruction was suggested instead of direct instruction. Explicit instruction refers to providing an appropriate level of scaffolding with students based on what the student realized before in the awareness part and what the student did not realize, and it was ensured that the questions emerged in awareness were answered. While the design part shows parallelism with IF-SO which proposes directing students to re-representation or transformation in a new context with a new challenge by being exposed to a new situation (applying creatively), here it was presented as a different approach to gradually increasing the challenge according to the student's level and gradually decreasing the scaffolding enabled by teachers. In this part, it is seen as an important element that the teacher provides progressive feedback. At last, in evaluation part, in addition to the assessment enabled by the teacher as an epistemic authority and the self-assessment of the student, a peer assessment was added differ from IF-SO, as it was found that it is important to evaluate the representations of others as an important step of RC.

How to transfer this whole learning process to the teaching process was explained through embedding and adapting the frameworks of the 'how of pedagogy', which was put forward by the New London Group (1996) and later developed under the title of 'Design by Learning Framework' by Cope and Kalantzis (2000, 2015), and ‘Design for Learning’ by Selander (2008).

DPE part was integrated with experiencing and setting part, TM part was integrated with primary transformation unit and conceptualising part, CF and TP parts were integrated with secondary transformation unit. All these have been tried to be expressed in an organized manner within the MpM model. In addition, unlike other studies, the principles of the teaching and learning process were expressed in different ways, as theoretically and practically. It is thought that all these will guide both researchers and practitioners about what to do and how to do it. Briefly, the MpM aims to provide teachers with guidance on how and in which ways to make their students representationally competent, how to learn with multimodal representations, and how to embed these learning processes into the teaching process.

At the end of the DBR, findings revealed that applying the MpM and its principles into the classroom environment improved RC skills (identify, describe, select, design, translate, analyze, evaluate, and explain appropriateness of representations to the subjects) of teachers.

There are some studies that show that teaching and learning practices similar to the design principles of this model also improve RC (Andersen & Munkby, 2018; diSessa, 2004; Enyedy, 2005; Gebre & Polman, 2016; Hubber et al., 2010; Lunsford, Melear, Roth, Perkins, & Hickok, 2007). In the study of Gebre and Polman (2016), they stated that minimising direct instruction on multimodal representations and as well as enabling a progressive oriented feedback refinement led students to design more complex representations than iconic or depictive representations. Their teaching practices also show similarities with the teaching process of the MpM. This method enabled students to participate in the design process with increasing difficulty as the MpM, yet it does not include the activities of transforming one mode into another and establishing intermodal relations between them. Hubber et al. (2010) indicated that putting the principles – (1) introducing multiple representations of force and motion unit, (2) supporting students to generate their own representations, (3) conducting explicit discussion on the adequacy of representations- into practice in designing multimodally rich force and motion unit enhanced students' RC. In a similar vein, McDermott and Hand (2016) also pointed out that immersing guided meaning making practices into learning environment positively impacted RC of students. These practices consist of similar principles as the MpM, such as having lots of opportunities to re-represent or transform representations into new ones through collaborative peer learning and teacher-guided discussion around adequacy of representations. In another study, Andersen and Munksby (2018) conducted a design based research and found that a didactic design with its three basic design principles provided students with gaining awareness of modes' affordances and designing digital multimodal representations. The design principles revealed by Andersen and Munksby's educational design research showed that providing dialogue among students, increasing interaction, presenting students' representations and giving feedback to each other have a significant impact on the development of representational competence.

In this study, the MpM model and principles revealed by educational design research showed that Andersen and Munksby's design principles may not be enough to make designers fully representationally competent, because these design principles do not focus on transforming one mode, which are important elements of RC, to another. Furthermore, just making discussion on the affordances of modes –such as, text for describing and sequencing events, image for visualizing and concretizing the events- may not raise awareness fully. The functions and forms of modes should also be understood, for what purposes they are used, they should be aware of the intermodal relations between them and how to increase or decrease the coherence within the representations.

It was seen that the design principles revealed by the studies mentioned above partially reflect the principles of the MpM, and it seems difficult to claim that RC, which covers a wide range from definition to design to evaluation, will develop with these design principles. Briefly, Gebre and Polman (2016) emphasized minimising direct instruction, enabling a feedback oriented progressive, and increasing difficulty; Hubber et al. (2010) stated introducing multimodal representations, generating their own representations, discussing about representations; McDermott and Hand (2016) indicated immersing students into multimodally rich environment, transforming of one mode to another, and peer assessment; Andersen and Munksby (2018) highlighted encouraging dialog and interaction between students.

All in all, although all these design principles partially reveal important elements of a multimodal pedagogical model, they seem inadequate to provide a comprehensive set of design principles. And most importantly, they cannot express the theoretical principles on which these principles to be applied in practice were created. This study elaborated, expanded and revized these design principles and tried to show which theoretical principles these practical design principles emerge as a result.

5.1.5 Impacts of the MpM on Representational Competence of Teachers

Numerous attempts have been made to enrich the teaching environment semiotically in this study. For instance, a large number of multimodal representations, which students can choose according to their interests, have been presented to them as videos, animations and textbooks. Thus, the teacher enriched the number of available designs by presenting them with different mediums. In order to pay attention of to the learners with these representations, attention was paid to presenting examples reflecting daily life. For example, vaccination and global warming were determined as subject titles. The first purpose of situating learners in such an environment was to enable learners to experience meaningful and orchestrated texts designed by the teacher, and provide them to realize how these representations convey meaning and how meaning is distributed among different representations. In all these immersed into activities, the learners were provided to experience multimodal representations spontaneously without being taught anything, they were asked to describe and identify what roles representations play in making meaning. Then, the teacher chose to teach the points that the students could not discern, with appropriate scaffolding, based on the points they could distinguish.

It can be said that immersing learners in such a rich multimodal environment led to improvement in their RC skills, especially in *identifying*, *selecting*, and *describing* skills. The findings show parallelism with other studies in the literature (Keles, 2016; McDermott and Hand, 2010, 2013; Hubber et al., 2010; Stieff, 2011; Tippett, 2016). In the study of Keles (2016), she stated that embedding multimodal representations in instructional methods had positive impacts on students' understanding of multimodal representations. In another study, Stieff (2011) indicated that including such tools in the learning environment in chemistry subjects improve students ability to identify features of representations and to explain why specific representation is appropriate for a particular purpose. Hubber et al. (2010) also found that exposing students to a representation-rich learning environment improve RC of students.

Another reason why teachers became representationally competent could be the discussions realized on the multimodal texts that they design and that the teacher designs and presents to them, since these discussions are about the properties, structure and function of representations, affordances and limitations of modes, how they are integrated with each other, for what purposes these integrations are made, and how and why teachers made these integrations in their own designs. It can be said that the discussions on all these parameters could have positive impacts on the important elements of RC, namely *defining*, *analyzing*, and *evaluating*. In parallel with this study, Daniellson and Selander (2016) told that realizing meta-textual discussions -including negotiations on general structure of representations, how different modes operate, and how they are combined to convey meaning- on multimodal representations in science textbooks affected RC of students in a positive way. Andersen and Munskby (2018) also revealed that discussions made on affordances of modes positively affected the abilities of *identifying* and *designing* multimodal representations. Moreover, Hubber and Tytler (2017) confirmed that conducting explicit discussion on form, function, and adequacy of representations provide students with build their meta-representational competence. Apart from these studies, diSessa (2004) and Kozma and Russell (2005) emphasized the importance of cooperative discussion between students-teacher and students-students on designing and describing multimodal representations.

Another reason why teachers' RC skills are improved could be that teachers were exposed to the representational challenge with increasing difficulty, increasingly being allowed to be autonomous in their designs, and the level of scaffolding is gradually decreasing.

The MpM realized this in the following order. First, all available designs were given to the teachers both as texts and images, they were asked to choose the ones they wanted according to their interests and to design their own multimodal representations. At the end of the design, explanatory feedback was given as scaffolding. Then, re-design was asked them. In the second step, a half-completed infographic was given to the teachers, they were asked to complete the missing parts by providing transformation between images and texts (image to text and text to image) and considering text coherence, and they were asked to redesign by giving semi-explanatory and questioning based feedback as scaffolding at the end of the design. In the third step, approximately twenty percent of the multimodal representation was presented to the teachers, and they were asked to design the remaining parts by making transformations between image and text and regarding text coherence. At the end of the design, questioning based feedback was given to enable them to re-represent. In the fourth step, the researcher only informed them about the subjects they could design and asked them to design multimodal representations by choosing the appropriate modes, integrating them, considering the intermodal relations between the modes and the text coherence. Finally, an questioning based feedback was provided by the researcher and the teachers were asked to edit their designs. Finally, teachers were asked to analyze the multimodal representations of their friends and to give explanatory feedback to their friends.

It can be said that all this increasing difficulty and decreasing scaffolding process directly affected skills of *selecting*, *designing*, *translating*, and *evaluating*, which are the important components of RC, and indirectly affected other elements in a positive way. It can be claimed that this process resulted in an improvement in RC, as it made teachers motivated when they were successful and led them to autonomy in the learning process by increasing their independence. As stated by

Waldrip et al. (2010), experiencing independency and being active in designing, manipulation, and revising multimodal representations; and also facing representational challenges played imperative roles in enhancing RC skills of students. Hubber and Tytler (2013) indicated that providing students with a sequence of representational challenge in astronomy subject resulted in using representational vocabulary competently.

The other reason for the development of RC could be that the model offered important opportunities in terms of transforming modes to each other. These transformations refer to the conversion of the available designs provided to them into a new representation according to their interests (Jewitt, 2003; Kress, 2010). From the perspective of CHC-Based Multimodal Generative Learning Approach, this seems to be a very complicated process in which learners have to activate a broad range of their cognitive structures during internalization and externalization (Schnotz & Iowe, 2003).

Intermodal transformation activities are an important element in a design-oriented and multimodal-based teaching, since these activities encourage the learners to think about the intermodal relations between the modes, and the structure and functions of the modes. Therefore, a large number of design activities were conducted in all four micro-cycles. It can be claimed that these activities could be effective in improving RC skills, as they were deeply exposed to the meaning-making process (Kress & Selander, 2012; Selander, 2008).

On the contrary of the present study, Yeo et al. (2021) conducted an experimental study and they found that there is no statistically significant difference between experimental group (inquiry based instruction based on to image to writing approach) and control group (a mix of direct instruction and inquiry activities without explicit focus on multimodal representations), however experimental group scored higher in terms of RC in the post-test. The difference in the result could stem from two reasons. First, it may be due to the fact that researchers in this study used only some of the RC criteria suggested by Kozma and Russell (2005). Kozma and Russell mentioned five basic RC abilities: the ability to use representations symbolically and depictively, the ability to contruct syntactically correct scientific explanations, the ability to produce semantically coherent and complete explanations, and the ability to explain the affordance and purpose of representations. Yeo et al. (2021) determined the representation competencies of the participants with a rubric that took into account the first four of these features. From this point of view, it can be argued that they did not find any improvement in RC because they did not measure other basic features of RC such as identifying, selecting, and analyzing. The latter reason could have originated from the method of image to writing approach which does not include awareness, identification, and evaluation activities, and lacks adequate design process opportunities. This is emphasized by Airey and Linder (2009, 2017) as follows. Repetition and working with representations constantly provide students to gain fluency in their representations and in transducting between modes. However, there are some studies that found similar results as in this study. For instance, Pérez Echeverría et al. (2010) revealed that enabling students with frequent opportunities to transform one mode to another improved their RC skills. Waldrip and Prain (2012) also stated that advancement of representational competence was realized through representational passes done by designers since opening up the opportunitİes for thinking on how representations are integrated. In another study, Keles (2016) and Tippett (2011) pointed out that applying multimodal based teaching approaches which include transformation activitİes help students to comprehend aspects of multimodal representations. In line with this study, Gunel et al. (2016) asserted using non-traditional writing task embedded with multiple modes of representations resulted in improved RC skills, since these tasks provide opportunities for learners to translate between different modes.

Briefly, it could be claimed that RC skills of teachers are improved as representational passes activities in the MpM include making selection, decision making, designing, explaining appropriateness, and tranduction processes.

Providing opportunities for learners to evaluate both the competencies of their own representations and the representations of their friends could be the other reason for the improvement of RC. At the end of each activity, the participants were asked to evaluate the adequacy of their own representations, and discussions were held on why they designed such multimodal representations in one-on-one interviews. Moreover, when teachers reach a certain competence level, they were asked to evaluate the representations of their peers and to give explanatory feedback on how they could do better (Cope & Kalantzis, 2015; Lim, 2018; Selander, 2008; Waldrip et al., 2010). Encountering with multimodal representations designed by peers has also enabled the opportunity to learn from others, and the richness of available designs has thus increased. It can be asserted that these activities lead to improvements in RC as they familiarize teachers with the analysis and explanation elements of RC skills. Andersen and Munksby (2018) reached a similar conclusion in their educational design research and even added this pattern among the didactic principles of the approach they proposed. They stated their design principle as follows: "…reflect on and evaluate these (multimodal representations) on the basis of known assessment criteria…" In similar vein, Tolpanen, Rantaiinitty and Aksela (2016) conducted a series of activities, which were applied in the following order. First, they distributed a written text to the learners and asked them whether this text was competent to convey the meaning; the latter, they are asked what can be done to improve; as a third asked them to examine how the meaning is conveyed by looking at different sources, and to create a rubric so that they could evaluate them, and forthly asked them to examine other sources according to this rubric; and finally asked the participants to design a multimodal text. They found that this practice increased students' awareness towards the use of multimodal representations.

Explicit instruction about intermodal relations and text coherence could be the other reason for the development of RC. It includes all parameters mentioned above. Explicit instruction refers to informing learners about multimodal representations and guiding them to design these texts, and sometimes explicit instruction is required to know conventions of representations. Through explicit instruction, researcher has strived to present a science toolkit regarding multimodal representations. It has also been stated in other studies that explicit instructions enhance RC. For instance, Nam and Cho (2016) conducted an experimental study in which experimental group were exposed to an instruction method including recognition process about multimodal representations, and control group were exposed to direct instruction. Results showed that learners in the treatment group were better at designing multimodal representation than control group. Similar results have been reported by other studies (Chandrasegaran et al., 2008; Gee, 2005)

All in all, the study concluded that applying the MpM with its theoretical or practical principles in different contexts had positive impacts on improving representational competence of teachers.

5.1.6 Discussion on Teachers' Views and Perceptions

Interviews were done with teachers in order to reveal their views about which difficulties they experienced during the training program, the MpM model, its teaching process, what purposes it serves in teaching and learning process, and whether there is a change in perceptions on multimodal representations. Findings showed that common difficulties experienced by teachers is generally about the design process. They indicated that embedding scientific process by emphasizing hypotheses, research questions, data, and justification of the results into multimodal text is very challenging for them.

The researcher claims that the problem could have originated from three main reasons. The former, it could be due to the fact that they are not sufficiently exposed to such texts, because the available sources provided to them do not pay attention to these elements and often contain descriptive and authoritative text types (Kloser, 2016; Phillips & Norris, 2009). The latter could be stemmed from difficulties emerging from the nature of constructing scientific explanation which requires a particular body of knowledge and scientific process skills (Simon, Erduran, & Osborne, 2006; Izquierdo-Acebes, 2020). The last is about lack of proper pedagogy about this concerns. Teachers also stated that designing augmentation and interpretational multimodal representations. This result is not surprising, and but also these views could be accepted as a verification, because both of them are the most difficult ones regarding types of intermodal relations

(Keles, 2016; Tippet, 2011). The other challenge experienced by teachers was about use of digital tools. Although detailed instruction about use of these tools was given, they insisted on to being free in use of instructional technology. In this context, it was seen that adaptation to new teaching technologies is more challenging and more demanding for them. This can be due to that teachers do not have self-efficacy to use new digital instructional technologies (diGregorio & Liston, 2018), or the problem can be about having persistent beliefs on their effectiveness of current practices (Ertmer, 2005) and lack of technological pedagogic content knowledge (Thompson & Mishra, 2007).

Teachers views on the model and its teaching process revealed that they are all positive to apply this model in their instructional methods because of the purposes –improving students' engagement and interest, presenting challenges, enabling interaction, increasing motivation, encouraging individuality and creativity, impact their students' learning products- it serves in classroom environment of gifted. Applying teaching process around independency, designing, increasingly improved challenge and decreasing scaffolding, the nature of intermodal relations (which activetes each parts of Bloom's cognitive taxonomy) designed in multimodal texts and text coherence patterns could have impacted teachers to hold these views (Kim, 2017; Lim, 2011; McDermott & Hand, 2013; Treaugust, 2007). Moreover, when teachers were asked to what motivate them to participate and continue in this type of training program, they stated that the training program points the real need which is also determined by many of studies in the literature (Cope & Kalantzis, 2015; Kuo et al., 2017; Selander & Kress, 2012).

Teachers were asked also about whether there is a change in their perceptions about multimodal representations. They stated in a consensus that they gained self-criticism towards selecting available multimodal representations in textbooks and online digital environments, and also designing new ones in both settings. The critical view towards multimodal representations also indicates gained in awareness towards these texts, that is improvement in RC.

5.2 Implications and Recommendations

The dissertation has implications both theoretically and pedagogically. First, it proposes two analytical frameworks regarding intermodal relations and text coherence for multimodal representations. These frameworks can serve as a metalanguage for scholars, teachers, and text designers. The metalanguage guides researchers to investigate teachers', students', and text designers' choices about modes and patterns of text coherence while they are designing multimodal representations such as presentations, infographics, textbooks, video, and etc. In other words, the metalanguages can be used for developing explicit and observable criteria in order to examine other multimodal artefacts. In this way, they can examine the multimodal nature of representations. Such a metalanguage can also be used by instructors and text designers to understand intermodality mechanisms between images and texts and text coherence in written texts, and it enables them to make meaningful choices regarding these issues (Jewitt, 2008; Tang, 2016). If teachers are provided with these frameworks, they can improve a deeper comprehension of multimodal texts (Daniellson & Selander, 2016). Moreover, although there are many anaytical frameworks to analyze multimodal representations (Ainsworth, 2006; Ge et al., 2018; Meneses, et al., 2018; Prain, Tytler, & Peterson, 2009; Tang, 2016; Tang et al., 2014; Wilson & Bradbury, 2016), none of them specifically deal with intermodal mechanisms and attributes of text coherence. Having such a framework would be an important breakthrough in designing multimodal representations towards the goals teachers strive to achieve in the classroom environment, such as participation, discussion, interaction and questioning. Moreover, since there is no agreed upon measurement method of RC (deVries & Lowe, 2011), these frameworks serve as a tool to measure RC levels of designers. Furthermore, frameworks can guide textbook designers about certain points that ought to be considered in the designing process: image-text relations and attributes of text coherence.

Second, the present study proposes a new approach to the studies of learning with multimodal representations, as ARDE. Despite many studies on learning with representations (Ainsworth, 2006; Prain & Tytler, 2012; Waldrip, Prain, & Carolan, 2010;), there is no widely accepted model on this issue (Tippett, 2011). In this respect, ARDE expands and differentiates these studies emphasizing awareness activities, explicit instruction, explanatory and questioning-oriented feedback, increasing the challenge step by step-decreasing the scaffolding, and peer assessment. Third, the dissertation offers CHC-Based Multimodal Generative Learning Approach which explains how learning occurs with modes from the perspective of multimodality and cognitive theory. The theory aims to explain how the information is encoded, how the data will stimulate the sensory and perceptual system, how the data is organized, associated and integrated in the working memory. Moreover, it explains how the intermodal interactions can be increased or decreased according to the student's level, and how the load on the working memory can be increased or decreased according to the student's level.

Forth, the MpM model was proposed as a teaching method by combining and adapting lots of theories like Cognitive Load Theory, Generative Learning Theory, Cattle-Horn-Carroll's Cognitive Theory, Multimodal Learning Theory, and framework of learning with representations. The MpM differs from other models by explaining *how of pedagogy* with its practical principles and activities. Finally, the dissertation extends literature by enriching and categorizing design principles of multimodal based teaching theoretically and practically. It claims that specifying the theoretical principles from which the practical principles are built will provide a more comprehensive explanation and more meaningful guidance to researchers and practitioners.

As pedagogical implications, the model designed in this study can potentially benefit teachers in using multimodal representations designed with respect to criteria of intermodal mechanisms and text coherence to support the teaching and learning process. In this respect, this model and its theoretical and practical principles would be an effective starting point for further improvement in multimodal-based pedagogical interventions. Also, understanding the concurrent and complementary relationship between modes can provide teachers to engage, enthuse, educate the students, and realize disciplinary specific classroom discourse more effectively (Prain & Waldrip, 2006). The identification of teaching and learning process from above mentioned frameworks and designing its core principles may contribute useful knowledge on experimental research in different contexts (Fernandez-Fontecha et al., 2019). Comprehending the dynamic nature of multimodal representations, in which ways and for what pedagogical purposes these are designed, allowed teachers to make correct decisions on how to select and design these texts in ways that improve students' learning (Jaipal, 2010). These enhanced understanding would result in improvements in teaching materials, classroom practices, and teaching methods (Tippett, 2011). Making intermodal relations and text coherence explicit to the teachers decreases semantic divergence originated from arbitrary design of representations, which generally brings about misconceptions (Lim, 2011). Sensitising the teachers toward to the use of pedagogical aim specific intermodal relations via training program would be helpful to them to design appropriate pedagogy for their students, whether they are gifted or need special support. Furthermore, the model designed in this study can inform future studies on learning with multimodal representations which integrate cognition, SFL, multimodality (Tang, et al., 2014). It could be a preliminary stage for these types of models. Since increasing availability of multimodal representations in the digital learning environment, teachers have opportunities to teach their lessons with these text. Hence, the model can guide them in their instructional process.

Future studies should be conducted as educational design researches in different contexts to not only teachers but also students in real, digital, or blended learning environment in order to verify effectiveness of model in improving RC. Since multimodal meaning is not only realized through image and text in classroom discourse, further research is needed to improve measurement tool of RC (analytical frameworks), not only considering image and text, but also other modes such as gesture and spoken language.

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A
PRE-INTERVIEW QUESTIONS

1. Bir konuyu, kavramı (örneğin: küresel ısınma, fotosentez, su döngüsü, seri ve paralel bağlama) anlatmadan önce gösterimlerinizi hazırlarken veya tasarlarken nasıl bir plan yaparsınız?
   a. Gösterim/mod türlerini nasıl belirlersiniz?
   b. Nasıl bir sıra oluşturursunuz?
   c. Öğrencilerinizin bilişsel seviyesine ne ölçüde dikkat edersiniz?
   d. Gösterimleriniz bir zorluk/challenge sunar mı? Nasıl?
2. Sınıftaki etkileşimi ve öğretimi artırmak için temsiller ve sunumlar seçerken veya tasarlarken hangi stratejileri ve ilkeleri düşünüyorsunuz ve dikkate alıyorsunuz?

   Sunumunuzun/gösterimlerinizin/temsillerinizin olmazsa olmazları şunlardır, dediğiniz ilkeler nelerdir? Karakteristik özellikleri nelerdir?

   Ya da ebayı açıp öğrencilere bir temsil gösterdiğinizde bunları seçerken nelere dikkat edersiniz?
3. Öğrencilerinize bir konuyu öğretmek için sadece yazıdan oluşan bir kitap sayfası verdiğinizi düşününüz. Bir kavramı yalnızca yazıyla öğretirseniz, metnin ne tür özelliklere sahip olmasına dikkat edersiniz?

   Bu metni siz nasıl yazarsanız daha öğretici olur? Öğrenci daha iyi anlamlandırır? Sorgulatıcı bir metin nasıl tasarlarsınız? Metin 1 ve Metin 2'ye bakınız? Metin 3 ve Metin 4'e bakınız? Metin 5 ve Metin 6'ya bakınız? Sizce nasıl farklılaşıyor? Niçin?

1 Pankreas

Pankreas, mide ile ince bağırsağın ilk kısmı arasında yer alan üçgen bir organdır. Pankreas, vücutta birçok rol oynar. Örneğin pankreas, ince bağırsağa dökülen ve nişastaları, proteinleri ve yağları parçalamaya yardımcı olan enzimler üretir. Enzimler, biyokimyasal reaksiyonların daha kolay ve genellikle çok daha hızlı gerçekleşmesine yardımcı olan proteinlerdir. Pankreas ayrıca hormon salgılar. Hormonlar, kan dolaşımından geçen ve vücudun diğer kısımlarını etkileyen küçük moleküllerdir. Hormonlar, onları tanıyan ve bu hücrelerin ve organların çalışma şeklini etkileyen belirli hücreler üzerinde etkiye sahiptir. Pankreasın ürettiği bir hormona insülin denir. İnsülin, Langerhans Adacıkları adı verilen özel pankreas hücrelerinde üretilir. İnsülin daha sonra kan dolaşımına salınır ve karaciğer ile kas hücrelerine gider. İnsülin, bu hücrelerin şekeri almasına ve enerji için kullanılabilmesi için depolamasına yardımcı olur.

Diyabet ve Vücutta İnsülin Kullanımı

Diyabet, milyonlarca insanı etkileyen bir durumdur. Şeker hastası olan kişilerde ya yeterli insülin üretmeyen bir pankreas vardır ya da vücut hücreleri insülini düzgün kullanamaz. Sonuç olarak, diyabetli bir kişinin kanda yüksek şeker seviyeleri vardır ve hatta idrarda şeker bile salgılayabilir. Aslında, yüzlerce yıl önce, şeker hastalığı olan insanlar tatlı kokulu idrarlarıyla tanımlanıyordu.

Diyabetli bireyler genellikle yedikleri şeker miktarını sınırlayan diyetlere sahiptir çünkü vücutları onu parçalayamaz. Kullanılmayan şeker vücudu idrarda bırakır ve enerji için kullanılamaz. Tedavi edilmezse, diyabetli kişiler kilo değişikliği yaşarlar, zayıf hissederler ve genellikle aç hissederler. Ayrıca şeker hastaları, böbrekler vücuttaki fazla şekeri atmaya çalışırken sık sık idrar yapabilir ve susayabilir. Diyabetin uzun vadeli etkileri ciddidir ve körlük, böbrek yetmezliği ve kalp hastalığını içerebilir.

İki ana diyabet türü vardır. Tip I diyabet genellikle çocuklukta veya erken yetişkinlikte başlar. Tip I diyabette, pankreas çok az insülin üretir veya hiç üretmez. Bu rahatsızlığı olan kişiler, bazen sağlıklı kalmak için vücutlarına insülin enjekte etmek için bir iğne kullanmalıdır. Tip II diyabet genellikle yetişkinlik döneminde gelişir. Bu durumda pankreas yeterince insülin üretmez veya vücut hücreleri mevcut insüline normal yanıt vermez. Tip II diyabet hastaları, uygun beslenme, kilo kontrolü ve egzersiz yoluyla semptomlarını kontrol edebilirler.

2 Pankreas kan şekerini nasıl kontrol eder?

İnsanlar diyabeti yüzlerce yıldır biliyorlar. Uzun zaman önce, şeker hastaları vücutlarında fazla miktarda kullanılmayan şekerin neden olduğu tatlı kokulu idrarlarıyla tanımlanıyordu. Bu hastalık, hücreleri kandan şeker alamayan ve enerji için kullanamayan milyonlarca insanı etkilemiştir. Diyabet kilo değişikliğine, halsizliğe ve sürekli açlığa neden olabilir. Zamanla diyabet körlüğe, böbrek yetmezliğine ve kalp hastalığına neden olabilir.

1889'da Joseph von Mering ve Oskar Minkowski adlı iki bilim adamı, mide ve bağırsaklara yakın bir organ olan pankreasın vücudun enerji için şeker kullanmasına yardımcı olabileceğine inanıyordu. Bilim adamları, pankreas hayvanların enerji için şeker kullanmalarına yardım ederse, pankreası olan bir hayvanın kanında düşük miktarda kullanılmamış şeker bulunurken, pankreası olmayan bir hayvanın yüksek miktarda kan şekeri olacağı ve diyabet geliştireceği sonucuna vardı.

Bilim adamları, pankreasın vücudun enerji için şeker moleküllerini kullanmasına yardımcı olduğunu öğrendikten sonra, bunun nasıl gerçekleştiğini bilmek istediler. Frederick Banting ve Charles Best, pankreasın, hücrelerin şekeri almasına ve kullanmasına yardımcı olmak için diğer hücrelerin işlevini etkileyen küçük bir molekül olan bir hormonu kana saldığına inanıyordu.

Hipotezlerini test etmek için Banting ve Best bir deney yaptı. İlk olarak, bilim adamları pankreası birkaç köpekten çıkardı. Beklendiği gibi, bu köpeklerin kan şekeri seviyeleri normal % 9'dan çok daha yüksekti.

Sonra, pankreas içindeki sıvıyı aldılar. Bu sıvı, hücrelerin şekeri almasına yardımcı olmak için salınabilen pankreastan küçük moleküller içeriyordu. Bilim adamları bu sıvıyı diyabetik köpeklerin damarlarına iğne ile enjekte etti. Pankreastaki moleküllerin kan şekeri seviyesini etkileyip etkilemediğini görmek için köpeklerin kan şekeri seviyelerini tekrar ölçtüler. Kan şekerinin normal seviyesinde olduğunu gözlemlediler.

Bilim adamları, pankreastan enjekte edilen moleküllerin köpeklerin kan şekeri seviyelerini kontrol etmesine yardımcı olduğunu gördüler. Bu, Banting ve Best'in, pankreasın diğer hücrelerin enerji için kullanılabilen kandan şeker almasına yardımcı olan hormonları salgıladığı hipotezini destekledi. Beş yıl sonra hormon izole edildi ve insülin olarak adlandırıldı. İnsülin artık yapay olarak üretiliyor ve bazı şeker hastaları kan şekeri seviyelerini kontrol etmek için kendilerine insülin enjekte ediyor.

Metin 3

Dolaşım sistemi, ısının vücutta dağılımından sorumludur. Bu hem sıcakkanlı hem de soğukkanlı hayvanlar için geçerlidir. "Sıcakkanlı" terimi, vücut sıcaklıklarını çevrelerindekinden daha yüksek tutabilenlere verilen bir addır. Kuşlar ve memeliler örnek olarak verilebilir.

Ancak bu her zaman böyle değildir; bazıları, örneğin kış uykusuna yatanlar sıcaklıklarının ortam sıcaklığına yakın olmasına izin verir. Ve bunlardan bazıları da, örnek olarak tropikal savanadaki memeliler, vücut sıcaklıklarını yaşamlarını sürdürmek için çevredeki kavurucu sıcaklıkların altında tutarlar. ancak, kuşlar ve memelileri, hayvanlar aleminin geri kalanının çoğundan ayıran iki özellik vardır:

Ortam sıcaklığı ne olursa olsun vücut sıcaklıklarını dar sınırlar içinde tutarlar. Bu nedenle genellikle homeotermik olarak tanımlanırlar.

Endotermiktirler; vücut ısısını korudukları ısı vücutta üretilir. Bazı soğukkanlı hayvanlar, örneğin güneşin tadını çıkaran kertenkeleler, kuşlarınki kadar yüksek vücut sıcaklıkları geliştirirler, ancak bunlar ektotermiktir; dışarıdan bunu yapmak için ısıyı korurlar.

Metin 4

Dolaşım sistemi, ısıyı bir hayvanın vücudundaki kan damarları yoluyla dağıtır. Bu sistem, hem sıcakkanlı hayvanlar hem de soğukkanlı hayvanlar için ısı taşınmasından sorumludur.

Sıcakkanlı hayvanlara kuşlar ve memeliler, soğukkanlı hayvanlara sürüngenler, amfibiler ve balıklar örnek olarak verilebilir. Sıcakkanlı terimi vücut sıcaklıklarını çevrelerinden daha yüksek tutabildikleri ve genellikle bunu yapabildikleri için kuşlara ve memelilere verilen bir addır.

Ancak bu her zaman geçerli değildir çünkü bazı sıcakkanlı hayvanlar -örneğin kış uykusuna yatanlar- kış uykusuna yattıklarında vücut sıcaklıklarının çevrelerindeki havanın sıcaklığına yakın olmasına izin verir.

Tropikal savanların sıcağında yaşayan memeliler de, vücut sıcaklıklarını her zaman çevredeki sıcaklıktan daha yüksek tutmayan sıcakkanlı hayvanların bir başka örneğidir. Bu hayvanlar genellikle vücut sıcaklıklarını çevrelerindeki kavurucu sıcaklıkların altında tutmak zorundadır.

Bununla birlikte, sıcakkanlı hayvanları, hayvanlar aleminin geri kalanının çoğundan ayıran iki özellik vardır:

1. Sıcakkanlı hayvanlar homeotermiktir. Yani diğer hayvanlardan farklı olarak kuşlar ve memeliler vücut sıcaklıklarını çevreleyen (veya ortam) sıcaklık ne olursa olsun vücut sıcaklıklarını dar sınırlar içinde tutarlar.

2. Sıcakkanlı hayvanlar endotermiktir. Endotermik hayvanlar, vücut ısısı dış kaynaklardan gelen ısı ile korunan soğukkanlı hayvanlardan farklıdır. Bu nedenle güneş altında güneşlenen kertenkeleler gibi bazı soğukkanlı hayvanlar, kuşlarınki kadar yüksek vücut sıcaklıkları geliştirseler de, bu canlılar vücut ısılarını dışarıdan korurlar. Bu tür hayvanlara ektotermik denir.

Metin 5

Karbon Döngüsü Sürecinde Gerçekleşen Olaylar

1.Emisyon: Karbon emisyonu, karbon içerikli yakıtların oksijnle tepkimeye girmesi sonucu açığa çıkan karbondioksit gazının atmosfere yayılmasıdır.

2.Fotosentez: Yeşil bitkilerin ışık enerjisini yakalayarak kimyasal enerjiye dönüştürmesi olayına fotosentez denir.

3.Solunum: Canlılar metabolizma faaliyetlerini sürdürmek için enerjiye ihtiyaçları vardır. Bu enerji hücrelerde glikozun oksijenle kimyasal reaksiyona girmesi, bunun sonucunda karbondioksit, su ve enerji olarak çıkması ile elde edilir. Bu olaya da solunum denir.

4.Ayrışma: Ölmüş organik yapıların ayrıştırıcılar tarafından inorganik yapılar haline getirilmesi sürecine ayrışma denir.

5.Fosilleşme: Ölüm sonrası meydana gelen çürüme sonucunda canlıların sert kısımlarının tortullara kaplanıp mineralleşmesine fosilleşme denir.

Metin 6

Karbon Döngüsü Sürecinde Gerçekleşen Olaylar

1.Emisyon: Karbon emisyonu (*salınımı*), karbon içerikli yakıtların (*fosil yakıtlar: petrol, doğalgaz, kömür vb*) oksijnle tepkimeye girmesi (*yanması*) sonucu açığa çıkan karbondioksit gazının atmosfere yayılmasıdır.

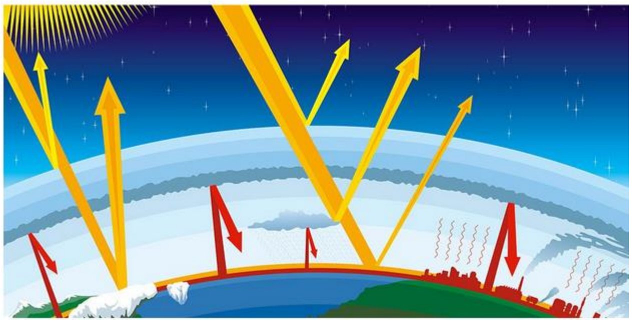
2.Fotosentez: Yeşil bitkiler kökleriyle topraktan su ve mineral, gövde ve yapraklarıyla atmosferden karbondioksit, ve güneşten ışık enerjisini alırlar. Bu enerjiyle karbondioksit ve su molkeüllerini önce ayırıp, sonra birleştirerek besin (*glikoz-şeker*) ve oksijen üretmesi olayına fotosentez denir.

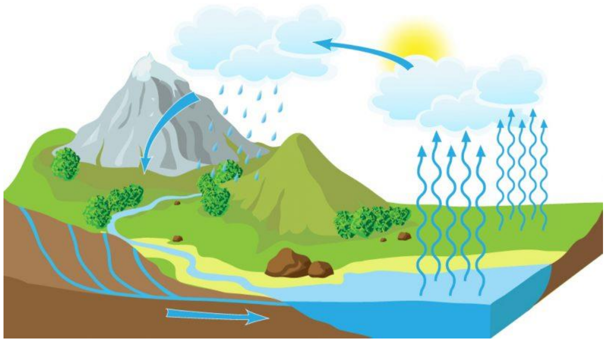
3.Solunum: Tüm canlılar metabolizma (*yaşamsal*) faaliyetlerini sürdürmek için enerjiye ihtiyaçları vardır. Örneğin, sindirim ve boşaltım. Bu enerji hücrelerde glikozun (*şekerin*) oksijenle (O_2) kimyasal reaksiyona girmesi (*yanması*), bunun sonucunda karbondioksit (CO_2), su (H_2O) ve enerji (ATP) olarak çıkması ile elde edilir. Bu olaya da solunum denir.

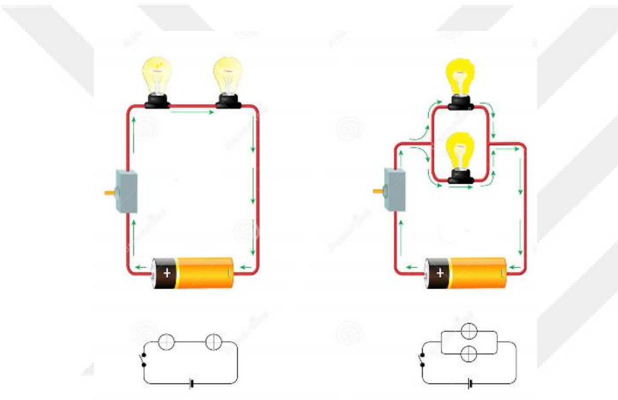
4.Ayrışma: Ölmüş organik (*C,H, ve O'den oluşan*) yapıların ayrıştırıcılar (*bakteri ve mantar*) tarafından inorganik (*mineral ve vitamin*) yapılar haline getirilmesi sürecine ayrışma denir.

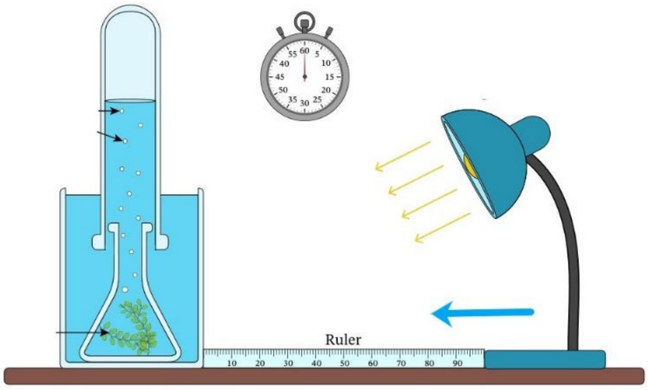
5.Fosilleşme: Ölüm sonrası ayrıştırıcılar tarafından çürütülen canlının sert kısımları (*iskelet*) tortullara (*kum ve tuz*) kaplanarak mineralleşmesine (*kabuğun yapısında bulunan minerallerle etrafında bulunan kalsiyum ve demir gibi minerallerin birleşmesi*) fosilleşme denir.

4. Bir kavramı sadece resimlerden oluşan bir metin/kitap sayfası ile gösterseniz öğretici olması için/daha iyi anlamlandırabilmeleri için nelere dikkat edersiniz? Resmin hangi özelliklerine sahip olmasına dikkat ederdiniz?
Resim 1, 2, 3 ve 4'e bakınız.









a. Resimler sizce farklı amaçlara hizmet ediyor mu? Nasıl?
b. Birinci resim tek başına küresel ısınma olayını anlatabilir mi? Neden? Siz olsanız nasıl yapardınız?
c. İkinci resim su döngüsü olayını tek başına anlatabilir mi? Neden? Siz olsanız nasıl yapardınız?
d. Üçüncü resim ampul parlaklığını etkileyen bir faktörü anlatabilir mi? Siz bunu kullanır mıydınız?
e. Dördüncü resim fotosentezi etkileyen bir faktörü anlatmak için kullanılabilir mi? Nasıl? Siz olsaydınız nasıl tasarlardınız?
f. Bu dört metinden hangisi/hangileri sizi daha çok sorgulattı?
g. Bu dört resim sizce farklı sınıflara/kategorilere ayrılabilir mi? İsimlendirir misiniz?
h. Eğer farklılarsa daha önce resim türlerinin bilişsel seviyeye göre farklılaştığını farkında mıydınız?

B
MID-INTERVIEW QUESTIONS

1. Sizce aktiviteler süresince uygulayıcıların ve katılımcıların üstlendikleri roller (araştırmacı, geliştirmeci, bilgi alan ve veren, tasarımcı, işbirlikli katılımcı) ve sorumluluklar istenilen tasarım hedeflerine ulaştırmada yeterli midir? Daha farklı neler yapılabilir?
2. Süreç içince yaşadığınız zorluklar nelerdir? (zaman yönetimi, program kullanımı, bağlantı, aktiviteler ve tasarlanma şekilleri) Bu zorlukları aşmak için neler yaptınız?
3. Aktivite tasarlarken sizin katılımınızı ve tasarımınızı zorlayan etkiler nelerdir? Yapmak istediğinizle yaptığınız arasında ne gibi farklılıklar var? Sürecin uygulanmasında sizin katılımınız en olumlu etkileyen etmen nedir?
4. Uygulamada kullanılan araçlar tasarım hedeflerine ulaştırmak bakımından ne derece etkili buldunuz? Etkisiz yanları nelerdir?
5. Araştırmacıların planladığı tasarım aktivitelerini içerik açısından değil de işlevleri açısından (farkındalık, tanıtma, açıktan öğretim, tasarım) ne derece etkili buldunuz?
6. Sizce tasarım aktiviteleri nasıl farklı veya etkili yapılabilirdi?
7. Bu aktiviteler yazı içi ve yazı görsel arasın anlamsal ilişkileri tasarlamada ne derece etkili, gelecekte yapılacak aktiviteler için sürekliliğe sahip midir neden neler tekrardan düzenlenmelidir?
8. Bu bizim yazı içi anlamsal ilişki için tasarladığımız ilk aktivite (fotosentez) anlamsal ve bilgisel olarak düşük ve yüksek metinler çeşitli anlam ilişkileri kullanmışsınız?
9. Hangi yazı-görsel arası anlamsal ilişkiyi tasarladınız bunu nasıl gerçekleştirirdiniz? Bu anlamsal ilişkisi nasıl güçlendirebilirdik?
10. Hangi yazı-görsel arası anlamsal ilişkiyi tasarladınız bunu nasıl gerçekleştirirdiniz?
11. Sizce bunlardan hangilerini kullanırsak daha interaktif ve sorgulatıcı olur sınıf ortamı öğrencilerle iletişimiz?
12. Bundan sonra bir platformdan sunum/gösterim seçerseniz nelere dikkat edersiniz?
13. Sizce aktiviteler süresince uygulayıcıların ve katılımcıların üstlendikleri roller (araştırmacı, geliştirmeci, bilgi alan ve veren, tasarımcı, işbirlikli katılımcı) ve sorumluluklar istenilen tasarım hedeflerine ulaştırmada yeterli midir? Daha farklı neler yapılabilir?
14. Araştırmacıların planladığı tasarım aktivitelerini içerik açısından değil de işlevleri açısından (farkındalık, tanıtma, açıktan öğretim, tasarım) ne derece etkili buldunuz?

15. Uygulamada kullanılan araçlar tasarım hedeflerine ulaştırmak bakımından ne derece etkili buldunuz? Etkisiz yanları nelerdir?
16. Bu aktiviteler yazı içi ve yazı görsel arasın anlamsal ilişkileri tasarlamada ne derece etkili, gelecekte yapılacak aktiviteler için süreklili̇ğe sahip midir neden neler tekrardan düzenlenmelidir?
17. Aktivite tasarlarken sizin katılımınızı ve tasarımınızı zorlayan etkiler nelerdir? Yapmak istediğinizle yaptığınız arasında ne gibi farklılıklar var? Sürecin uygulanmasında sizin katılımınız en olumlu etkileyen etmen nedir?

C
POST-INTERVIEW QUESTIONS

1. Bir konuyu anlatmadan önce o konuyla ilgili metinlerinizi hazırlarken nasıl bir plan yaparsınız? Nasıl bir sıra oluşturursunuz? Metinleriniz bir zorluk/challenge sunar mı? Nasıl? Öğrencilerinizin bilişsel seviyesine ne ölçüde dikkat edersiniz?
2. Öğrencilerinize bir konuyu öğretmek için sadece yazıdan oluşan bir kitap sayfası verdiğinizi düşününüz. Bir kavramı yalnızca yazıyla ögretirseniz, metnin ne tür özelliklere sahip olmasına dikkat edersiniz?
3. Hangi yazı içi anlamsal ilişkileri tasarlamada zorluklar yaşadınız? Neden? Bu problemi nasıl aşabiliriz?
4. Bir kavramı yazı modu ve resim modu ile birlikte öğretirseniz iki mod arasında nasıl bir ilişki tasarlarsınız?
5. Hangi yazı-görsel arası anlamsal ilişkileri tasarlamada zorluklar yaşadınız? Neden? Bu problemi nasıl aşarız?
6. Yazı ve görsel arası anlamsal ilişkileri tasarlarken hangisinden yola çıktınız? Neden? Yazıdan başlayıp anlamsal ilişkileri tasarlamak mı kolay, yoksa görselden başlayıp tasarlamak mı? Neden?
7. Ebayı açıp öğrencilere bir metin gösterdiğinizde bu metinleri seçerken nelere dikkat edersiniz?
8. Sizce metinleri bu anlamsal ilişkilere göre tasarlama sınıf içerisinde hangi amaçlara hizmet eder? (ilgi çekme, motivasyon, tartışma, sorgulama, yaratıcılık, özyeterlik…)
9. Üstün yeteneklilerin eğitiminde anlamsal ilişkileri düşünerek metin hazırlama bize hangi açılardan yardımcı olur, hangi eksiklikleri giderir? özel yeteneklilerin eğitimi için nasıl katkılarda bulunur?
10. Öğrencilerinizi düşündüğünüzde Özel yeteneklilerin eğitim materyallerini hazırlarken bunları dikkate almak ne derece ve nasıl etkili olabilir?
11. Hangi aktiviteler (görselleri veya yazıyı karşılaştırarak tanıma-video-tasarım ve geridönüt) yazı içi ve görsel yazı anlam ilişkilerini uygulamada size daha yardımcı oldu? Nasıl? Siz yapsanız neler yapardınız.
12. Yapılan aktiviteler yazı içi (başlıklar, içerik: bilgi verici-otoriter vs ikna edici-gerekçelerle açıklayıcı-veriler-belirsiz zamir vs isim- örneklerle açıklayıcı- bağlaç kullanımı-argüman örtüşmesi-bilimsel vs gündelik dil-kapalı-açık söz dizimi-vurgulama) ve görsel yazı anlam ilişkilerini (dekoratif-örneklem-yansıtıcı-açıklayıcı-karşılaştırmalı-organizasyonel-artırılmış-yorumsal) kavramada size nasıl yardımcı oluyor ve yazı ve görsel arası anlam ilişkilerini tasarlamanızı etkili bir şekilde çözüyor mu? Ne

yapmalıyız? Bunu besleyen veya engelleyen koşullar nelerdir? Siz yapsanız neler yapardınız.

13. İkinci mülakatımızda ek kaynak talep etmiştiniz, ek kaynak ne derece etkili oldu?
14. Tüm süreci değerlendirdiğinizde Süreç içinde yaşadığınız zorluklar nelerdir?
15. Eğitim sürecini nasıl genişletir veya daraltırdınız?
16. Aktivitileri siz nasıl tasarlardınız? Tasarım aktitiveleri nasıl farklı yapılabilirdi?
17. Geridönütler yapılanın dışında nasıl olmalıydı?

D
ACTIVITY 3

Sera Gazları

Sera gazları, ısıyı yakalayabilen gazlardır. Adlarını seralardan alırlar. Sera, cam veya şeffaf plastik duvarlı ve çatılı bir yapıdır. Bu yapısı güneş ışığının içeri girmesine izin verir. Seralara giren güneş ışığı ortamın sıcaklığını ve ısısını artırır. Seralar dış yapısıyla ısının dışarı çıkmasını engeller.

Seralara bakıldığında gece vakti dışarısı daha soğuk olmasına rağmen seranın içerisinin oldukça sıcak olduğu görülür. Bunun nedeni, seranın cam veya plastik duvarlarının Güneş'in ısısının kaçmasına izin vermemesidir. Bir sera, gün boyunca Güneş'ten gelen ısıyı alır. Cam duvarları, güneşin ısısını yakalar ve bu da seranın içindeki bitkileri soğuk gecelerde bile sıcak tutarak büyüme ve gelişmelerini sağlar.

Atmosferdeki bazı gazlar da seraya benzer şekilde ısıyı yakaladıkları için sera gazları adı verilmiştir. Sera gazlarına karbondioksitle birlikte su buharı, metan, azot oksit (nitrojen oksit) ve ozon gazı örnek olarak verilebilir.

Sera Gazları ve Küresel Isınma

Sera gazları tıpkı sera gibi dünyadaki ısının atmosferden uzaya kaçmasını engelleyerek dünyamızı yaşanabilir hale getirmektedir. Sera gazlarının etkisi olmadan dünya yaşam sürdürmek için çok soğuk olabilirdi.

Sera gazı etkisi dünya yüzeyi ve havasının ısınması anlamına gelir. Bu güneşten gelen enerjiyi hapseden havadaki gazlardan kaynaklanmaktadır. Kısaca sera gazı etkisi şu sırayı takip eder. Güneş radyasyonu Dünya atmosferine ulaşır - bunun bir kısmı uzaya geri yansıtılır. Güneşin enerjisinin geri kalanı kara ve okyanuslar tarafından emilerek Dünyayı ısıtır. Isınan dünya bu sefer radyasyonu uzaya doğru yayar. Bu ısının bir kısmı atmosferdeki sera gazları tarafından hapsedilerek Dünya'nın yaşamı sürdürebilmesi için yeterince sıcak tutulmasını sağlar.. Bu doğal süreç kirlilik, kömür, petrol ve doğalgaz gibi yakıtların yakılması, tarım ve arazi temizleme gibi insan faaliyetleri ile bu gazların atmosferde bulunma oranı artırılırak bozulmaktadır. Daha fazla sera gazı daha fazla ısı yakalar ve dünya ve yüzeyinin her geçen gün ortalama sıcaklığının yükselmesine neden olur. Bu olay da küresel ısınma olarak adlandırılır.

Sera Gazları

Sera gazları, güneşten gelen radyasyonu (ışıma) emen gazlardır. Bu gazlar adlarını seralardan alırlar. Seranın cam da ya da plastik çeperleri (duvarlar) fotonların (güneş ışınları) geçmesine izin verir, ancak bu yapılar aynı zamanda binanın içinde biriken ısının bir bölümünü de tutar. Daha küçük ölçekte, güneşli bir günde camları kapalı bir aracın nasıl ısındığını düşünün. Seralara giren fotonlar ortamın sıcaklığını ve ısısını artırır.

Gündüzleri ısıyı soğuran (emen) seralara bakıldığında gece vakti dışarısı daha soğuk olmasına rağmen iç ortamının sıcak olduğu görülür. Bunun nedeni, seranın cam veya plastik çeperlerinin güneşten gelen ısıyı hapsetmesidir. Bir sera, gün boyunca Güneş'ten gelen ısıyı soğurur. Cam duvarları, güneşin ısısını hapseder bu yüzden sera içindeki bitkileri soğuk gecelerde bile büyüme ve gelişmelerini sağlayacak ortamı oluşturur.

Atmosferde bulunan gazlar seranın yapısına benzer şekilde ısıyı hapsettiklerinden bu gazlara sera gazı adı verilmiştir. Sera gazları olarak bilinen bunların bazıları karbondioksit, su buharı ve metan gibi doğaldır. CFCler ise sentetiktir (yapay).

Sera Gazları ve Küresel Isınma

Seraya benzer şekilde sera gazları, Dünya atmosferindeki (gaz tabaka) güneş ışınlarını geçirirler ve bir kısmını soğururlar. Böylece, sera gazları atmosferde ısıyı yakalayan bir battaniye işlevi görürler. Battaniye işlevi gören izolasyon (yalıtım) artışı dünyanın ortalama sıcaklığını yaşanabilir düzeyde tutar.

Sera gazı etkisi yerkürenin (dünya yüzeyi) ve atmosferinin (hava) ısınması anlamına gelir. Bu etki güneşten gelen fotonları emen atmosferdeki gazlardan kaynaklanmaktadır. Güneş radyasyonu (ışınları) Dünya atmosferine ulaşır - bunun bir kısmı uzaya (uzay boşluğu) geri yansıtılır. Isı ve ışık enerjisinin geri kalanı kara ve okyanuslar tarafından emilerek Dünyayı ısıtır. Isınan dünya radyasyonu uzaya doğru yansıtır. Atmosferdeki sera gazları bu enerjiyi emer bu yüzden dünyada canlı yaşamı için gerekli olan ortalama sıcaklık elde edilir. Bu şekilde doğal yollarla dünya kendi ısısını korumuş olur ancak bu doğal süreç hava kirliliği, fosil yakıtların yakılması, ormanların yok edilmesi gibi insan faaliyetleri ile bu gazların atmosferde bulunma konsantrasyonu (oranı) gün geçtikçe artmaktadır. Artan sera gazı miktarı emilen ısı oranını artırtırdığından yerküre ve atmosferin her geçen gün ortalama sıcaklığını yükselmektedir. Bu olay da **küresel ısınma** olarak adlandırılır.

Dünyamız neden ısınıyor?

Sanayileşme sonrası artan kirlilik ve olağan dışı hava olayları bilim insanlarını doğal dengenin bozulmasından endişelenmeye itti.

Bu endişelere sahip olan Joseph Fourier 1824 yılında kirlilikten yeryüzü ve havanın güneş ışınları verimli bir şekilde uzaya iletmediğini ve yüzey sıcaklığının arttığını iddia etse de ispat edemedi. Fizikçi Claude Pouillet de su buharı ve karbondioksitin kızılötesi ışınları yakalayıp atmosferi ısıtabileceğini öne sürdü. Fourier gibi bu gazların ışımadan ısıyı emdiğine dair deneysel bir kanıt ortaya atamadı.

1896'da Svante Arrhenius, atmosferdeki karbondioksit ve su buharının güneş ışınlarını önemli ölçüde emme ve geçici olarak tutma gücüne sahip olduğunu ve bunu yüzey sıcaklıklarında beş-altı derece artışa sebep olduğunu hesapladı.

1960'da Charles David Keeling daha önceki yıllarda yaptığı atmosferdeki karbondioksit seviyesi ölçümlerini grafik haline getirerek atmosferdeki karbondioksit seviyesinin aslında yükseldiğini gösterdi. Bugüne kadar devam eden bu hesaplama her yıl karbondioksit seviyesinin arttığını ispat etmektedir. Daha sonra Manabe ve Wetherald, karbondioksit artışının dünya yüzeyindeki sıcaklığı artırdığını iddia etti. Bunu test etmek için mevcut iklimi üç boyutlu bir küresel iklim modeli geliştirdiler. Modelin atmosferindeki karbondioksit'in ikiye katlanması, küresel sıcaklıkta kabaca iki derecelik bir artış sağladı. 2014 IPCC (Hükûmetlerarası İklim Değişikliği Paneli) raporlarına göre de dünyanın sıcaklığı son yüz yılda 0.8 derece artmıştır. Bu artışın yüzde 75'i son otuz yılda ortaya çıkmıştır. Bu rapora göre bu yüzyılın sonuna kadar sıcaklıkta iki ile dört buçuk derecelik artış olasılığı vardır. Sanayileşmeden önce karbondioksit seviyesi 280 ppm iken bu oran 2013'de 396 ppm düzeyine çıkmıştır ve bu seviye yülselmeye devam etmektedir.

1985'te Ramanathan ve diğerleri su buharı, metan ve diğer gazlarla birlikte kloroflorokarbonların da dünyanın sıcaklığı üzerine etkisini olduğuna inanıyordu. Bu yönde tasarladıkları iklimsel modellerde bu gazlardaki artışların önemli bir iklim etkisine sahip olabileceğini gösterdiler.

Bu modeller ve deneyler şunu göstermiştir. Dünya atmosferine ulaşan ışığın yaklaşık yarısı atmosferden geriye gönderilir. Geriye kalan kısmı atmosferi geçerek yeryüzünü ve yüzeyini ısıtır. Isınan yeryüzü ısıyı tekrar atmosfere yayar. Sıcaklıktaki değişikliklere fiziksel ve kimyasal tepki veren CH_4, CFC5, N_2O, CO_2, H_2O gibi sera gazları ısının yaklaşık yüzde 90'ını emer. Titreşim ve öteleme hareketi yapan gaz tanecikleri ısıyı her tarafa yayar. Kısacası; tüm bu gazlar yerküre ve havanın ısınmasını sağlar. Bu bir kısırdöngü olarak devam eder. Örneğin, ısınan atmosfer, daha fazla su buharı tutar, daha fazla su buharı da daha çok ısı tutarak yer yüzeyini ısıtır. Isınan yeryüzünden daha çok su buharlaşır. Daha çok su buharı, daha çok ısıyı hapseder…Aynı kısırdöngüyü buzulların erimesi ve ormanların yok edilmesi açısından nasıl açıklayabiliriz?

Dünyamız neden ısınıyor?

Sanayileşme sonrası hava kirliliği ve doğal felaketler artmıştır bu yüzden bilim insanları doğal dengenin bozulmasından endişelenmeye başlamıştır.

Bu endişelere sahip olan Joseph Fourier 1824 yılında kirlilikten atmosferin radyasyonu (ışıma) verimli bir şekilde uzaya yansıtmadığını ve yüzey sıcaklığının arttığını iddia etse de ispat edemedi. Fizikçi Claude Pouillet de su buharı (H_2O)ve karbondioksitin (CO_2) radyasyonu emip atmosferi ısıtabileceğini öne sürdü, ancak bu gazların termal radyasyondan ısıyı soğurduğuna dair deneysel bir kanıt ortaya atamadı.

1896'da Svante Arrhenius, atmosferdeki karbondioksit (CO_2) ve su buharının (H_2O) fotonları (güneş ışınlarını) önemli ölçüde soğurma ve geçici olarak tutma gücüne sahip olduğunu ve bunu yerkürenin ortalama sıcaklığında 5-6 °C artışa sebep olduğunu hesapladı.

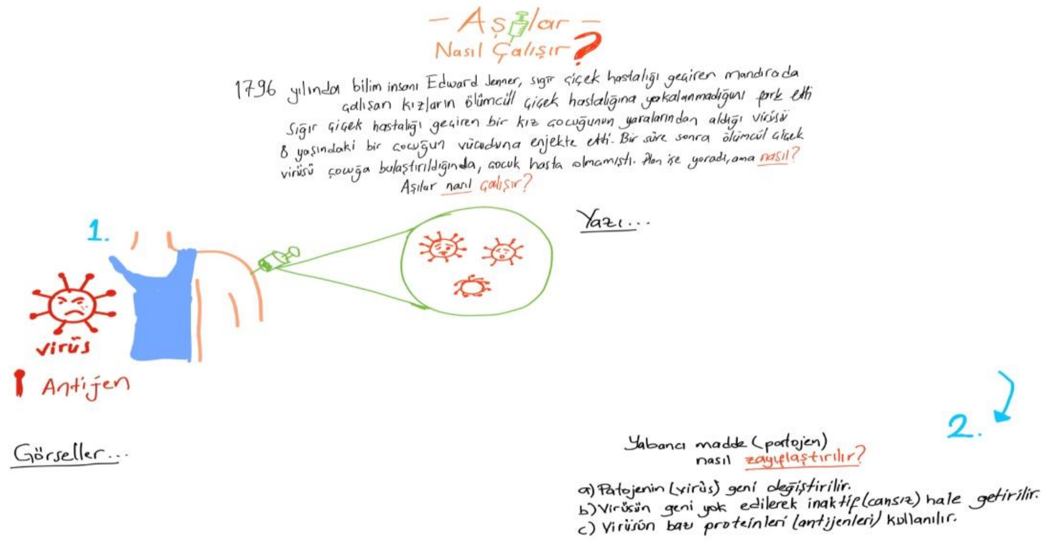
1960'da Charles David Keeling daha önceki yıllarda yaptığı atmosferdeki karbondioksit (CO_2) konsantrasyonu ölçümlerini grafik haline getirerek atmosferdeki CO_2'nin aslında yükseldiğini gösterdi. Bugüne kadar devam eden bu hesaplama her yıl CO_2 konsantrasyonun arttığını ispat etmektedir. Daha sonra Manabe ve Wetherall, CO_2 artışının dünya yüzeyindeki sıcaklığı artırdığını iddia etti. Hipotezini test etmek için üç boyutlu bir küresel iklim modeli geliştirdiler. Sonuç olarak modelin atmosferindeki CO_2'in ikiye katlanması, küresel sıcaklıkta ortalama 2°C'lik bir artış sağladı. 2014 IPCC raporlarına göre ortalama küresel sıcaklık son 100 yılda 0.8°C artmıştır. Bu artışın yüzde %75'i son otuz yılda ortaya çıkmıştır. Bu rapora göre bu yüzyılın sonuna kadar sıcaklıkta 2-4.5 derecelik artış olasılığı vardır. Sanayileşmeden önce karbondioksit konsantrasyonu 280 ppm iken bu oran 2013'de 396 ppm düzeyine çıkmıştır ve bu seviye yükselmeye devam etmektedir.

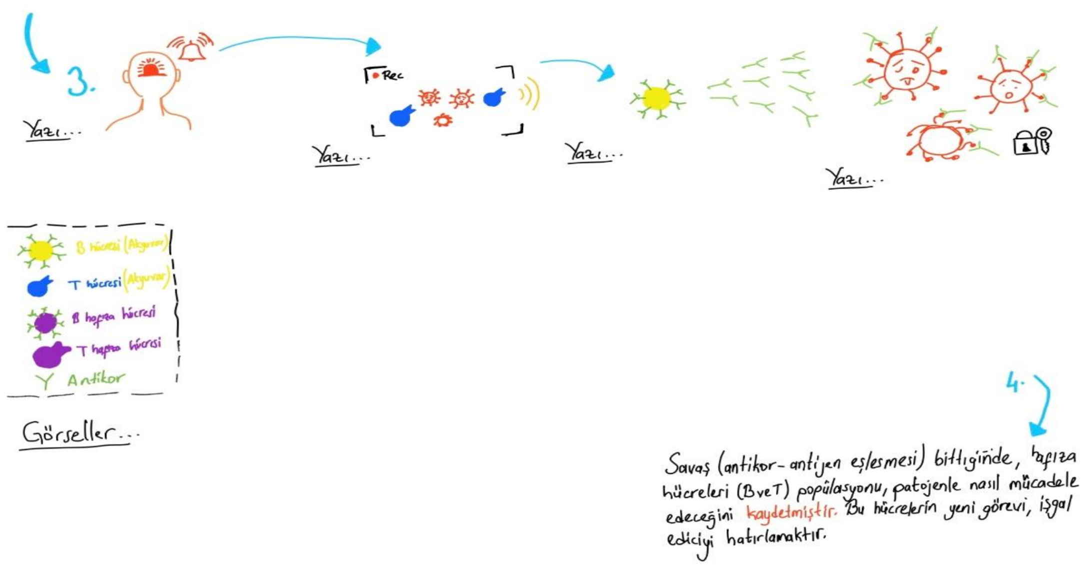
1985'te Ramanathan ve diğerleri su buharı (H_2O), metan (CH_4) ve diğer gazlarla birlikte kloroflorokarbonların (CFC) da küresel sıcaklık üzerine etkisini olduğuna inanıyordu. Bu yönde tasarladıkları iklimsel modellerde bu sera gazlarının artışların önemli bir iklim etkisine sahip olabileceğini gösterdiler.

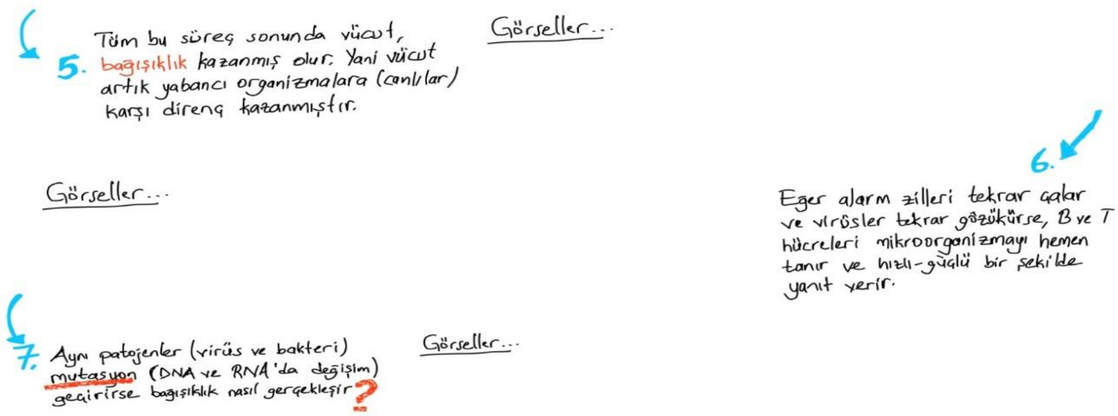
İklim modelleri ve deneyler şunu göstermiştir. Dünya atmosferine ulaşan fotonların (güneş ışınlarının) yaklaşık yarısı atmosferden geriye yansır. Geriye kalan kısmı atmosferi geçerek yerküreyi ısıtır. Isınan yerküre ısıyı tekrar atmosfere yansıtır. Atmosfer, yansıtılan gezegensel radyasyonun etkili bir soğurucu sudur. Atmosferde bulunan metan (CH_4), kloroflorokarbon (CFC), azotdioksit (N_2O), karbondioksit (CO_2) ve su buharı (H_2O) gibi sera gazları molekülleri arasındaki bağlarının yaptığı bükülme ve gerilme hareketleri ile radyasyonun %90'ını soğurur. Titreşim ve öteleme hareketi yapan gaz tanecikleri ısıyı ışıma yoluyla her yöne yansıtır bu yüzden tüm bu sera gazları yerküre ve havanın ısınmasını sağlar. Bu bir geribesleme olarak devam eder. Isınan atmosfer ve su buharı (sera gazı) arasındaki birbirini etkileyen süreci nasıl açıklayabilirsiniz? Isınan yeryüzü, atmosfer ve su buharı (sera gazı) arasındaki birbirini tetikleyen süreci nasıl açıklayabilirsiniz? Ormanların yok edilmesi ile küresel ısınma arasındaki ilişkiyi nasıl açıklayabilirsiniz? Bulutların yakın ve uzak olması ile küresel ısınma arasında nasıl bir ilişki vardır.

E
ACTIVITY 5 AND 6

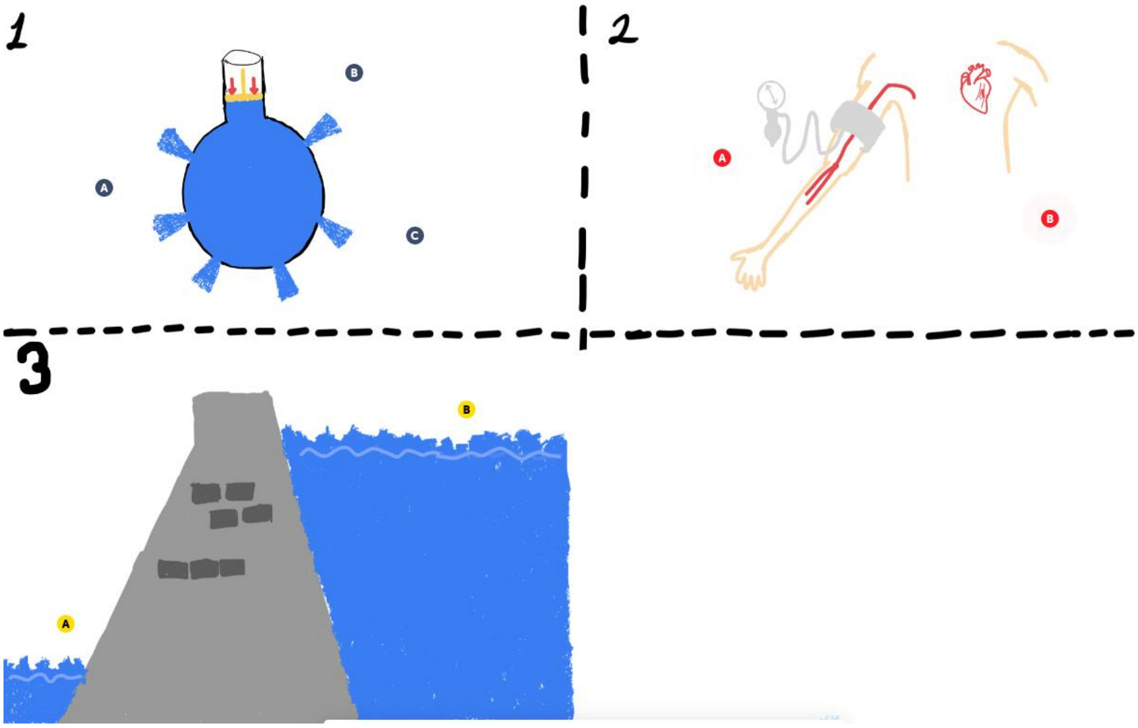
Activity 5






5. Tüm bu süreç sonunda vücut, bağışıklık kazanmış olur. Yani vücut artık yabancı organizmalara (canlılar) karşı direnç kazanmıştır.
Görseller...
Görseller...
6. Eger alarm zilleri tekrar çalar ve virüsler tekrar gözükürse, B ve T hücreleri mikroorganizmayı hemen tanır ve hızlı-güçlü bir şekilde yanıt verir.
7. Aynı patojenler (virüs ve bakteri) mutasyon (DNA ve RNA'da değişim) geçirirse bağışıklık nasıl gerçekleşir?
Görseller...

Activity 6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DFL PROJECT

Yazı İçi ve Görsel-Yazı Arası Anlamsal İlişkiler

ÖĞRETMENİN EL KİTABI

DFL PROJECT

Bu el kitabı, sizlere yazı içi ve yazı-görsel arası anlamsal ilişkileri tasarlamada rehberlik etmeyi hedeflemektedir. Bundan sonraki çalışmalarımızda yazı-görsel arası anlamsal ilişkileri tasarlarken yazı içi anlamsal ilişkileri de dahil etmemiz gerekmektedir.

Proje Ekibi

Yıldız Teknik Üniversitesi

Bölüm 1: Yazı İçi Anlamsal İlişkiler

Yazı içi anlamsal ilişkileri tasarlarken iki temel noktaya odaklanırız.

Birincisi, semantik yani **anlamsal** olarak metinleri amacımıza göre daha güçlü veya zayıf (semantically considerate or not) hale getiririz.

İkincisi, epistemik yani **bilgisel** olarak metinleri daha yoğunlaştırılmış ya da sade (epistemically considerate or not) hale getiririz.

Bu amaçlara uygun olarak yazı içi toplam 8 farktan bahsedebiliriz.

1. Başlıklar

1.1. Başlık bilgi verici ve odak noktasıdır.

Örneğin: Pankreas, İnsülin ve Glukagon, Küresel Isınma, Aşılar

1.2. Başlık sorgulatıcıdır, okuyucuyu metne dahil eder.

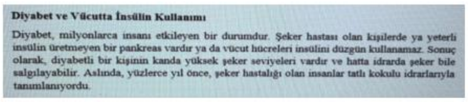
Örneğin: Pankreas Kan Şekerini Nasıl Kontrol Eder? İnsülin ve Glukagon Arasında Nasıl Bir İlişki Vardır? Dünyamız Neden Isınıyor? Aşılar Nasıl Elde Edilir?

2. İçerik

2.1. İçerik bilgi verici, tanımlayıcı ve otoriterdir. Bilimsel süreçten ve nitel-nicel veriden bahsetmez.

Örneğin: Pankreasın nerede olduğundan ve vücuttaki ne görev yaptığından direk bahseder. Bilen metindir ve ikna etmekle uğraşmaz.

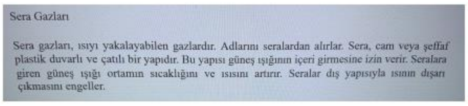
Diyabetten ve neden olduğuyla ilgili açıklama yapar.



Diyabet ve Vücutta İnsülin Kullanımı

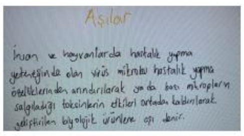
Diyabet, milyonlarca insanı etkileyen bir durumdur. Şeker hastası olan kişilerde ya yeterli insülin üretmeyen bir pankreas vardır ya da vücut hücreleri insülini düzgün kullanamaz. Sonuç olarak, diyabetli bir kişinin kanda yüksek şeker seviyeleri vardır ve hatta idrarda şeker bile salgılayabilir. Aslında, yüzlerce yıl önce, şeker hastalığı olan insanlar tatlı kokulu idrarlarıyla tanımlanıyordu.

Küresel ısınmadan sera etkisi nedeniyle dünyanın sıcaklığının artması diyerek bir tanım yapar.



Sera Gazları

Sera gazları, ısıyı yakalayabilen gazlardır. Adlarını seralardan alırlar. Sera, cam veya şeffaf plastik duvarlı ve çatılı bir yapıdır. Bu yapısı güneş ışığının içeri girmesine izin verir. Seralara giren güneş ışığı ortamın sıcaklığını ve ısısını artırır. Seralar dış yapısıyla ısının dışarı çıkmasını engeller.



Aşılar

İnsan ve hayvanlarda hastalık yapma yeteneğinde olan virüs mikrobu hastalık yapma özelliklerinden arındırılarak ya da bazı mikropların salgıladığı toksinlerin etkileri ortadan kaldırılarak geliştirilen biyolojik ürünlere aşı denir.

Aşıların bazı aminoasitlerden ve zayıflatılmış mikroplar içerdiğini anlatır.

2.2. İkna edici, iddiaları gerekçelerle açıklayıcıdır. Bilimsel süreçten bahseder ve nitel-nicel veri içerir.

Örneğin: Bilim insanlarının süreç içerisinde insülin, küresel ısınma ve aşılarla ilgili gözlemlerini, araştırma sorularını, hipotezlerini ve nitel-nicel verilerini ortaya koyar.

Bilim adamları, pankreasın vücudun enerji için şeker moleküllerini kullanmasına yardımcı olduğunu öğrendikten sonra, bunun nasıl gerçekleştiğini bilmek istediler. Frederick Banting ve Charles Best, pankreasın, hücrelerin şekeri almasına ve kullanmasına yardımcı olmak için diğer hücrelerin işlevini etkileyen küçük bir molekül olan bir hormonu kana saldığına inanıyordu.

Hipotezlerini test etmek için Banting ve Best bir deney yaptı. İlk olarak, bilim adamları pankreası birkaç köpekten çıkardı. Beklendiği gibi, bu köpeklerin kan şekeri seviyeleri normal % 9'dan çok daha yüksekti.

1896'da Svante Arrhenius, atmosferdeki karbondioksit (CO_2) ve su buharının (H_2O) fotonları (güneş ışınlarını) önemli ölçüde soğurma ve geçici olarak tutma gücüne sahip olduğunu ve bunu yerkürenin ortalama sıcaklığında 5-6 °C artışa sebep olduğunu hesapladı.

1960'da Charles David Keeling daha önceki yıllarda yaptığı atmosferdeki karbondioksit (CO_2) konsantrasyonu ölçümlerini grafik haline getirerek atmosferdeki CO_2'nin aslında yükseldiğini gösterdi. Bugüne kadar devam eden bu hesaplama her yıl CO_2 konsantrasyonun arttığını ispat etmektedir. Daha sonra Manabe ve Wetherall, CO_2 artışının dünya yüzeyindeki sıcaklığı artırdığını iddia etti. Hipotezini test etmek için üç boyutlu bir küresel iklim modeli geliştirdiler. Sonuç olarak modelin atmosferindeki CO_2'in ikiye katlanması, küresel sıcaklıkta ortalama 2°C'lik bir artış sağladı. 2014 IPCC raporlarına göre ortalama küresel sıcaklık son 100 yılda 0.8°C artmıştır. Bu artışın yüzde %75'i son otuz yılda ortaya çıkmıştır. Bu rapora göre bu yüzyılın sonuna kadar sıcaklıkta 2-4.5 derecelik artış olasılığı vardır. Sanayileşmeden önce karbondioksit konsantrasyonu 280 ppm iken bu oran 2013'de 396 ppm düzeyine çıkmıştır ve bu seviye yükselmeye devam etmektedir.

3. Belirsiz zamirler, anlamın kolaylaşması için isimlerle değiştirilir.

Örneğin:

Ortam sıcaklığı ne olursa olsun vücut sıcaklıklarını dar sınırlar içinde tutarlar. Bu nedenle genellikle homeotermik olarak tanımlanırlar.

Endotermiktirler; vücut ısısını korudukları ısı vücutta üretilir. Bazı soğukkanlı hayvanlar, örneğin güneşin tadını çıkaran kertenkeleler, kuşlarınki kadar yüksek vücut sıcaklıkları geliştirirler, ancak bunlar ektotermiktir; dışarıdan bunu yapmak için ısıyı korurlar.

1. Sıcakkanlı hayvanlar homeotermiktir. Yani diğer hayvanlardan farklı olarak kuşlar ve memeliler vücut sıcaklıklarını çevreleyen (veya ortam) sıcaklık ne olursa olsun vücut sıcaklıklarını dar sınırlar içinde tutarlar.

2. Sıcakkanlı hayvanlar endotermiktir. Endotermik hayvanlar, vücut ısısı dış kaynaklardan gelen ısı ile korunan soğukkanlı hayvanlardan farklıdır. Bu nedenle güneş altında güneşlenen kertenkeleler gibi bazı soğukkanlı hayvanlar, kuşlarınki kadar yüksek vücut sıcaklıkları geliştirseler de, bu canlılar vücut ısılarını dışarıdan korurlar. Bu tür hayvanlara ektotermik denir.

Bu modeller ve deneyler şunu göstermiştir. Dünya atmosferine ulaşan ışığın yaklaşık yarısı atmosferden geriye gönderilir. Geriye kalan kısmı atmosferi geçerek yeryüzünü ve yüzeyini ısıtır. Isınan yeryüzü ısıyı tekrar atmosfere yayar. Sıcaklıktaki değişikliklere fiziksel ve

İklim modelleri ve deneyler şunu göstermiştir. Dünya atmosferine ulaşan fotonların (güneş ışınlarının) yaklaşık yarısı atmosferden geriye yansır. Geriye kalan kısmı atmosferi geçerek yerküreyi ısıtır. Isınan yerküre ısıyı tekrar atmosfere yansıtır. Atmosfer, yansıtılan gezegensel

8 yaşındaki bir çocuğun vücuduna enjekte etti. Bir süre sonra bu virüs çocuğa bulaştırıldığında, hasta olmamıştı.

8 yaşındaki bir çocuğun vücuduna <u>çiçek virüsü aşısını</u> enjekte etti. Bir süre sonra <u>çiçek virüsü</u> çocuğa bulaştırıldığında, <u>çocuk</u> hasta olmamıştı.

4. Örneklerle açıklayıcı hale getirilir.

Örneğin:

Bu hem sıcakkanlı hem de soğukkanlı hayvanlar için geçerlidir.

VS

Bu sistem hem sıcakkanlı olan <u>kuşlar ve memeliler</u> hem de soğukkanlı olan <u>sürüngenler, amfibiler ve balıklar</u> için geçerlidir.

.....

Bu doğal süreç artan insan faaliyetleri yüzünden bozulmaktadır.

VS

Bu doğal süreç <u>hava kirliliği, fosil yakıtların yakılması, ormanların yok edilmesi</u> gibi insan faaliyetleri yüzünden bozulmaktadır.

.....

Seralara giren güneş ışığı ortamın sıcaklığını ve ısısını artırır.

VS

Seralara giren güneş ışığı ortamın sıcaklığını ve ısısını artırır. <u>Daha küçük ölçekte, güneşli bir günde camları kapalı bir aracın nasıl ısırdığını düşünün.</u>

5. Fikirler arası ilişkileri belirtmek için bağlaç kullanımı yapılır.

Bu her zaman böyle değildir. Bazıları örneğin kış uykusuna yatanlar sıcaklıklarının ortam sıcaklığına yakın olmasına izin verir.

VS

Bu her zaman böyle değildir <u>çünkü</u> bazıları örneğin kış uykusuna yatanlar sıcaklıklarının ortam sıcaklığına yakın olmasına izin verir.

.....

Cam duvarları güneşin ısısını yakalar. Bu seranın içindeki bitkileri soğuk gecelerde bile sıcak tutarak büyüme ve gelişmelerini sağlar.

VS

Cam duvarları güneşin ısısını yakalar <u>bu yüzden</u> soğuk gecelerde bile büyüme ve gelişmelerini sağlayacak ortamı oluşturur.

6. Argüman örtüşmesi için kelime ekleme veya değiştirme yapılır. Kapalı sözdizimi açık hale getirilir.

Dolaşım sistemi, ısının vücutta dağılımdan sorumludur.

VS

Dolaşım sistemi, ısıyı hayvanın vücudundaki kan damarları yolu ile dağıtır.

.....

Sera gazları dünyadaki ısının atmosferden uzaya kaçmasını engelleyerek dünyamızı yaşanabilir hale getirir.

VS

Sera gazları atmosferdeki ısıyı yakalayan bir battaniye işlevi görerek yalıtım yapar ve dünyanın ortalama sıcaklığını yaşanabilir seviyede tutar.

.....

Aynı patojenler mutasyon geçirirse bağışıklık nasıl gerçekleşir?

VS

Aynı patojenler DNA ve RNA'larında geri dönüşü olmayan bir değişiklik yani mutasyon geçirirlerse bağışıklık nasıl gerçekleşir?

7. Bilimsel dil, gündelik dille desteklenir.

Canlılar metabolizma faaliyetlerini sürdürmek için enerjiye ihtiyaç duyarlar.

VS

Canlılar metabolizma (yaşamsal) faaliyetlerini sürdürmek için enerjiye ihtiyaç duyarlar.

.....

Sera gazları, güneşten gelen radyasyonu soğuran gazlardır. Seranın cam ya da çeperleri fotonların geçmesine izin verir.

VS

Sera gazları, güneşten gelen radyasyonu (ışıma) soğuran (emen) gazlardır. Seranın cam ya da çeperleri (duvarları) fotonların (güneş ışınlarının) geçmesine izin verir.

.....

Aynı patojenler mutasyon geçirirse bağışıklık nasıl gerçekleşir?

VS

Aynı patojenler (mikroplar) mutasyon (değişim) geçirirse bağışıklık (direnç) nasıl gerçekleşir?

8. Vurgulamalar farklı renkte, italik veya böldüm olarak yapılır.

Örneğin:

Ölmüş organik yapıların ayrıştırıcılar tarafından inorganik yapılar haline getirilmesine **ayrışma** denir.

Artan sera gazı miktarı emilen ısı oranını artırdığından yerküre ve atmosferin her geçen gün sıcaklığı artmaktadır ve bu olay da **küresel ısınma** olarak adlandırılır.

Bölüm 2: Görsel- Yazı Arası Anlamsal İlişkiler

Görsel-Yazı arası anlamsal ilişkilerini tasarlarken metinle okuyucu arasında:

1. interaktifliği,
2. metni okuyanın benzerlik ve farklılıkları farkedebilmesini,
3. metni sorgulamasını,
4. süreci takip edebilmesini,
5. örnekleri görmesini,
6. dikkatini çekmesini,
7. öğrenmeyi pekiştirmesini hedefleriz.

Bunlarla beraber, metni okuyan kişinin bilişsel seviyesini dikkate alırız.

Tüm bunları düşündüğümüzde yazı ile görsel arasında basitten gelişmişe doğru sekiz anlamsal ilişki kurabiliriz.

1. Dekoratif Anlamsal İlişki

Bu tip anlamsal ilişkide yazı ile görsel arasında çok çok az bir anlamsal ilişki vardır ya da hiç yoktur. Dikkat çekmek için kullanılabilir.

Örneğin:

Yazı iç salgı bezlerini öğretmekten bahsederken orada sadece bir mercek görseli bulunmaktadır.

Görsel yazıya çok zayıf bir şekilde atıf yapmaktadır.

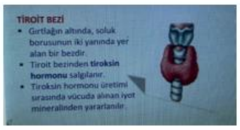
Aşı görseli, aşıların nasıl çalıştığı ile ilgili bir anlam taşımamaktadır

Dekoratif anlamsal ilişki kötü bir ilişki anlamına gelmez. Dikkat çekmek için kullanılabilecek bir anlamsal ilişki olarak kullanılabilir..

2. Örneklem Anlam İlişkisi

Bu tip anlamsal ilişkide yazı ve görsel birbirine sadece içinde barındırdığı bir bölüme dair atıfta bulunur.

Örneğin görsel burada sadece tiroit bezinin yerini göstermektedir. Tiroksin hormonundan ve minerallerden bahsetmemektedir.



Görsel burada sadece ormanların yok edilmesine atıfta bulunmaktadır.

Burada görsel sadece hafızaya kaydedilen antijenleri işaret etmektedir.

Buradaki ilişkilerin tam tersi de oluşturulabilir. Yani görsel yazının değil de, yazı görselin bir kısmına atıfta bulunabilir.

3. Yansıtıcı Anlamsal İlişki

Bu tip anlamsal ilişkide yazı ile görsel birbirini anlam olarak birebir yansıtır. Yazı ne diyorsa görsel de onu ifade eder, ya da tam tersi. Anlamı pekiştirmede faydalıdır.

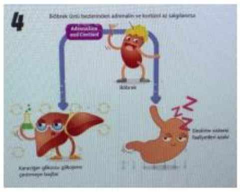
Yazı ve görsel aynı şeyi ifade eder tekrarlar.

Seranın yapısı, ışığı geçirmesi ve hapsetmesi görsel ve yazıda tekrar ifade edilmiştir.

B hücreleri ve üretilip gönderilen antikorlar birebir yansıtılmaktadır.

4. Açıklayıcı Anlamsal İlişki

Yazı ve görsel birbirini alternatif modla ifade eder. Yazı veya görseldeki anlam aynı genellik düzeyiyle yeniden ifade edilir. Anlam pekiştirilmesi sağlanır.



Sindirim sistemi faaliyetleri azalır anlamı, uyuyan bir mide ile azalan oklarla tekrar ifade edilmiş. Glikozun dönüştürülmesi de yine sembolle ifade edilmiştir.

Karbondioksit seviyesi hız ibresi ile, sıcaklığın artması da değişen yüzlerde bulunan emojilerle yeniden açıklanmıştır.

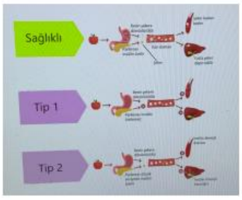
Kaydetme ifadesi kamera kadrajında gibi REC ifadesi ile bilgilendirme de sinyal ifadesi ile yeniden açıklanmıştır.

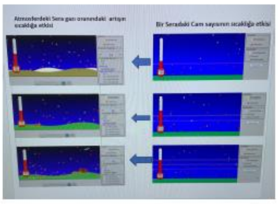
Burada yansıtıcı anlamsal ilişki de vardır. Gördüğümüz gibi birden fazla anlamsal ilişki bir arada kullanılabilir.

5. Karşılaştırmalı Anlamsal İlişki

Bu tarz anlamsal ilişkiler metni okuyanların benzerlikleri ve farklılıkları anlamalarına yardımcı olmak için karşılaştırma ve zıtlık sağlar. Bu da öğrencilerin bilgiler ve kavramlar arasında nasıl ilişki kurulacağını anlamalarını geliştirir.

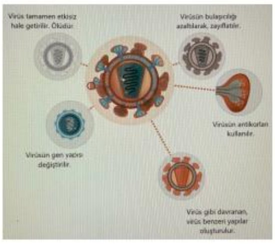
Sağlıklı, tip 1 ve tip 2 diyabetin benzerlikleri ve farklılıklarını karşılaştırma imkanı sunmuştur. Aynı zamanda süreç halinde gösterildiğinden bir sonraki anlamsal ilişki olan organizasyonel anlamsal ilişki de sağlanmıştır. İnsülin ve şekerin sembolleştirilip başka modla gösterilmesi de açıklayıcı anlamsal ilişki sağlamıştır.





Atmosferdeki sera gazındaki artış ve bir seradaki cam sayısının artırıldığında neler olacağının karşılaştırılması sağlanarak karşılaştırmalı anlamsal ilişki kurulmuştur. Aynı zamanda gazların artması farklı modla gösterildiğinden açıklayıcı anlamsal ilişki kurulmuştur.

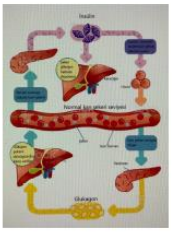
Hangi yollarla aşının elde edildiği farklı görsel ve yazılarla gerçek virüs etrafında ifade edilerek karşılaştırmalı anlamsal ilişki kurulmuştur.

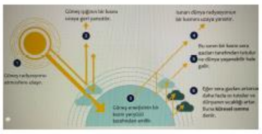


6. Organizasyonel Anlamsal İlişki

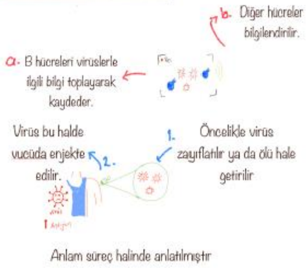
Bütünleşik yazı ve metin, konu veya kavramı bir süreç içerisinde anlatır. Anlam, yazı ve görsel arasında paylaşılır. Yazı sürecin bi kısmını görsel de bir kısmını anlatarak anlamsal ilişki tamamlanır.

İnsülin, glukagon ve kan şekeri arasındaki ilişki bir süreç bir içinde ifade edilerek organizasyonel anlamsal ilişki kurulmuştur. Aynı zamanda insülin, glukagon ve şeker farklı modlarla gösterilerek açıklayıcı anlamsal ilişki kurulmuştur.



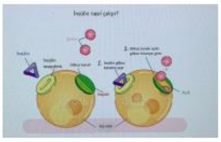


Küresel ısınma olayı bir süreç içerisinde ifade edilmiştir.



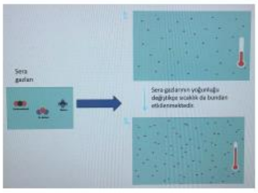
7. Artırılmış Anlamsal İlişki

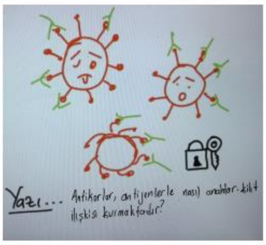
Görsel ve yazı birbirini benzetimlerle ve modellemelerle gerçeğe yaklaştırır. Birbirlerinin gerçeklik seviyesini artırır.



İnsülinin glikoz kanalını açan bir anahtar gibi betimlenmesi artırılmış anlamsal ilişki sağlamıştır. Bununla beraber süreç içerisinde anlatması ve sürecin bir kısmını yazının bir kısmını da görselin anlatması organizasyonel anlamsal ilişki kurulmasını sağlamıştır. Yine soruyla başlamak kısmi bir yorumsal anlamsal ilişki oluşturmuştur. Kısmi dememizin sebebi sorunun cevabını metnin vermesidir.

Sera gazları gerçeğe uygun modellenerek gerçekliği artırılmıştır. Aynı zamanda iki durumun karşılaştırılmasına imkan sağlamış, karşılaştırmalı anlamsal ilişki elde edilmiştir.. Yazının sürecin bir kısmını görselin de bir kısmını anlatması, görselle yazının ortaklaşa anlam kurduğu organizasyonel anlam ilişkisi de oluşturmuştur.



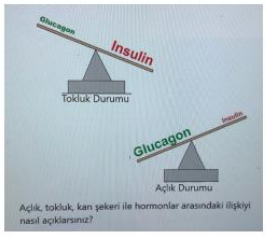


Virüslerin betimleme ve modellemesi yapılmış gerçekliği artırılmıştır. Anahtar kilit modellemesi de yapılmıştır. Bununla beraber görselle yazı arasında tam yorumsal anlamsal ilişki vardır çünkü nedensel bağın kurulmasını yazı-görsel birlikte istemiştir, ikisinden biri (yazı-görsel) soruyu cevaplamamıştır.

8. Yorumsal Anlamsal İlişki

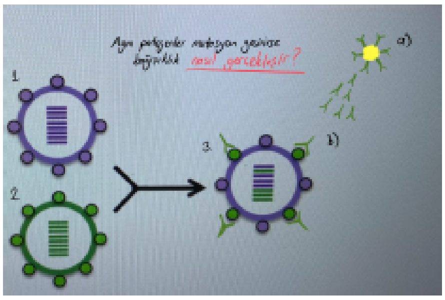
Öğrencilerin yazı ve görsel arasında ilişki ve nedensellik kurmasını sağlar. Sorgulatıcıdır. Kendini hemen ele vermez, okuyucuya metni anlaması için meydan okur.

İnsülin, glukagon, açlık ve tokluk durumu arasında nedensel bir bağ kurması için okuyuncaya meydan okuyan bir metin tasarlanmıştır. İnsülinin veya glukagonun büyük-küçük yazılması tahterevalli bu nedensel ilişkiyi metnin okuyucusundan beklemektedir. Ne yazı ne de görsel tüm anlamı verir. Hepsine bakılarak öğrencinin kendisinin anlamsal ilişki kurmasını bekler. Aynı zamanda dengenin tahterevalli ile modellenmesi de artırılmış anlamsal ilişki sağlamıştır.



Burada yazı-görsel metni okuyandan karbondioksitle nedensel bağ kurup soruyu cevaplandırmasın beklemektedir. Yorumsal anlamsal ilişki kurulmuştur. Aynı zamanda kısmi bir organizasyonel ilişki vardır. Oklarla bir süreç anlatılmıştır ama ne yazı da ne de görsel sürecin bir kısmını ne de diğeri bir kısmını anlatarak birbirini tamamlamamıştır.

Mutasyon süreci, B hücrelerinin antikor göndermesi, antikor-antijen eşleşmesi gibi olaylar arasında soruyla beraber nedensel ilişki kurarak yorumsal anlamsal ilişki kurulmuştur.



Bir metin içerisinde yazı ile görsel arasında birden fazla anlamsal ilişki kurulabilir. Burada size anlatılan anlamsal ilişkiler basitten gelişmişe (hatırlamaktan, analiz, sentez, tasarıma kadar) bilişsel seviyeye göre sıralanmıştır. Üstün yetenekli öğrencilerle birlikte çalıştığımızdan yazı içi ve yazı görsel arasında interaktifliği, sorgulatıcılığı ve tartışma ortamı yaratacak anlamsal ilişkileri dikkate almak onların yaratıcılığını ve eleştirel düşünme becerilerini geliştirecektir.

Birden fazla anlamsal ilişkiyi kullanmak bu yetenekleri geliştirmede ve metni okuyanların o kavramı zihinlerinde tasarlamasında (canlandırmasında ve öğrenmesinde) daha çok yardımcı ve güçlendirici olacaktır. Aynı zamanda güçlü ve bütünleşik anlamsal ilişkiler metni okuyanlara daha çok soru sorduracak ve cevabın peşinden gitmek için onları teşvik edecektir.

Bundan sonraki tasarım aktivitelerinde yazı-görsel arası anlamsal ilişkileri tasarlarken bir önceki yazı içi anlamsal ilişkileri de dikkate almamız gerekmektedir. Böylelikle daha güçlü ve bütünleşik tasarımlar elde edebiliriz.

G
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Papers

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Conference Papers

1. Gül, M.D., & Costu, B. (2021, Mayıs). *Çokmodlu Bilimsel Metinlerdeki Yazı ve Görsel Modlar Arası Anlamsal İlişkilerin Analizi ve Tasarımı İçin Bir Analitik Çerçeve.* 14. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi. Burdur/Türkiye