INVESTIGATING SEVENTH GRADE STUDENTS' METACOGNITIVE PROCESSES DURING AND AFTER COLLABORATIVE LEARNING: A MULTIMETHOD STUDY IN SCIENCE CENTER CONTEXT

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ABSTRACT

INVESTIGATING SEVENTH GRADE STUDENTS' METACOGNITIVE PROCESSES DURING AND AFTER COLLABORATIVE LEARNING: A MULTIMETHOD STUDY IN SCIENCE CENTER CONTEXT

Türkmen, Gamze
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Metacognition is a fuzzy term and needs deeper investigation in different learning context to inform the psychological learning theories and instructional design practices. Science centers among the world provide life-long learning environments for the citizens. As they become widespread, the constant need to understand cyclical educational and organizational practices to inform instructional design practices under the lens of theoretical perspectives have become one of the primary issues to deal with. Figuring out the current educational and instructional design considerations might give a privilege to designers, practitioners, and researchers to understand in which conditions learners are at the core of the educational processes. For a deeper investigation of instructional design issues within the science centers, this qulitative inquiry-driven multimethod study underpinned the current practices of science centers and investigated the indicators of individual and shared metacognition within these learning environments. Underpinning the current practices led to propose instructional design considerations that might increase the educational effectiveness in science centers, and provide an auxiliary resource for researchers from different professional branches who are engaged in or prepared to make researches on science centers. Whereas, investigating the indicators of metacognition within science center settings both informed the learning theories and instructional design practices.

Keywords: Science Centers, Instructional Design, Eye-Tracking Methodology, Collaborative Learning, Metacognition

ÖZ

YEDİNCİ SINIF ÖĞRENCİLERİNİN İŞBİRLİKLİ ÖĞRENME SIRASINDA VE SONRASINDA ÜSTBİLİŞSEL SÜREÇLERİNİN İNCELENMESİ: BİLİM MERKEZİ BAĞLAMINDA ÇOKLU YÖNTEM ÇALIŞMASI

Türkmen, Gamze
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Bulanık bir terim olan üstbiliş, öğrenme teorilerini ve öğretim tasarımı uygulamalarını bilgilendirmek için farklı öğrenme ortamlarında daha derin bir araştırmaya ihtiyaç duymaktadır. Dünyadaki bilim merkezleri vatandaşlar için yaşam boyu öğrenme ortamları sunmaktadır. Yaygınlaştıkça, teorik bakış açıları çerçevesinde öğretim tasarımı uygulamalarını bilgilendirmek için döngüsel eğitim ve organizasyonel uygulamaları anlama ihtiyacı sürekli olarak ele alınması gereken öncelikli konulardan biri haline gelmiştir. Mevcut eğitim ve öğretim tasarımı hususlarını anlamak, tasarımcıların, uygulayıcılara ve araştırmacılara öğrenicilerin hangi süreçlerde eğitim süreçlerinin merkezinde olduğunu anlama ayrıcalığını verebilir. Bilim merkezlerindeki öğretim tasarımı konularının daha derinlemesine araştırılması için, bu nitel sorgulamaya dayalı çoklu yöntem çalışması, bilim merkezlerinin mevcut uygulamalarını desteklemekte ve bu öğrenme ortamlarındaki bireysel ve paylaşımlı üstbiliş göstergelerini araştırmaktadır. Mevcut uygulamaların desteklenmesi, bilim merkezlerinde eğitim etkinliğini artırabilecek öğretim tasarımı ile ilgili düşüncelerin önerilmesine ve bilim merkezlerinde araştırma yapan ya da bu merkezlerde araştırma yapmaya hazırlanan farklı meslek dallarından araştırmacılar için yardımcı bir kaynak sağlanmasına yol açmıştır. Bilim merkezi ortamlarında üstbiliş göstergelerinin araştırılması ise hem öğrenme teorilerini hem de öğretim tasarımı uygulamalarını bilgilendirmiştir.

Anahtar Kelimeler: Bilim Merkezleri, Öğretim Tasarımı, Göz İzleme Metodolojisi, İşbirlikli Öğrenme, Üstbiliş

To my beloved family and a healthy life

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LIST OF ABBREVIATIONS

ABBREVIATIONS

SC: Science Center

SCE: Science Center Educator

FGSC: Feza Gürsey Science Center

KSC: Kocaeli Science Center

WE: Work and Energy

FP: Force and Pressure

ET: Energy Transformation

MLA: Mirrors and Light Absorption

SSB: Solar System and Beyond

APK: Activating Prior Knowledge

CU: Conceptual Understanding

CHAPTER 1

INTRODUCTION

Scientific knowledge and interest in science are decisive factors in our understanding of the world and our actions. Acquiring the basics of scientific knowledge and gaining interest in science begin in school ages in terms of access to scientific ideas. The acquisition of impeccable scientific knowledge is not merely the involvement of citizens in these processes to shape professional goals and scientific discoveries. Moreover, encouraging each individual in a society to discover scientific reasoning methods to develop a shared understanding is one of the essential aims of science education. Interest is one of the factors having a central role in predicting students' learning processes, the quality of learning outcomes, and the sustainability of learning over time, as well as their achievement and knowledge development. Although there is a relationship between interest and success, there is no conclusive finding on the conditions under which circumstances this relationship exists. Not only differences in subject matters but also differences in learning environment designs and educational processes might cause uncertain results for the relationship between scientific interest and success.

Metacognitive processes that emerged during the involvement in educational activities play a crucial role in students' successful scientific reasoning and learning. To fully understand the importance of metacognitive processes during students' conceptual learning activities, looking deeper into the science curriculum is meant to provide a consistent baseline with the theoretical orientations. The new science curriculum of Turkey considered "*metacognitive processes*" under the competence of "*learning to learn*" which refers to "the ability of the individual to pursue and insist on learning so that s/he can organize his/her learning action individually or in groups, including effective time and knowledge management." In addition to the definition under the competence to "*learn to learn*", it provides recommendations on which learning strategies can be applied in which environments offering science centers also for out-of-school experiences. Therefore, it is crucial to design such in-school and out-of-school learning environments, referring to inquiry-based research to make students learn meaningfully and permanently.

The importance of designing learning environments according to learning strategies is mentioned, and it is emphasized that informal learning environments can also benefit from learning processes. The science curriculum also offers informal learning environments such as science centers, museums, planetariums, zoos, which are also essential to carry out student activities with their peers and facilitate developing contradictory arguments in response to peer's claims. Although it was emphasized in the science curriculum prepared in 2018, these environments should be designed in a way to support peer learning within the school atmosphere; it is said that these competencies can be transferred to informal learning environments for the recently prepared curriculum. As being informal learning environments, science centers provide a learning environment by providing opportunities such as tours for exhibition units and workshop facilities for active learning of the scientific concepts. Science centers have been widespread as informal learning environments drawing the attention of the majority of the population, including school groups, families, and individuals from different ages and backgrounds. Science centers maintain a constant renewal period for their organizational and educational processes due to its complex and dynamic nature to communicate science effectively to the aforementioned enormous population. As being practical tools in science teaching for being used by many teachers and researches, science centers' challenge in structuralizing organizational and educational processes and how practices being used in instructional design impact learning to enhance effectiveness is still searching for answers. Studies focusing on the impact of instructional design on learning in such environments have various interventions for educational practices such as worksheet-design (Hauan & DeWitt, 2017; Nyamupangedengu & Lelliott, 2012), augmented reality technologies or knowledge-building scaffolds (Yoon, Elinich, Wang, Steinmeier, & Tucker, 2012).

Science centers aim to bring science to society in a fun way and to increase interest and curiosity in science. They also function as areas for activities and practices for specialized groups (non-advantageous individuals, migrants, refugees, mothers, teachers, etc.). Science centers are also essential for carrying out extra-curricular activities. Science center educators offer students an enriched learning environment with the guidance of volunteers or teachers. Interactive exhibitions, experimental equipment, and workshops to provide an in-depth understanding of concepts; is one of the critical tools and activities of science centers. It is thought that such activities facilitate conceptual understanding of visitors and contribute to their long term recall. J. H. Falk and Needham (2011), in their study conducted at the California Science Center between 2000 and 2009, reported that 87 percent of parents had increased awareness of their children's understanding of science and technology. Similarly, parents' verbal accounts suggest that their children's interest in science and technology is expanding. That cognitive outcomes such as cognition or learning are higher than those affective outcomes. In this study, J. H. Falk and Needham (2011) investigated whether the definition of "homeostasis" was correctly answered by the visitors of the science center over time. And, they found that a large proportion of visitors remembered the definition of the concept correctly.

While investigating the widespread effects of science centers on society, conceptual understanding and learning-oriented studies have been one of the primary sources. Although these studies are multi-faceted, for accurate learning prediction, long-term ethnographic studies are needed. Bamberger and Tal (2008) conducted oral interviews with people visiting the science center after 16-month-duration, and they found that very few students established a connection between the identified topics. Although the fewness in developing relationships, they emphasized the importance of visits to the science centers regarding the acquisition of learning outcomes, the link between different sources of information, and supporting life-long learning. During group visits, sharing students' knowledge with their peers plays a vital role in ensuring that learning is effective.

In addition to learning from peers, it is essential to differentiate the metacognitive processes referring to different learning environments, including informal learning environments and classroom settings. The reason for this is that these two environments have different learning dynamics. In the science center environments, students have a potential chance to develop their conceptual understanding while experiencing different exhibition units by free-exploration. One leg of instructional design researches is keen on finding the differences between students' pre- and post-conceptual understanding ratings. Yoon et al. (2012) investigated how knowledge-building scaffolds promote collaboration by encouraging them to discuss scientific concepts among their peers. Therefore, conceptual knowledge survey and open-ended questions were applied among students, and their level of conceptual understanding was measured. Findings suggested that digital augmentation promoted conceptual understanding of students. Furthermore, an increase in theorizing about the phenomenon also suggested students need to be scaffolded for advanced learning. Therefore, Yoon et al. (2012) suggested digital augmentation for conceptual development of scientific knowledge within science center environments.

In addition to technological implications, Achiam, Simony, and Lindow (2016) conducted a paleontology program by prompting questions embedded in objects and observed how museum visitors' authentic science learning experiences could contribute to paleontologists' design for the target concepts. As another example, Holmes (2011) conducted experimental research under four conditions on changes in students' motivation and academic achievement scores for scientific conceptual learning during a visit to a science museum. Results revealed a significant relationship between students' visits to the museum, and both academic achievement and level of motivation with a smaller effect size occur for delayed post-tests. The small effect was interpreted due to the novelty of the environment. Similarly, Guisasola, Solbes, Barragues, Morentin, and Moreno (2009) found a significant increase of students' conceptual understanding regarding the special theory of relativity after designing the teaching sequence for a guided visit based on contextual model of learning due to collaboration with the teacher for pre-during and post-visit activities (J. H. Falk & Dierking, 1997).

Another leg of the instructional design in science center environments is focusing on the interaction design for exhibition units. Flag (1990) developed a digital interactive exhibit that was also asked for refinement of the target audience about the exhibit's appeal, comprehensibility, accessibility, and responsiveness. Based on paper-based formative evaluation due to a tight budget, the science museum video disc was redesigned for the satisfaction of audiences' preferences and recommendations. This study involved three legs of instructional design for an interactive exhibit, which are instructional designers, researchers, and the target audience. And it supported the collaboration between practitioners, researchers, and the audience leads to more effective instructions. Recent research by Roberts and Lyons (2020) offered a framework for coding learning talk among museum visitors while they are engaging in interactive exhibits either in full-body or in handheld conditions. Being driven by sociocultural theories of learning, they gave importance to idiosyncratic social learning talk for designing exhibits with distinctive learning objectives and for promoting visitors for talking on their specific aims in situ. Their experiment results revealed that visitors in handheld condition produced significantly more learning talk compared to the full-body condition, which was taken as a condition driven by theories based on embodied cognition. They argued that the reason why interaction between visitors and interactive exhibits did not produce more learning talk might be the fluency of actions. Besides, since any delayed conversation among visitors could not be captured, the long-term effect of this intervention was not detectable. Such kind of research specifies the needs of exhibit design based on a sociocultural theory perspective during visitors engage in exhibits in a meaningful way. So, these researches might also be useful for gaining learning outcomes compatible with the learning objectives.

Considering the critical factor in exhibit design, the compatibility of learning objectives with the exhibition units is a critical issue. In other words, compatibility refers to establishing a linkage between the design of the exhibit and the lesson unit.

So, compatibility may facilitate the design and implementation of a teaching sequence adopted to the science museum visit. In addition to the compatibility of learning objectives, clarity of the learning objectives of the exhibits is vital for specifying the teaching sequence. As the content and learning objectives of the exhibits are more comfortable to make sense, for the design of a guided visit to the science museum may consider setting a bridge between goals of exhibition units and lesson unit objectives by teachers.

Similarly, Liu, Chen, and Hwang (2018)examined the difference between students either visiting the exhibition with mobile label assisted system designed as a context-aware technology and in a traditional way to answer the questions (i) whether there is a significant learning performance difference or not, (ii) whether there is a considerable visiting stay-time difference or not and (iii) what kind of difference in behavioral patterns among two groups exist. After they designed the label instruction based on the 5E learning cycle, pointing out engagement, exploration, explanation, elaboration, and evaluation phases, two groups were compared in a quasi-experimental setup. While no significant difference was revealed for learning performance among mobile-assisted and traditional group students, there existed a considerable difference in visiting stay-time among them. Besides, they conducted a sequential lag analysis to see the difference in behavioral patterns. And, the analysis showed that the mobile label assisted the visiting group had focused on each learning task in scope of instructional design and followed each activity one by one rather than passing from one task to another without focusing on them. This study proposes that context-aware technology developed as a guide-tour may have long-term benefits by making visitors focus on each task rather than skipping them after a quick engagement.

Besides studies focusing on conceptual understanding and interaction design for exhibition units, design for guided visits has been discussed as well. Nelson (2015) examined the possibility of implications of Merrill's first principle of instruction regarding three learning in museum perspectives: (i) contextual model of learning (J. H. Falk, 2011), (ii) design for intrinsically motivating exhibits (Perry, 2012) and (iii) learning by engaging with museum objects (Vayne, 2012). Nelson (2015) utilized the significance of real-world problems mostly encountered in science, and children's museums can promote learning in an informal context, referring to Merrill's first principle. The reason for this utilization is related to the importance of visitor's prior knowledge before engaging in exhibits in a museum context. Also, familiarization of the faced problems in the museum context may contribute to the activation of existing prior knowledge to solve the issues inherited, which promotes implicit learning.

Studies focusing on the instructional design show that due to science centers' complex and dynamic nature, each science center may have its own educational and organizational processes to compensate for their extensive workload. Studies on the school-museum partnership show that educational effectiveness can be possible. Houseal, Abd-El-Khalick, and Destefano (2014) investigated the teacher's crucial role in students' learning of inquiring and science concepts in informal learning environments within the scope of student-teacher-scientist partnerships program. The study suggests that teachers have a mediator role responsible for making students gain inquiry learning skills within informal learning environments. It seems that the partnership which puts the teachers in the center has a higher impact on both increasing students' content knowledge and making them develop positive attitudes toward scientists. Hence, specifying the roles for each agent may provide a shared understanding regarding the science center visits with distributed roles of agents. Since each agent of the science center visit may be able to access detailed descriptions regarding the visit, they will be possibly accustomed to their roles before and after the visit. Therefore, the collaboration level between agents may be maximized for ensuring educational effectiveness. Similarly, Tal and Steiner (2006) conducted a qualitative study in which they investigated the patterns of teacher-museum staff relationships in three phases as while planning, during and end of the visit. The study revealed the situations which describe that teachers who are involved in planning the educational activities provide opportunities for enhancing the quality of educational activities.

The above paragraphs illustrated the importance of scientific knowledge and conceptual understanding among society members. Although formal learning environments include objectives for the acquisition of scientific knowledge, informal learning environments also have a life-long effect. The high collaboration level between different partnership institutions and agents might be enhanced by analyzing the needs and providing comprehensive suggestions. Furthermore, detecting and specifying metacognitive processes within the educational settings might offer a useful conceptual and practical tool for instructional design in science center environments.

1.1 Problem Statement

The presence of an alternative learning environment to formal learning environments in Turkey context with the expansion of science centers has the educational potential to provide rich learning environments. By providing extra-curricular activities, science centers have a role in promoting scientific concepts in teaching as well. Therefore, organizational and educational processes within the science centers are essential to be focused on enhancing educational effectiveness within the long-term period. Although science center activities have been added to the science curricula in recent years, discussion on how to build operations within these environments is still preserving its freshness.

Many researchers argue that metacognition plays a vital role in successful learning. It is foreseen that there is a need to develop instructional approaches by integrating the mechanisms of metacognitive processes (Y. Kim, Park, Moore, & Varma, 2013). Although metacognitive processes have been studied in the classroom and informal learning environments, researchers have not provided a comprehensive framework of teaching approach to these specific settings. Falk's contextual model of learning framework (2009) does not offer a suggestion for metacognitive processes while defining learning activities in science center environments. To suggest activities which can provide metacognitive development in the context of science centers, these processes should be examined by considering individual, social and environmental components. To increase educational effectiveness, studies that consider these components in the science center environment are needed.

1.2 Purpose of the Study

This research aims to investigate the metacognitive processes of the seventh-grade students in science centers during their conceptual understanding of scientific concepts by considering individual, social, and environmental factors in a holistic way.

The study aimed to examine the current situation of science centers in Turkey and to investigate metacognitive processes among seventh-grade students within science centers during scientific conceptual understanding. The purposes are three-folded for potential instructional design issues within science center environments. The first one is to examine the current activities and implications of science centers in Turkey. The second one is to identify the science center educators' metacognitive processes across three different cases during the guided school visit. Besides, to determine the metacognitive processes of students in collaboration during scientific conceptual understanding and to investigate how they evaluate their video products after science center experience. The overall aim of this study is to bring science teachers, science center educators, and students together and investigate the ways of increasing the educational effectiveness of science center environments for autonomous learners from the metacognition perspective. By considering the issues as mentioned earlier, the following questions constituted the research questions of this study.

1.2.1 Research Questions

1. What are the current practices in science centers based on science center educators' and science teachers' experiences?
    a. What are the current educational practices in science centers?
    b. What are the current organizational practices in science centers?
2. What are the indicators of implicit metacognitive actions of science center educators through the guidance phase when interacting with students?
3. What are the indicators of individual metacognition in science center environments?
4. What are the indicators of shared metacognition among peers during the collaborative activity?

1.3 Significance of the Study

This study provides contributions to metacognitive processes within informal learning environments, more specifically science center environments, regarding three dimensions as theory, methodology, and practical implications. First of all, the *theoretical foundations of metacognitive processes* promote the studies conducted with individual learners. However, it is still a matter of curiosity how metacognitive processes change when collaborative learners are on the stage under the influence of the theory of mind. Also, cognitive tools and learning in different learning environments will help to consolidate the theoretical foundations of metacognitive processes and facilitate achieving a dynamic theoretical perspective. Considering environmental factors (human, teaching strategy, cognitive tools, etc.), micro-movements (eye movements, finger movements, etc.) and determinants at the macro-level (academic achievement, conceptual evaluation, etc.) may help in reinforcing the theoretical foundation of metacognition.

Second, *methodological aspects* have gaps in the metacognition research field. Although different methodologies are tried to study the dimensions of knowledge and regulation of metacognitive processes, there is not yet a robust methodological approach to understand these processes. Taking into account micro-movements, macro-determinants, and environmental factors will provide a holistic approach to understanding metacognitive processes.

Third, practical implications need to be examined for providing a life-long and adaptive impact on educational effectiveness within informal learning environments. Therefore, it is essential to provide the necessary information on various aspects such as cooperation of the science center with other institutions, organizations and individuals, the external and internal architectural structures of the science center, and the education and training activities carried out in the science center to increase educational effectiveness of science centers. To deeply understand these issues and the elements necessary to provide them, the current practices of the science centers should be understood around these issues. Science teachers' and science center educators' experiences regarding educational effectiveness within science centers are vital to investigate the current situation. Thus, how science center educators carry out existing educational activities and how science teachers use the science center environment as extracurricular activities are essential questions to be investigated. The answers for them may provide information regarding increasing educational effectiveness within the science center environments during students' conceptual learning activities. These remedies should target educational activities and instructional designs that take into account the current limitations and theoretical perspectives in the science center environment. This study aims to determine the current situation of the different factors affecting the educational activities of the science centers and to propose theory-based findings that can increase educational effectiveness.

Although the findings obtained through data on what can be done to increase educational effectiveness in science centers predict how teaching processes can be shaped, it is not sufficient. The implementation of the activities prepared in the science center environment by the main actors is vital to observe the behavioral and cognitive activities of students, science center instructors, and teachers under natural settings. In studying this, it is crucial to evaluate the planned activities with a theoretical focus. In the researches, it seems that different theory-based processes are examined in the light of qualitative and quantitative findings to increase educational effectiveness in informal learning environments. Understanding metacognitive processes in informal learning environments are one of the theory-based approaches that draw attention. Study findings show that the high level of metacognitive activities of students and teachers increase their success levels in their courses and performances. Although one of the main goals of science centers is to provide students fun and motivation on scientific subjects, it is also essential to ensure that students learn and understand scientific concepts on issues that can work in parallel with the course objectives. With the help of the guided visits, understanding what kind of metacognitive knowledge and regulation processes the science center educators involved in and how they interact with the students will provide suggestions to regulate the processes to increase the metacognitive activities in these environments.

Understanding what kind of metacognitive processes the science center educators are involved in during the guided visits may also facilitate to predict how one should organize that learning environment. It is also essential to understand students' metacognitive processes within those environments in addition to science center educators'. Preparing the ground for designing activities and learning environments supporting students' metacognitive activities during their individual and collaborative learning experiences would be foreseen when students' metacognitive knowledge and regulation processes are understood. Although there are instructions for teachers' metacognitive activities in teaching, there are no instructions for metacognitive activities in synchronized guided visits for science center educators. Having these instructions will facilitate and identify the role of science center educators and teachers in helping students organize their cognitive processes.

Although students' individual learning experiences within science center environments are highlighted, guided visits and leisure activities provide a collaborative learning environment for students as well. In addition to revealing the findings of the metacognitive processes of science center educators in these environments, it is also essential to describe the interaction of the students with their peers and the means of the metacognitive activities that this interaction creates. Metacognitive processes described as a result of the interaction between peer, teacher, and science center educators and student elements need to be handled both individually and in shared terms.

To develop activities that facilitate and increase the operation of students', teachers, and science center educators' metacognitive processes, processes should be defined within the science center environment. During this definition, it is crucial to understand how students interact with cognitive tools, their peers, or educators collaboratively. Existing methodological practices are inadequate to provide a comprehensive assessment of these processes. Azevedo (2015) have used qualitative and quantitative methods to investigate metacognitive processes. There are also eye-tracking techniques, survey applications, and self-evaluation activities in these methods. However, there is a lack of implementation of these methodologies during metacognitive knowledge, and regulation processes are carried out in the science center environment. Therefore, this study provides a new perspective on conducting research studies in similar settings.

This study draws on the first and third views of the metacognitive processes during the students perform the collaborative learning activity, including records pointing to eye movements, verbal expressions, and cognitive tools. The students answer the conceptual questions from the given worksheets concerning the exhibition unit of interest. Thus, this assessment facilitates the comprehensive deciphering of metacognitive knowledge and regulation processes in the science center environment. Besides, in the collaborative learning activities for different concepts, it is provided to understand what types of metacognitive processes and metacognitive and cognitive activities students have in which concepts and cognitive tools.

In addition to providing a comprehensive proposal for methodological limitations, understanding metacognitive processes according to behaviors, eye movements, and verbal expressions in science centers provides practical implication suggestions for instructional designers, teachers, science center educators, and students. These practical implications can be structuralized as questions that facilitate conceptual understanding, guidelines for novice science center educators for guided visits, guidelines for teachers accompanying guided tours, and activities to support students' metacognitive processes.

It is important for science center educators to manage metacognitive processes in guided visits and free-exploration time activities to enable students to learn individually and to support their collaborative learning experience. With this study, key points were investigated for science center educators to operate metacognitive processes effectively. Besides, suggestions were given for which concepts and in what order they can benefit from cognitive tools. Secondly, this study has a significant role in determining the roles of science teachers before, during, and after guided visits, and to derive opinions on what impact students may have on their metacognitive processes. Thus, science teachers may benefit from the findings of this study in preparing students for science center visits, helping them be metacognitively active and make sense of science concepts during science center visit, and help them revisit and retain their understanding of science concepts after science center visit.

1. **Practical Contributions:** Practical contributions of this thesis finding may provide information for science center educators, science center directors, teachers, and policymakers regarding enhancing the educational effectiveness within science centers.
    a. ***Educational Activities:*** Science center educators, science center managers, instructional designers and teachers may get information regarding how educational activities should be refined to enhance educational effectiveness. First of all, science center educators may see the opportunity for training alternatives for a variety of instructional strategies. Moreoever, science center managers may get insights regarding the effect of the lack of human resources on

educational effectiveness within the science center environments. Also, instructional designers may be informed about the metacognitive-oriented instructional design, the timing issue in the instructional design, the timing of the assessment, used concepts and material selection for better conceptual understanding. Finally, science teachers may

b. ***Organizational Structures:*** Science center management and policymakers may get informative hints regarding how institutions can be more effective and productive.

c. ***Behavioral Contributions:*** Science center educators and teachers may get information regarding how educational implications and interventions can be developed.

2. **Theoretical Contributions:** Theoretical contributions of this thesis study may possibly contribute to metacognition research. Theoretical contributions may propose five-facet understading for the metacognition research. First, since guidance in science center visit, and collaborative activity in science center require the real context, the metacognitive processes in wild had a potential to be detected in relation to students' conceptual understanding and exhibition units. So, the potential effect of the design of the science center environments, its embedded materials, and given guidance or hand-materials on students' metacognitive processes and conceptual understanding found a way to be understood. Second, the occurence of students' metacognitive actions and their relation to their conceptual understanding was another aspect for theoretical contributions. Thus, it was observable that under which place, condition and subject matter, students' metacognitive actions occur in what way. Third, the potential relationship between science center educators' metacognitive actions and students' metacognitive actions were observable by the field notes. This might pinpoint the bidirectional relationship for metacognitive actions during the guidance phase, and its potential relation to the collaborative phase for the individual and shared metacognitive actions.

Observing the potential mediator role of the instructional strategies during the guidance phase might give an insight for the future researches for metacognition in real-contexts. Fourth, metacognition-related eye movement patterns during the collaborative activity and their potential meaning may contribute to the elaboration of metacognitive concepts for further theoretical researches. Finally, occurence of individual and shared metacognition in science center contexts based on the available instructional design may bring the metacognition researches to temporal evolution of shared dimension of the metacognition throughout the collaborative activity regarding the placement.

3. **Methodological Contributions:** Methodological contributions of this thesis may contribute to the metacognition research field. Two important methodological contributions may be underlied via this thesis study aimed at better understanding the phenomena of metacognition: (1) the assessment method chosen to elicit the metacognition and (2) the time at which to assess the metacognition. In regards to the first contribution, metacognition theory of learning is applicable. Studies relying on the discrete metacognitive activities suggest that the use of briefly presented high challenging tasks may be useful in eliciting a discrete metacognitive activity such as underlying or highlighting. However, it is not always possible to validate the elicited discrete metacognitive activities are visible under high challenging situatios. Metacognitive activities may also be elicited by low challenging situations as a high challenging tasks for low performer students. Further, because high performer students may potentially shorten the problem solution period, and low performer students may potentially extend the problem solution period in either high challenging and low challenging situations, assessment of duration might be an important factor to understand the students' profiles acroos different dimensions of metacognitive processes. Also, timing of assessment was also an important issue due to need for observing on-line (in-situ) metacognitive activities. So, it is important to use multi-method studies

for metacognition researchers. And, this thesis study might possibly have a contributive effect on filling this gap. Synchronous collaborative pair analysis based on the eye-tracking video data was to triangulate the metacognitive actions. And, taking into account micro-movements (eye movement, pointing behavior), macro-determinants (conceptual understanding levels), and environmental factors (placement, affordances) might provide a holistic approach to understanding metacognition in wild.

1.4 Limitations

The limitations of this thesis study are three-folded: (i) *participants*, (ii) *duration period,* (iii) *methodological instruments,* and (iv) *contextual factors*. First of all, *participants for current practices* were both science center educators and science teachers. However, the sample size for science teachers were limited to three people and the researcher interviewed them based on their voluntariness. So, this only provided three teachers' perceptions regarding the current practices during the science center visit. Also, since the sample size for science teachers were limited to three people, the researcher could not relate science center educators and science teachers' perceptions for all science centers. Second, *duration period* for interviewing for the current practices lasted between August, 2016 and March, 2018. Since science centers are a dynamic environment and their adaptation rates for the innovations are comparable high, there might be limitations on recently emerged educational and organizational practices. Also, *duration period* for multiple case study lasted for three weeks for each lesson unit. There might be a longitudinal study to measure the effectiveness of the educational activities; however, this study focused on the metacognitive processes during guidance and collaboration phases. Third, *methodological instruments* were varied for the qualitative data including interview questions, video camera recording, and mobile eye-tracking. So, the validity of the study is limited to the reliability of the instruments. Also, for eye-tracking data, since students were on the move and made transitions between different exhibition units, and looked at a variety of sources during the collaborative activity, the ecological validity of the collaboration phase is limited to eye-tracking device. Finally, although internal and external validity issues were considered for each study part, *contextual factors* such as light, noise, and temperature might influence the results. The researcher tried to minimize the limitations and the risks of aforementioned confounding variables.

1.5 Delimitations

The delimitations of this thesis study are three-folded as well: (i) *selected lesson units,* (ii) *selected exhibition units,* and (iii) *selected science center contexts.* First of all, *selected lesson units* were delimited to Work and Energy, Mirrors and Light Absorption, and Solar System and Beyond. Thus, the scientific concepts for this study were delimited to the lesson objectives from these three units. Second, *selected exhibition units* were delimited to the selected science center contexts and the available exhibition units at there for selected lesson units. Finally, *selected science center contexts* were delimited to Feza Gürsey Science Center, and Kocaeli Science Center so that the exhibition units were selected as the science center environment allows.

1.6 Definition of Terms

Metacognition: Metacognition refers to planning, monitoring, and evaluating processes in order to understand one’s own performance. It includes critical awareness of one’s thinking and learning and oneself as a thinker and learner (Anderson, Nashon, & Thomas, 2008; Tanner, 2012; Zohar & Barzilai, 2013).

Shared metacognition: Shared metacognition refers to critical awareness of one’s learning during meaning construction in regard with self and others based on planning, monitoring, and evaluating processes (L. De Backer, Van Keer, & Valcke, 2015a, 2015b; Iiskala, Vauras, Lehtinen, & Salonen, 2011).

Shared understanding: Shared understanding refers to coordination of the behaviors towards common goals of more than one person based on mutual knowledge on the task, the person, and the strategy variables which are dynamically changing through the work (Afonso & Gilbert, 2006; J. Falk, 2004; Guisasola et al., 2009).

Joint attention: Joint attention refers to intentional attention to the same thing by two people. It does not involve an understanding based on the knowledge or belief in contrast to shared understanding. But, it may mean to construct a prior attention for acquiring further knowledge or belief (Abrahamson, Shayan, Bakker, & van der Schaaf, 2015; Hwang, Wang, & Pomplun, 2011).

Science Center: Science center refers to explorative environments encouraging visitors to practice hands-on exercises or interactive exhibits.

Science Center Educator: Science center educator refers to a person who guides the students during the guided tours or field-trips and takes an active role during instructional design processes of the science center.

Field-trip: Field-trip refers to school science center visit as curricular or extracurricular activities. It may be guided or free-explorative for a variety of objectives.

CHAPTER 2

LITERATURE REVIEW

This chapter includes a literature review related to the science center, science education and metacognition, and instructional design processes that might be beneficial in enhancing the educational effectiveness of the science center activities. Following titles begin to pinpoint the relationship between science centers, science education and metacognition, the relationship between the collaboration and the metacognition including both eye-tracking and traditional experimental and qualitative types of research, instructional design for science center environments and potential contribution of metacognitive researches to instructional design processes, the historical development of the science centers among the world, and the historical development of the metacognition researches. Figure 2.1 shows the organization of the literature.

Furthermore, in this literature review, the metacognition construct will be extended to social perspective and studies on shared metacognition and found indicators of shared metacognition will contend.

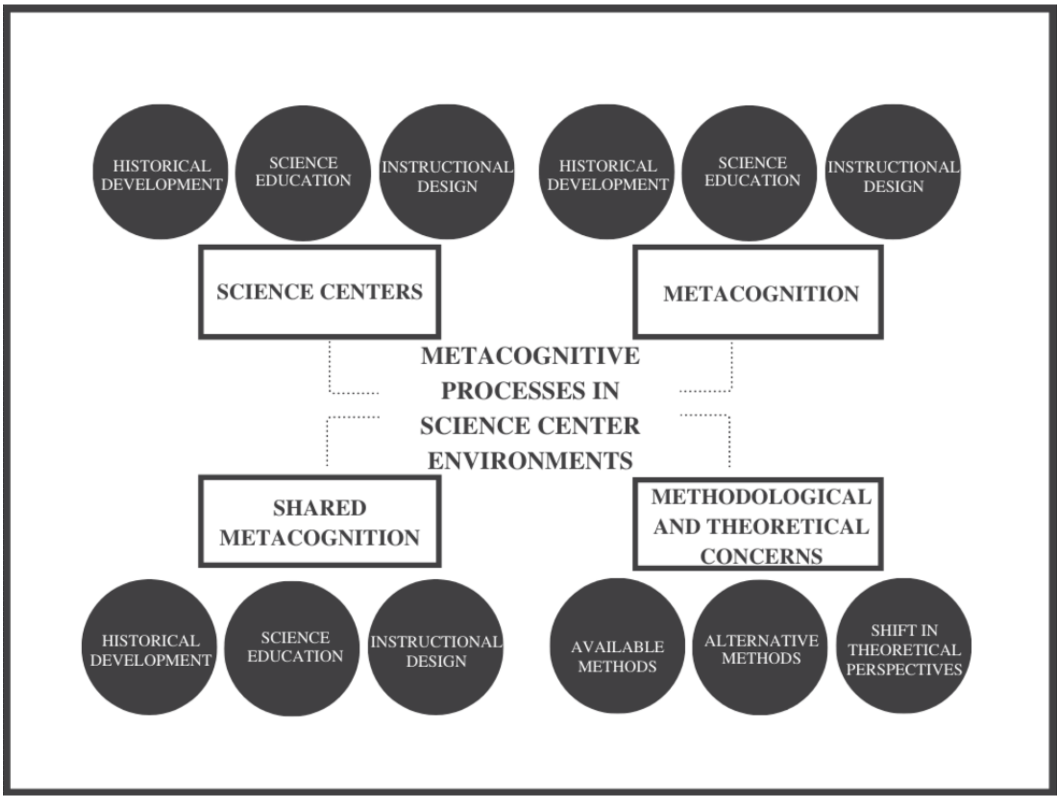


Figure 2.1 The organization of the literature

Recent Information on Education in Turkey

In the studies, it was found that in countries where the number of teachers per student is high, the results of PISA and TIMMs are above average in comparison with the results in countries with a low number of teachers. Considering the context of Turkey, the number of teachers per 100 students and the number of students per class varies by region. Figure 2.2. illustrates these differences graphically. This number ranges from five to eight. In addition to this, when we look at the OECD countries, according to 2015 data, the ratio of public and private spending to Turkey's education, remains below the average for OECD countries (see Figure 2.3.). This increase, which may be based on a lack of economic resources, seems to be related to the country's economic policies. It appears that there is a need for suggestions and guidance on what kind of work can be done to make the most effective financial situation, teacher employment, and inadequacy of teaching activities in the current situation.

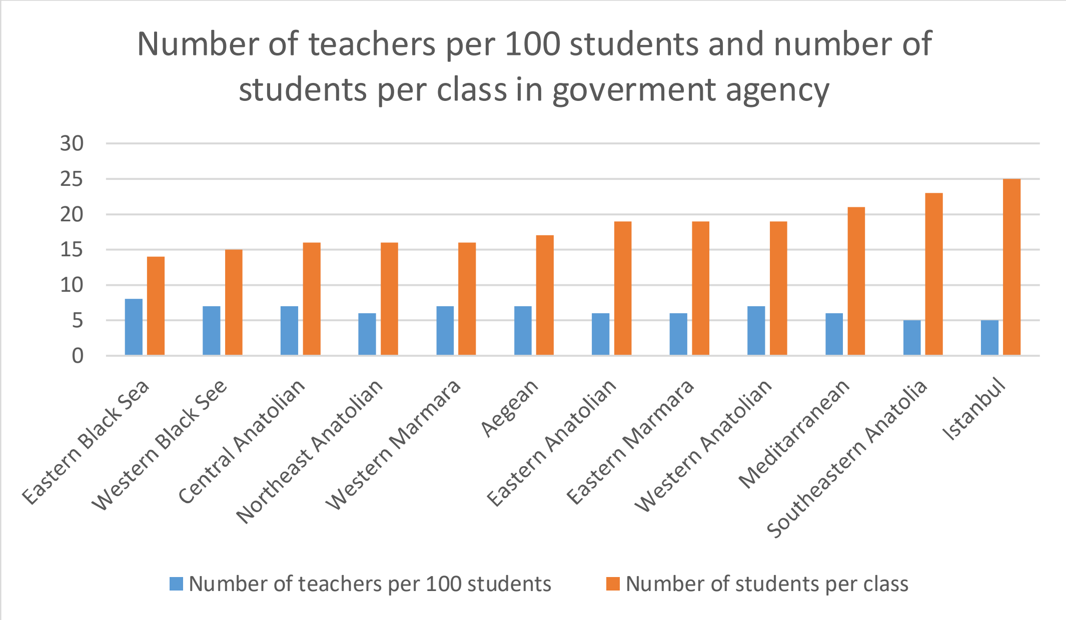


Figure 2.2 The number of teachers per 100 students and the number of students per class in the government agency

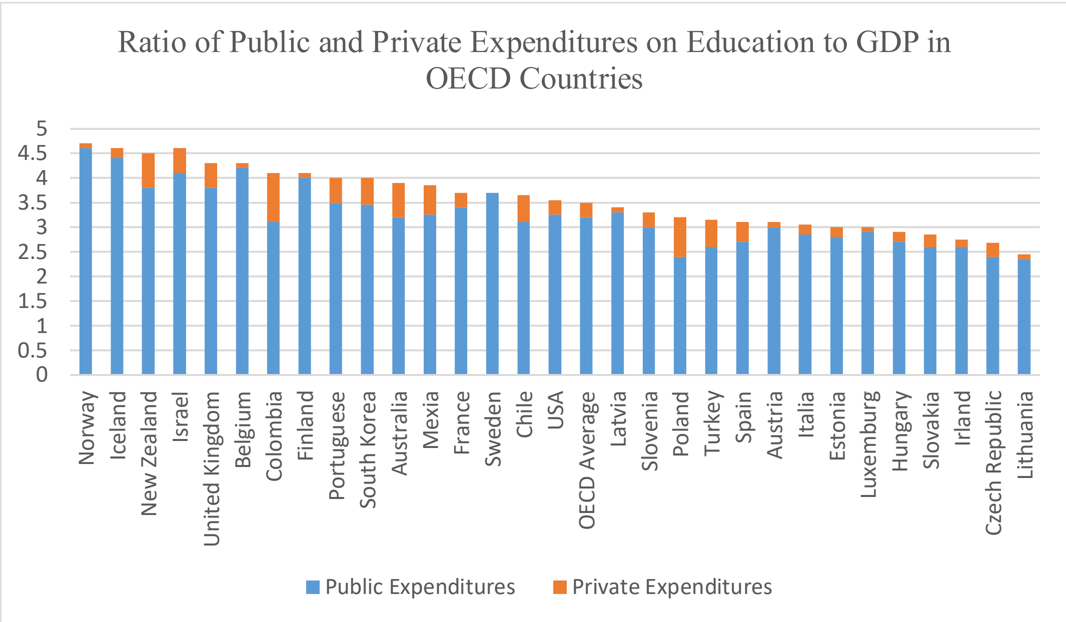


Figure 2.3 The ratio of public and private expenditures on education

2.1 Science Centers

Science centers were established in the 19th century to contribute to the training of industrial workers. However, over time, the target audience and science center environments have changed. With the target population of science centers being the whole society, the centers have started to determine the gains aimed at the society. The change in the target audience leads to changes in the interior environments of science centers as well. During its establishment, it has undertaken the task of object catalog that introduces the underlying scientific concepts to visitors. Over time, however, supportive materials have been added for student and teacher groups. Science centers such as the Deutsches Museum, the London Science Museum, or the San Francisco Exploratorium have evolved into an educational role for the target audience. This educational role includes educational programs for school education programs. Together with these school education programs, it aimed to strengthen the communication between the teacher and the science center and to increase the educational effectiveness in the science centers by supporting the school curriculum.

2.1.1 Historical Development of Science Centers

The foundation of the science center was set up in Turkey, referring to the implementation plan of the State Planning Organization in 1983 by providing budget support for science museums and science centers. In 1984, an international panel of consultants determined the basic principles of science museums and science centers in Turkey. These principles were centered around seven issues as the need for international support, the design of the architectural structure, the exhibition policies, research activities, library property, special groups, and planetarium. The committee specified special groups, research activities, and the placement of exhibition units as essential factors. The reasons for this emphasization were to determine the limitations of the learning environment and define the characteristics of school group visits. Referring to these characteristics, Feza Gürsey Science Center, which was the pioneering one, was established in Turkey in 1994. Later than this, universities, municipalities, and private institutions founded the science centers. And, as of 2010, the establishment process of science centers has been expanded through TUBITAK.

It was stated that science museums and centers are practical tools in science teaching for being used by many teachers and academicians. Although the factors on which effectiveness in teaching is not yet clearly defined, it is seen that it is important to have the exhibition units which will enable the active participation of the visitors and self-learning. Leading science museums and centers, such as London Science Museum, Deutsches Museum, Chicago Science and Industry Museum, Ontario Science Center and La Villette Science and Industry Center were established considering learning by doing and experiences which are aiming at learning the basic principles of daily life examples by experiencing without requiring any prior knowledge. These pioneering science museums and centers have been conducting various social and cultural project activities without waiting for the visitors, but they are also trying to attract visitors to science museums and centers and make people experience daily science as a mobile science center.

Worldwide Examples

Exhibition policies of museums prioritized the educator role rather than exhibiting foundations and evolution of science over time. The exhibition tools related with the foundations and evolution of science after the Industrial Revolution were exhibited in the competitions by Western European countries as international exhibitions to inform the public in the 19^{th} century, and thus they served as a source for science centers and museums (Aktüre, 1988).

London Science Museum (LSM), one of these international exhibitions, is one of the first sources of these museums serving as an “object catalog”, aiming at introducing the foundations of science to visitors. Besides, this museum had instructive explanations and supplementary documents for school groups, supportive materials for teachers accompanying students during the museum visits, and appropriate worksheets in consideration with students' ages to make the museum visit more effective and to measure to what extend museum visit is educative.

In addition to LSM, Deutsches Museum (DM) has pioneered the science museums, which provide active participation of visitors and highlight the educational function. Although the purpose of the establishment was to contribute to the training of industrial workers, the target group has changed today. Its objectives have been renewed as to accustom the society to the basic sciences and the technologies based on them. Similar to LSM, DM guides students in school groups and introduces the environment and exhibition units to them before the science museum visit.

Beside LSM and DM, the City of Science and Industry in Paris (CSI) was established to describe the conceptual sides of the basic research considering the relationship between science and research to its visitors. This science center, which was established under the University of Paris, allows adults and childhood visitors to meet with scientific research. This science center, which has been accounted as the pioneer of the science center approach, has played a role model in the establishment of many scientific centers such as San Francisco Exploratorium. Exploratorium, founded with this exemplary model, was designed to avoid the instructional attitude of the exhibition halls and to enable students to learn and explore.

Ontario Science Center (OSC), on the other hand, concepts having a scientific basis in everyday life were presented to visitors through having experiences on them. OSC prepared educational programs supporting the school education program and served as a mobile science center for schools having a lack of opportunity to visit the science center.

When we look at the science museums and centers around the world, we see that they are trying to present their self-learning experience with active participation as well as being entertaining. We understand that they are supporting school curriculums and trying to establish teacher-science center cooperation prior to the school group visits, which may be counted as factors for enhancing educational effectiveness in science centers.

Science Centers and Museums in Turkey

The activity rate for science museums and centers has started to increase by the provision of budgetary support and study and planning studies included in the implementation plan of the State Planning Organization in 1983. In the panel of TUBITAK Natural History and TUBITAK Science and Technology Museums International Consultants Panel, which was held in 1984, the decisions regarding the planning studies on the establishment of science museums and centers under the leadership of TUBITAK were revealed. Due to the limited knowledge of Turkey's science museums and centers, many scholars and experts focusing on central planning and sustainability of science museums from abroad and the country were involved. In this meeting, factors assured as important such as international support, the architectural structure of science museum and centers, exhibition policies, research activities, library facility, special groups, planetarium and issues regarding organizational structures were taken into consideration to be held during the establishment phase. Among these considerations, special groups, research activities, and arrangement of exhibition units were stated as essential factors for setting the boundaries of learning environments and defining the characteristics of school group visits.

Following the panel, the Science Center and Science Garden was planned in the light of these decisions. In the planning stage, it was stated that the purpose of Science Garden is to provide interactive exhibitions in comprehending the scientific principles for students. After planning stage, the center was considered as a whole and the exhibition units, natural history research department, planetarium, library, film and conference hall and workshops and auxiliary science were designed under five sub-units. At the end, Science Garden was planned as three subfields: science and technology, botany and zoology.

2.2 Science Education in Science Centers

Science education in science centers might concern four-dimensional issues to take into consideration such as student interactions via gaming in science centers (Atwood-Blaine & Huffman, 2017), the long-term effect of science center visits (Bamberger & Tal, 2008), stakeholders' contributions to science education within science center, and short-term influence of science center visits on students' learning processes. These four issues mentioned previously might be the centeral factors to understand the educational activities and concerns targeting science education within science centers.

First of all, student interactions in a science center converge diverse educational concerns embedded in the science education such as mobile gaming (Atwood-Blaine & Huffman, 2017). Mobile-based gaming technology in science centers have become popular to encourage students for interacting with the environment (their peers, exhibition units, educators etc.) either in a variety of fun ways or taking a goal-oriented approach. Atwood-Blaine and Huffman (2017) found that female and male students differentiate in ways of enjoyment and perceptions of game. In findings, female students perceived the game more difficult in case they completed more challenges; whereas, male students perceived the game more enjoyful and felt victorous in case they completed more challenges. This difference in interpretation of the game success among female and male student might be due to the level of collaboration and competition preferences for an adaptive mobile game embedded in science center activities.

In addition, students' visits to science centers or their outreach labs as extracurricular learning activities have potential effects on students' achievement levels. Itzek-Greulich et al. (2015) reported that only school environment had greater impact on students' achievement levels for science subjects compared to students' achievement levels within science center outreach laboratories. The reason of this might be the novelty effect of the specific features within the laboratory environment. As a follow-up study, Itzek-Greulich and Vollmer (2017) reported that science center lab works contributed positively to students' motivation and emotional outcomes in case science center laboratory works combined with the in-class activities. However, contributions of only science center laboratory works did not reveal significant results for students' motivational and emotional outcomes. This might refer to unboundness of the environmental setting of the intervention with the emotional and motivational outcomes. Since students' expectations focused on hands-on practice within the laboratory setting and they encountered the theory part first, they experienced boredom due to the hands-on practice only expectations. Thus, the findings supported that "content" of the scientific works was relatively important than the "environment" those works carried out.

Beside short-term effects of science center visits, investigating the long-term effects of science center visits is also a vital matter for understanding students' cognitive, non-cognitive and metacognitive outcomes. There have been few studies on the effects of the science center visit on the long-run on students' cognitive and non-cognitive outcomes (J. H. Falk & Dierking, 1997; Krange, Silseth, & Pierroux, 2019).

A gap exists between teachers' expected science center activities and and actual science center activities for Turkey case (Karademir, Kartal, & Türk, 2019). Based on preschool teachers' expectations and actual activities carried out, the gap occurs for existing materials, material selection and method selection. Besides, students' negative interest or physical condition in a museum, called as museum fatigue, might provide a proof-by-contradiction approach for specification of the factors and features affecting students' science learning (M. Kim, Dillon, & Song, 2018). While lack of exhibits in science centers result in unsatisfying the students' needs regarding the scientific learning experiences, lack of adaptive exhibition units compatible with the students' academic levels reduce students' scientific interest (M. Kim et al., 2018).

H. Zimmerman, Reeve, and Bell (2008) investigated parents and their children behaviors in a science museum center and adopted a theoretical framework considering individual, social and cultural accounts throughout analyzing the learning processes of children. Conversation analysis of parents and their children released two categories which are related with making the epistemic moves for leading to different social and intellectual roles in the conversations which may keen on the prior science activities and distributed roles among the family members and museum environment which contributed to the conversation. Based on this research, H. Zimmerman et al. (2008), as a future research, suggested to use interaction analysis for the designers and developers for identifying the potential areas which contribute to school groups or families to make sense of the content.

Similarly, T. White and Pea (2011) investigated how a designed learning environment can contribute to students' engagement in learning the relationships among multiple representations while they are working together on a shared task. Findings of the study revealed that the managing the challenges during the relevance process for multiple representations leads to group members to rearrange their roles for different meaning and the use of flexible tools accompanied with the difficulty sequences for the tasks. In addition, Gentner et al. (2016) tested children's analogical learning and conducted a naturalistic activity with their parents.

2.2.1 Definitional History of Metacognition

Metacognition refers to after, behind or beyond cognition which has been appointed as a difficult concept in distinguishing the terms between meta and cognition (Brown, Bransford, Ferrara, & Campione, 1983; Flavell, 1979). Thus, before making concrete definition of metacognition to proceed in this thesis study, it is important to specify what metacognition is not and what kind of boundaries can be drawn to bring the differences between cognition and metacognition to light.

Being known as a mixing metaphor, *metacognition* has been referred to different meaning from different researchers. While Brown (1987) defined metacognition as one's knowledge and control of own cognitive system, (Flavell, 1979) defined as knowing and being aware during monitoring and control of their own knowledge and processes. Moreover, Weinert (1987) and Kuhn (2000) defined *metacognition* as a second-order cognition.

Table 2.1 Definitional History of Metacognition

Researcher	Definition	Indicators
Flavell (1977)	Self-knowledge and control of own cognitive system	Self-knowledge
Brown (1987)	Knowing and being aware during monitoring and control of one's own knowledge and processes	Self-awareness
Weinert (1987)	Second-order cognition	Other-awareness
Kuhn (2000)	Second-order cognition	Other-awareness, Self-knowledge

Although common belief regarding the definition of *metacognition* includes monitor and control of own knowledge and processes which refer that cognition *succeeds and applies to its own products* (Newell, 1994), being perceived as fuzzy meaning has promoted the researchers to clarify the historical roots of metacognition constructs. Dinsmore, Alexander, and Loughlin (2008) and (Schunk, 2008) investigated the differences between metacognition constructs and defined each construct to be used in the further researchers and they acknowledged them in clearly defining the metacognition constructs so that the researchers will not be disconnected from the theory in itself and propose lack of educational outcomes.

Metacognitive constructs which are mentioned as two main categories are oversimplified to proceed in metacognition reearchers as knowledge of cognition and regulation of cognition. The historical roots until the emergence of aforementioned *metacognition constructs* stressed out reflective thinking, self-knowledge, and memory. Table 2.2 shows how pioneer educational researchers related reflection to metacognition-related phases and how they defined the related conceptual constructs in regard to metacognition.

Table 2.2 Pinoeer researchers' reflection to metacognition-related phases

Researcher	Metacognition related phases	Contextual environment
Dewey (1933)	State of doubt, act of searching, reflective thinking	Individual reflection in problem context (self-metacognition)
(Vygotsky, 1980)	Internalization of speech, internal dialogue	Voluntary self-regulated behavior arises as an internal function

In addition to relationship between metacognition and reflective thinking, self-knowledge has been considered as an important element in providing connections between metacognition and reflective thinking. Bogdan (2000) assured that self-knowledge which can be also affected by the interaction with others is related to both reflection and metacognition; whereas, Flavell (1979) assured that self-knowledge which is affected by the learner's beliefs on metacognitive knowledge and their beliefs regarding themselves inside the world is also fundamental for metacognitive processes in problem solving situations. Similarly, Schraw and emphasized self-knowledge is an essential component of Schraw and Dennison (1994) metacognition. Beside the self-knowledge, prior knowledge is also important to develop metacognition upon existence knowledge according to Dewey (1933) and Kant (1933).

Memory-related ideas in relation to *metacognition* also found the baseline for metacognition researchers. Table 2.3 shows the memory-related concepts and their relation to metacognition based on researchers' ideas.

Table 2.3 Pioneer researchers' reflection to memory-development in relation to metacognition

Researcher	Relation to metacognition	Contextual environment
Flavell (1979)	Facilitating the solving of mnemonic problems, ability to reason and make inferences and interpretations during the processing, storing and retrieval of information	Self-metacognition in problem solving contexts
Corsini (1999)	Interaction between the task and prior experience relies upon memory development and the development of mnemonic strategies in problem solving context	Self- and shared-metacognition in problem solving contexts
Brown (1987)	Effective use of plans, schemes or mnemonic strategies such as processes or strategies applied during problem solving	Self-metacognition in problem solving contexts
James (1992)	Use of memory strategies to monitor and facilitate recollection	Self-metacognition in problem solving contexts
Wellman (1985)	The connection between memory and metamemory is based upon a theory of mind involving interaction between knowledge and action	Self- and shared-metacognition

The contextual environment of memory-related studies mostly relies upon problem solving context either a possibility for prediction of the relation to type of metacognition. Flavell (1979) assured that memory development facilitate the solving of mnemonic problems and gains ability to reason and make inferences and interpretations during the processing stording and retriecal of information. The extension of this view in regard to memory-development may be related with self-metacognition within problem solving contexts due to evaluation of the information processes as individual unit. Similar to Flavell (1979), Brown (1987)'s and James (1992)' account on memory development has been founding the basis of self-metacognition in problem solving contexts as a descriptive procedure of use of memory strategies for monitoring and facilitating recollection. As the use of memory strategies along the memory development periods shows similar descriptions to metacognition, from the social perspective, it also shows similar processes to social aspect of metacognition or social metacognition. Corsini (1992), and Wellman (1983) emphasize the interaction between tasks, environments and persons which may found the basis for social metacognition.

Table 2.4 Flavell and Wellman's four broad categories of memory matched with Brown's taxonomy of memory

Brown's taxonomy of memory	Flavell and Wellman's categories	Description
	First category	Basic, unconscious memory operations include processes applied in recognizing an object, recall of absent objects or situations and cueing
Knowing	Second category	Direct, involuntary and unconscious effects of the level of cognitive development on memory including the development of strategies to acquire, store and retrieve information and find similar meaning and conceptual links. Adults find it much easier than children to do this.
Knowing how to know	Third category	Variety of conscious, voluntary, mnemonic strategies and control processes used to meet task requirements
Knowing about knowing	Fourth category	Awareness and knowledge of memory and apprehension, storage and retrieval processes or specifically metamemory or knowledge about memory

Since memory-development ideas are believed to closely related with metacognitive development, doing comparison between Brown's taxonomy of memory and Flavell (1979) and Wellman (1985)'s categories of memory which constructed the baseline for metacognitive researches is important to see the matched categories and how they are related to metacognitive development. In Bron's taxonomy of memory, there are three categories which begins by knowing; whereas, Flavell (1979) and Wellman (1985) added a priori category which is based on the ground of basic and unconscious memory operations.

2.2.2 Models of Metacognition

Beside the historical perspective to metacognition which was dominantly affected by reflection, self-knowledge and memory researches, conceptual emergence of metacognition has been understood in regard to constructed models. Table 2.5 shows the models of metacognition and the main categories of metacognition which are taken as fundamental constructs.

Table 2.5 Models of Metacognition

Researcher	Model	Main Categories
Flavell (1979)	Model of Cognitive Monitoring	Reflective awareness, monitoring of mental states
Brown (1987)	Conceptualization of Metacognition	Knowledge of cognition (metacognitive knowledge), regulation of cognition (metacognitive regulation)
Pressley, Borkowski, and Schneider (1987)	Good Information Processing Model	Metacognitive acquisition, specific strategy knowledge, general strategy knowledge
Kuhn (2000)	Theory of meta-knowing	Metacognitive knowing, metastrategic knowing

Flavell (1979)'s model of cognitive monitoring relies upon the reflective awareness and monitoring of mental states. According to model of cognitive monitoring, knowledge and problem solving develops over time with exposure to and experience in solving different problems. This developed knowledge includes the ability to clarify unclear goals, pursue several goals, set explicit goals intentionally, and adopt and deliberately pursue goals which are not self-selected. These cognitive goals and subgoals can be either *implicit* or *explicit* objectives which aim to facilitate the initiation, progression and completion of the problem or cognitive enterprise. Although cognitive goals and subgoals of the problem or cognitive enterprise can be facilitated by cognitive actions, increase in the complexity of problems may also affect the relationship between cognitive goals and cognitive actions.

Model of cognitive monitoring takes the metacognitive knowledge as either as *implicit* or *explicit* application of knowledge which can be grouped under two categories as declarative or procedural. Person metacognitive knowledge in model of cognitive monitoring includes beliefs and intuitions regarding the cognitive ability and nature of oneself and others and encompasses subcategories as universals of cognition, intra-individual differences, and inter-individual differences. In addition, task metacognitive knowledge includes two categories as task information and task demands.

In addition to Flavell's model of cognitive monitoring, Brown (1987) conceptualizes the metacognition by defining it as the knowledge of cognition and resembles it to a form of self-awareness. Although Brown (1987) assured that knowledge of cognition is the primary process of metacognition, he considered that regulation of cognition is a secondary process of metacognition. According to Brown (1987), knowledge informs the regulatory processes so that both knowledge of cognition and regulation of cognition are underpinned. According to Brown's conceptualization of metacognition, knowledge of cognition is related with the ability to judge knowledge accessibility and the awareness of information that is not known and information inferred from what is already known; whereas, regulation of cognition is described under the scope of *executive functioning*.

Borkowski and Pressley's good information processing model, on the other hand, assures that contextual and situational elements and self-system have influence on the development of general and specific strategy knowledge. Also, metacognitive acquisition procedures and specific strategy knowledge has been effected by strategy transferability.

2.2.3 Taxonomy of Metacognition

Metacognition has been investigated under two main constructs as metacognitive knowledge and metacognitive regulation; whereas, affective beliefs and metacomprehension are also considered as an extension of the main constructs. *Metacognitive knowledge* has been defined as the knowledge about when, how, and why to engage in various cognitive activities (Baker, 1989) and includes person, task and strategy knowledge by being separated declarative, procedural and conditional types of metacognitive knowledge. While *declarative metacognitive knowledge* is mainly related about the domain knowledge (stored information about the domains of reality) and cognitive knowledge (stored assumptions, hypotheses, and beliefs about thinking); *procedural metacognitive knowledge* is about knowing how. In addition, *conditional metacognitive knowledge* is defined as knowing when and why to use declarative and procedural knowledge (Schraw, 1998). Table 2.6 shows the subcategories of metacognitive knowledge with their relations.

Table 2.6 Subcategories of Metacognitive Knowledge

Categories	Subcategories	Findings
Declerative	Person knowledge	Includes knowledge of self and others.
	Task knowledge	Includes knowledge of task and context including sensitivity influencing awareness of task complexity
	Strategy knowledge	This includes knowledge of cognitive strategies influencing development of strategy knowledge
Procedural	Person knowledge	Includes knowledge of self and others influencing strategy selection and monitoring of strategy
	Task knowledge	Includes sensitivity to task influencing awareness of the cognitive goals and subgoals
	Strategy knowledge	Includes sensitivity to strategy application influencing the identification of appropriate strategies
Conditional	Person knowledge	Includes knowledge of self and others influencing applicable strategy selection in different conditions
	Task knowledge	Includes knowledge of task type, demands and context influencing awareness of adaptive application
	Strategy knowledge	Includes sensitivity to strategy initiation influencing strategy use, transfer and regulation in different contextual conditions

In addition to metacognitive knowledge, *metacognitive regulation* or *regulation of cognition* is a main category of metacognition. B. Zimmerman (1989)'s definition on metacognition pointed out "decision-making processes that regulate the selection and the use of various forms of knowledge" which also assured that metacognition is a subprocess of self-regulation. Since metacognition and self-regulation's main interaction is control, monitoring and regulation of strategies to meet task demands and goals, metacognition may be assured as a key subprocess of self-regulation.

In addition to metacognitive knowledge and metacognitive regulation, *metacognitive experiences* are seen as a category of metacognition which are those instigated during the monitoring of cognitive, problem-solving or task situations and not all forms are directly relate to memory monitoring. Metacognitive experiences are not exactly the same as affect or emotions but they do involve metacognitive judgements, feelings or experiences during problem solving and tend to be person-generated or related, whereas metacognitive knowledge can be generated by oneself and with others. Efklides (2002) assured that metacognitive experiences occur within and provide an intrinsic context which is both influenced by and influences person, task and strategy variables, especially during problem solving. Efklides (2002) considers that they are product of the person-task interaction. Moreover, metacognitive experiences are influenced by especially person-characteristics including beliefs regarding ability to meet the task demands in light of difficulty, complexity and context. Sensitivity to the task, including its variables, demands and context, both familiar and unfamiliar, influence metacognitive experiences and the interaction between person and task variables is fundamental to them. Since metacognitive experiences monitor the person and task variables and the interaction of them, context can also exert a number of influences including substantial or subtle context changes, task or problem familiarity or unfamiliarity, task complexity related to the knowledge domain but also involving multiple contexts. This would be especially evident in complex problems. Metacognitive experiences are described as *online monitoring of cognition* or *online awareness* which occur during problem solving or a cognitive task. The interaction between metacognitive knowledge and metacognitive experiences is fundamental to metacognitive processes. Through monitoring processes, metacognitive experiences, especially metacognitive feelings, provide feedback on the process of problem solving and stimulate control and strategy processes. They can be both implicit and explicit. During *task monitoring*, metacognitive experiences, especially metacognitive feelings, can be quickly generated without specific, explicit awareness of their activation.

Relying upon the interaction between person and task variables, a second order metacognition which needs awareness of other's thinking processes developed on a common ground is debatable on adding as a new construct within the taxonomy of metacognition. In the development of researches focusing on joint attention, shared understanding and theory of mind, shared metacognition and its sub-constructs are being debated as a hot topic to understand the mechanism. Following titles will refer to metacognitive researches in education referring to self-regulated learning and shared metacognition to draw a wider picture.

2.3 Metacognition in Education

2.3.1 Metacognition and Self-Regulated Learning

Metacognition is indicated as a vital and key subprocess to effective self-regulation. Although there is a debate on metacognitive aspects of self-regulation is a subprocess of metacognition, since it limits the field of area with especially regulation of cognition, metacognition has a broader understanding compared to metacognitive aspects of self-regulation. Zimmerman (1989) defines metacognition in relation to self-regulation as “decision-making processes that regulate the selection and the use of various forms of knowledge”.

Regardless of why metacognition can be counted as a broader term compared to self-gulation and although metacognition is an important subprocess of self-regulation, alone it is insufficient to enable successful self-regulated learning. Self-regulated learners are metacognitively, motivationally and behaviorally committed, independent and active learners (Butler & Winne, 1995), focused, goal-oriented, persistent in their learning, and aware of their knowledge, beliefs and volition. They are also highly motivated and use regulatory processes to monitor and control their motivation to meet task demands (Wolters, 2003). Generally, self-regulated learners initiate their own learning strategies to attain desired learning goals and monitor the effectiveness of these strategies. They are goal-oriented and apply a number of metacognitive strategies to attain these goals. They are aware of the importance of efficiently monitoring strategy applications and modifying strategies to meet task demands to achieve task goals.

2.3.2 Collaborative Problem Solving and Metacognition

Many researchers has paid attention to the importance of quality of interaction and collaboraiton. Quality of social interaction draw attention to metacognitive interaction attributes beside the cognitive content of the disscussions through a collaborative problem solving activity (Lee, O'Donnell, & Rogat, 2014). These attributes can be characterized in reference to metacognitive rules of interaction, monitoring cognitive process considering social level, and regulation of collective memory usage. Collaborative learning in studying socially-shared metacognition has also importance to understand the other participant's thinking and interpreatation framework. Since teaching-learning processes includes more than one actors having their own intentions and interpreatations affecting others' knowledge, thoughts and values, it is considered as a complex social situation. In such kind of process, actors should participate in the construction period of shared cognitive products to be successful so that this reuqires shared understanding based on a focus and shared assumptions for each actor (Hadwin, Järvelä, & Miller, 2011).

In a well-developed peer collaboration, there is a special kind of reciprocity between collaborators since although interaction is based on shared baseline, construction of the shared concept of the collaborative problem is based on unconcious metacommunicative rules or contracts between collaborators. In order to construct and maintain a shared concept for the collaborative problem requires synchronization by coordinating the actions. Monitoring and controling are important metacognitive processes in individual level which describes the collaborative action as how much monitoring and how better to use these observations to guide the problem solving actions. On the other hands, in a collaborative problem solving, monitoring thinking processes by other group members is a significant characteristics. In a complext mathematical problem solving, students working in dyads demonstrate more high-level of control compared to students working in indivuals. These high-level controls are triggerred when errors and misundestandings occur. Similarly, questions including monitoring action such as "Why did you think that?", "How did you come with that result?" and "Where do this bring us to?" is a key reason to why collaborative problem solving is more productive compared to individual problem solving.

In a collaborative situation, individuals need to explain their own thought and concepts by externalizing the ideas and this leads to construct better mental model for the concept. Externalization in social interaction is based on making internal processes visible. By using external devices, in a collaborative situation, learners can offload their cognitive process demand, and at the same time, they can regulate the reciprocal use of shared external representations. Cognitive value of social interaction is manifested when people cannot activate the complex hypotheses individually.

2.3.3 Metacognition in Education as Individualistic Concept

Research investigations have been showing a variety types of relationships with metacognition which plays an important role oral communication, writing, language acquisition, problem solving, self-control and self-instruction. Flavell (1979), in his pioneering article, introduced a model of cognitive monitoring (cognitive regulation as well in his words). He mentioned that the cognitive monitoring occurs as a result of the interaction among for components which are metacognitive knowledge, metacognitive experiences, goals and actions.

Schraw, Olafson, Weibel, and Sewing (2012) contended two distinct components of the metacognition as knowledge of cognition and regulation of cognition (see Figure 2.4). They applied metacognitive awareness inventory which is to examine the relationship between metacognitive knowledge and field-based learning in environmental education setting. The study concluded that the more students have metacognitive awareness, the easier they learn science lessons. However, this is an explanation rather than understanding the mechanism behind why those students are believed to have more metacognitive awareness. It is easy to say if a student has more metacognitive awareness they can learn science easier and better. But, we interpret these results based on our constructed instruments.

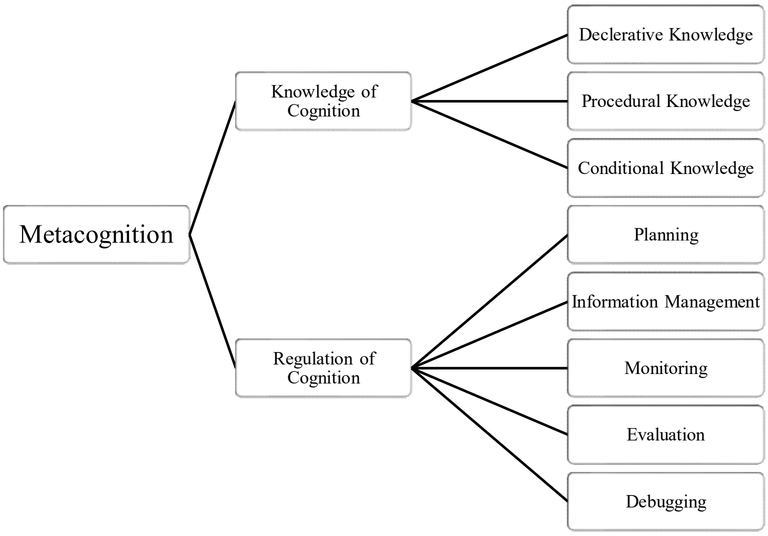


Figure 2.4 Distinct components of metacognition

Lesh, Lester, and Hjalmarson (2003) assured that collaborative learning settings provide flexibility in researching for both individualistic and social approach to metacognition. Iiskala et al. (2011), on the other hand, criticized the thought in which metacognition is taken as an individualistic concept which can be affected by social factors; however, can be modeled within one individual's conceptual system. Y. Kim et al. (2013), also, assumed a congruent underpinning with Lesh et al. (2003) by taking the individual as the *unique agent of metacognition* and suggested to explore the other social and environmental factor in the center of the individual. Although these two perspectives for metacognition which are alternative to only individualistic approach has different philosophical orientations and extensions for the educational contexts, they have common purpose to draw attention to social and environmental concerns of metacognition.

Flavell (1979) describes metacognitive knowledge as the knowledge or beliefs which can be affected by a variety of factors as a result of cognitive enterprises and consists of three categories as person, task, and strategy. Similar to Flavell (1979)'s divisions, researches on metacognitive knowledge divides it into three types of subcomponents which are declarative, procedural and conditional knowledge. Metacognitive declarative knowledge is about the immediate knowledge which can be constructed in reference to their own thoughts and thinking. Metacognitive procedural knowledge is about how to perform cognitive and learning activities and it provides an indication for the task success. And, metacognitive conditional knowledge is about knowing when and why to employ procedural and declarative knowledge and why it is important to do so. Flavell (1979) stated that the metacognitive knowledge has on many impacts on cognitive monitoring functions such as selection, evaluation, revision and abandon cognitive tasks, goals and strategies.

Thomas and Anderson (2013) investigated parents' metacognitive knowledge in procedural and conditional domains for self and others' learning and thinking processes and strategies for further suggestion of science museum exhibit design. They proposed the lack of studies referring to relationship between participants' metacognition and their science learning within and beyond the science museum settings.

B. White and Frederiksen (2005) conducted a study on fostering the metacognitive knowledge through inquiry. They followed distributed model expertise idea by assigning different roles within a learning system to both students and teacher-advisors which says that each student had their own functions. Salomon (1997) proposed a distributed model of expertise in accompanied with the distributed cognition theories to foster students' learning.

Although Schraw et al. (2012) proposed a cycle including five key regulation skills (see Figure 2.5), L. De Backer et al. (2015a) investigated the key regulation skills and proposed four components including orienting, planning, monitoring and evaluating and they divide all key components of the cycle into two levels as low-level and deep-level.

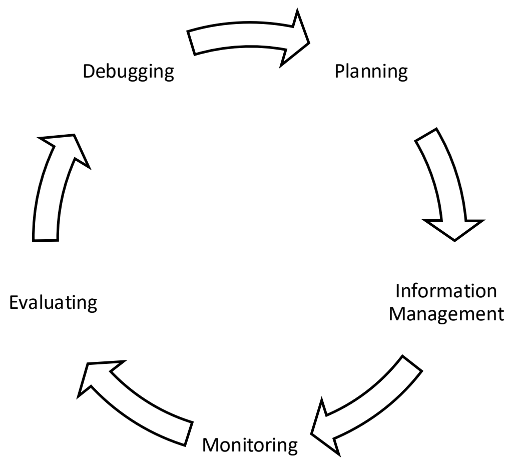


Figure 2.5 Metacognitive regulation cycle

Moreover, L. De Backer et al. (2015b) investigated the metacognitive regulation through peer-tutoring and scaffolding for providing better collaborative learning among peers. The peer-tutoring was reciprocal which includes a mutual relationship throughout the learning process among peers. In the study, one peer having the tutor function had an advisor role for the other peer taking support from the peer-tutor is called as tutee. In the study, among reciprocal peer tutoring groups, scaffold types fostering the metacognitive regulation during collaborative learning was investigated. Researches offered doing interaction analysis and investigation of the particular features embedded in learning environment which may also affect the metacognition of participants to better understand of the exploration of the evolution in reciprocal peer tutoring groups.

Bannert, Sonnenberg, Mengelkamp, and Pieger (2015) assured that the metacognitive scaffolds facilitate overcoming the difficulties of regulating collaborative learning in open-ended learning environments by directing students attention toward particular regulative acts. Also, they mentioned about the metacognitive scaffolds which can be taken as the supportive aids embedded in the learning material or context so that students can perceive and cognize the knowledge to regulated their own thoughts and behaviors.

Metacognitive monitoring is the relation between the task performance and the judgements regarding one's own performance. The table shows that metacognitive monitoring as stating the correct or incorrect judgements for one's own performance in an accurate or inaccurate ways. The inaccuracy of the performance judgements have been stated as illusion of knowing and not knowing. However, Webster and Hadwin (2015) shows that the illusion of knowing and not knowing decrease over time and with practice.

Lesh and Zawojewski (2007) assured that the individuals' learning processes can be reevaluated, monitored and the errors are debugged when the interaction with another knowledgeable learner including peers and teachers. Iiskala et al. (2011) emphasized the importance of other external sources for triggering the metacognition. Therefore, not only interaction between peers or teacher-students, but also interaction with the learning environments have potential direct effects on metacognition. Y. Kim et al. (2013) stated that these interactions between the learning environments and students help to deal with misconceptions and debug the errors throughout the metacognitive process.

Lesh and Zawojewski (2007) offered model-eliciting activities as alternative to problem solving activities in researching on metacognition based on self-reports. Model-elicit activities provide test, debug and retest steps within a group including three or four students. Y. Kim et al. (2013) conducted a single-case naturalistic case study to investigate metacognitive process by addressing to question "How students' thinking develop metacognitively while working within a group in a naturalistic classroom setting." (p. 385).

2.3.4 Metacognition in Science Education

Zohar and Barzilai (2013) conducted a systematic analysis of 178 peer-reviewed journal articles on metacognition in science education and stated the findings mentioning as a core objective of the field of science education. Zohar and Barzilai

(2013) identified the research gaps on metacognition in science education under four main themes. The first theme was about the empirical studies on development of metacognitive knowledge among students rather than the development of students' metacognitive skills. The second theme was about the lack of control for the research designs to establish cause and effect relationships between metacognitive instruction and science learning. The third theme was about the lack of studies focusing on the metacognition among pre-school students and the final themes was about insufficient studies on the professional development among teachers' knowledge on metacognition.

Tanner (2012) provided self-questions for promoting the students' metacognition within biology classes via building a culture encourage students with different activities based on specified phases. She offered a way to divide overall self-questions into four main course activities mentioned as class session, active-learning task, exam and overall course. These divisions are questioned in a three-phased way as planning, monitoring and evaluating.

For measuring metacognition in science education, Azevedo (2015) argues having process data on engagement and learning in science will lead to advances in models, theory, methods, analytical techniques and ultimately instructional recommendations for learning contexts that effectively engage students. He presented different methods to present either the methodology is ideally suitable or not for capturing and measuring engagement-related activities (see Table 2.7).

Table 2.7 Illustration of different methods used during engagement (adapted from Azevedo, 2015)

Data Type	Method/Tool	Cognition	Metacognition	Affect	Motivation
Process	Screen recordings				
	Concurrent think-alouds				
	Retrospective think-alouds				
	Eye tracking				
	Log-files				
	Facial expressions of emotions				
	Physiological sensors				
Product	Pretest-posttest-transfer tests				
	Quizzes				
	Summaries				
Self-Reports	Self-report questionnaires				
Knowledge construction	Note-taking and drawing				
	Classroom discussion				

2.3.5 Shared Metacognition

Peer learning constitutes the basis for understanding to manifestation of metacognition during collaborative problem solving studies which are requiring social interaction (King, 1998; liskala, Vauras, & Lehtinen, 2004; Vauras, Iiskala, Kajamies, Kinnunen, & Lehtinen, 2003). Development of new methods to measure the social-level awareness, monitoring and regulation processes during dyads' collaborative problem solving is the main purpose of these studies to feed the future studies. Iiskala, Vaura and Lehtinen (2004) analyzed high-achieving 10-year-old dyads' video recordings, verbal and nonverbal texts qualitatively during their engagement in collaborative problem solving focusing on mathematical word problems to explore the manifestation of shared metacognition during their collaborative problem solving activity. They reveal that metacognition should not be defined as an individual concept and awareness, monitoring and regulation processes should be investigated considering inter-individual level and offered socially-shared metacognition as the primary terminology for research area.

Metacognitive regulation can be described as a socially-shared metacognition which cannot be induced to individual regulation and play a part in a true collaboration. In nonequvialent situations, when one of the dyads are managing one of the key elements of the collaborative task, regulation can be described as other-regulation.

In balanced situations, Iiskala et al. (2004) have shown that students are dealing with a common and equitable discourse to understand and solve problems. During such discourses, the shared metacognition concept relates research to common, peer-mediated learning. However, the self-regulation is the bottom line of the socially-shared regulation and the intra and interpersonal regulation takes place momentarily. Iiskala et al. (2004) aimed to understand the multiple nature of finding and identifying indicators for inter-individual arrangements.The main purpose of the study is to show how the socially-shared metacognitive processes are evolving during the cooperative solution of mathematical tasks by presenting case studies of two pairs of learners. From the individual's perspective, there are researches that provide empirical evidence for interpersonal metacognition.

Hogan (2001) argues that metacognition is used in social interaction and that we have to find out how the results of metacognitive movements are differentiated within the group. We can get better possibilities of the intellectual production of groups by correcting the metacognitive knowledge and control processes of the groups. As a result, Iiskala et al. (2004) discuss and develop methods for analyzing these metacognitive processes in their research during common problem solving. In their articles, Sfard and Kieran (2001) implemented the interaction flow conditions for analysis of metacognition in inter-individual level. Thus permitting inter-individual metacognitive movements to be more transparent than presenting discourse discourses. Systematic interaction flow diagrams provide quantitative interpretation of quantities in their studies. In their studies, Iiskala et al. (2004) selected four pairs of fourth grade students (highly successful) for taking part in the study. Two of the couples consisted of male and female students. In the study, a couple of boys and a couple of girls were used. The students were successful on the average of all of the monitoring measures. These were non-verbal intelligence, reading comprehension, four transactional problems, metacognitive knowledge and cooperative skills.

The selection of high-performing students in the study seems to be one of the signs of higher-level cognitive thinking. Highly successful students seem to be able to apply knowledge and skills to new environments and tasks instantaneously. Previous research has found that the social competences of low-achievers are not as good as their peers and contribute to group effort as much as other students. Highly successful and competent students in cognitive, metacognitive and social skills have been selected to increase the likelihood of high level collaboration among peers. In the study, in the classroom environment, each scale was applied to students before their game sessions. These were nonverbal intelligence scale, standard progressive matrices, reading comprehension (students' correct choices used as an indication), metacognitive knowledge about learning and cooperation skills (Junttila, Voeten, Kaukiainen, & Vauras, 2006). The study was applied in a computer-assisted mathematical learning game environment. Each dyad played for 30-45 minutes twice a week for eight weeks. Investigative couples were involved to work in close proximity and the researcher was explicitly involved only when couples asked for help, or when the students reached a dead end. In this direction, the possibility of dyads monitoring and organizing their own activities at the metacognitive level increases only when there are areas for discussion. Thus, in their opinion, dyads in their real problem-solving phase had the freedom to find their own way of working together and gain the awareness of tracking and regulating common problem areas.

In addition, there was no time limit in the course of problem solving. Dyads solved four processing problems in five different difficulty ratings. As the problem became more difficult, more points could be obtained. The problems reflected the spirit of the game and multiple stage problems were used, which were multiplication, division by tasks of comparison and combining, addition and subtraction. Dyads could also use external helpers at the same time. The interaction analysis applied to the five selected problems to obtain a deep insight into interaction flow through interaction (Sfard & Kieran, 2001). With the help of this analysis, metacognitive movements have become more inter-individual negotiations. Iiskala et al. (2004) applied the interaction flowchart to measure inter-individual metacognitive processes in two groups of girls and boys. In simple tasks, students do not observe interpersonal metacognition, but in difficult tasks, high-achieving students have gone beyond their qualifications and have sought new ways to search. The students realized the mistakes and misunderstandings of their and their peers and they made it clear. For this reason, emotional openness holds an important place in a successful and metacognitive shared collaboration.

Moreover, Goos, Galbraith, and Renshaw (2002) have shown how unhelpful social interaction can hide processes. Finally, they have claimed that the social-shared metacognition is not limited to 10 years of age for an indicator of social-shared metacognition. For the social-shared metacognition, they have argued that social and individual intellectualism must be at a certain level. Finally, metacognition is suggested not only in the way of individual, but also in socially-shared learning environments.

2.4 Summary

The metacognitive processes within science center environments, and the practices which may have potential influence of the emerged metacognitive actions of students and science center educators have been explored within there cases and investigating the current practices of science center among Turkey. A variety of methods including qualitative, quantitative or mixed were employed to identify the metacognitive actions for a diversed subject areas including writing, reading, and science courses. However, when the literature review in this thesis are considered, metacognitive processes are generally made through think-aloud protocols, within either formal learning environments or rarely in informal learning environments.

During their research, the researchers did not engage in the full session for the collaborative activity by observing the students and analyzing the eye tracking video data to evaluate the data within a holistic approach. Also, the researchers did not offer a way to examine the metacognitive processes by integrating the exhibition units with the specific learning objectives in align with the students' school hours.

Therefore, the contribution of this thesis study to Turkish literature can be listed under three issues:

1. The investigation of the current educational and organizational practices of the science centers in Turkey
2. Documenting the similarities and differences of the science centers regarding their characteristics
3. Besides the specific learning objectives, an integration of science center activities for the science curriculum was offered

Also, the contribution of this thesis study to international literature can be listed under three issues:

1. The occurrence of metacognitive processes during students engaged in diversed lesson units
2. The occurrence and the definition of eye movements during students' collaborative activities
3. The potential relation of science center educators' metacognitive actions to students in a sequential study

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter presents a detailed description of the research methodology of this study. It includes an introduction for research methodology, research design, sampling procedure, data collection instruments, the validity and reliability of data collection instruments and data collection procedures. Beside this core sub-sections, this chapter presets data analysis, the trustworthiness of data analysis, and methodological limitations within the study.

The primary purpose of this study was to investigate how science centers can embed instructional design supporting metacognitive processes during science conceptual understanding of students in Turkey context by examining the perceptions of science center educators and science teachers and cognitive and metacognitive activities of students during an offered instructional design with discovering their associations with and contributions into the metacognitive knowledge and metacognitive regulation. Within this purpose, the research is designed within two phases as curent practices and multiple cases. While current practices study includes experiences of science center educators and science centers, multiple case study involves students three research stages as guidance by science center educators, collaborative activity with a match-pair, and video edition of their own self-fenerated videos. Thus, students' in-stu metacognitive processes throughout the three stages would be possible to be observed. The research questions guiding this study are as follows:

1. What are the current practices in science centers based on science center educators' and science teachers' experiences?
    a. What are the current educational practices in science centers?
    b. What are the current organizational practices in science centers?

2. What are the indicators of implicit metacognitive actions of science center educators through the guidance phase when interacting with students?
3. What are the indicators of individual metacognition in science center environments?
4. What are the indicators of shared metacognition among peers during the collaborative activity in science centers?

3.2 Research Design

The complex nature of science centers requires using multiple methods and multiple data sources to understand both individual and inter-individual metacognitive processes. To have a deeper understanding of the research questions, this thesis has been established on the constructivist-qualitative ontology. Constructivist-qualitative ontology emphasizes the reciprocal construction of the knowledge through the world experience between the knower and the known (Denzin & Lincoln, 2018).

In constructivist-qualitative ontology, the holistic understanding of phenomena and the importance of the context are essential factors in the interpretation. Based on the constructivist-qualitative methodology, the researchers are the primary research instrument, and there is no attempt to manipulate or control findings using statistical tools (Denzin & Lincoln, 2018). Studying within the natural setting is vital for the data collection processes. And, the open-ended processes have handled the data analysis without imposing the opinion to pre-existing data. This study takes its assumptions regarding the constructivist-qualitative methodology.

Unique characteristics of the qualitative research highlighted the following issues: (a) the meaning is discovered and understood by focusing the processes, (b) real context is selected for conducting the research, (c) the researcher is seen as an instrument which requires interpretation based on personal view and experiences, (d) the research process is inductive, and (e) the investigated phenomena has complex interrelationships as a result of detailed findings (Merriam, 2009; Miles & Huberman, 1994; Patton, 2002; Yıldırım & Şimşek, 2013).

Creswell and Poth (2016) emphasizes that qualitative research is conducted around a "central phenomena," which is to be explored as a critical idea. The central phenomenon in this research is the "Science centers as metacognitive contexts" which requires holistic research processes including the implementations of the science centers and visitors' behaviors, cognitive and metacognitive accounts. Therefore, this needs to embed the researcher as a research process instrument into the natural settings of the science centers. To be more precise, researchers prefer to employ the methodology based on the constructivist-qualitative ontology when the aim is to understand people's perception and how they make sense and construct meaning in a specific context (Merriam, 2009; Stake, 2010).

A Multimethod research design, a qualitative methodology (current practices), and qualitative methods (multiple case research design), each complete in itself and addressing different research questions of the study, was performed in the present study. As clearly elucidated by Morse (2003), the difference between multimethod and mixed methods design is that "in multimethod design all projects are complete in themselves" (Morse, 2003, p.199). He further indicates that unlike the mixed method, in multimethod design, "each study is planned and conducted to answer a particular sub-question" (p.199). In mixed method design, on the other hand, research questions have emerged from the previous part of the study, and they have integrated one or more phases of the study (Tashakkori & Teddlie, 2010). This study fits well with the multimethod design rather than the mixed method. First of all, this study consists of two separate studies that are complete on their own. Second, each study is designed to answer a particular sub-question. Also, the sample of the first study is different from the second study. That is, the first study sample consists of science centers and science teachers who experience science centers' educational activities. The second study, on the other hand, involves a different samples of individuals who are 7th-grade students in Turkey and science center educators who are guiding them. Next, they are *interrelated with each other* since each part conducted within the umbrella of the general purpose of the study, which is providing research base guidelines for policymakers, instructional designers, science center educators, and science teachers about enhancing the educational effectiveness of science centers during their activities. Finally, results are integrated at the final stage of the study. As a result, when all these points considered together, it is safe to say the study suits well with the multimethod design. By the help of a multi-method approach, the researcher is able to look at the potential instructional design issues of science centers in a broader perspective.

The research study drew on the strength of the qualitative research approaches, including current practices and multi-case study approaches. Therefore, the research study founds on these approaches by aiming at providing an in-depth understanding of the aspects that contribute to or hinder the educational effectiveness of science concept learning within science center environments. Also, based on describing the educational effectiveness in science center context through the lens of metacognitive processes, the qualitative multi-case study approach is aiming to understand the aspects of both individual and inter-individual metacognitive processes through the science center interaction of seventh-grade students.

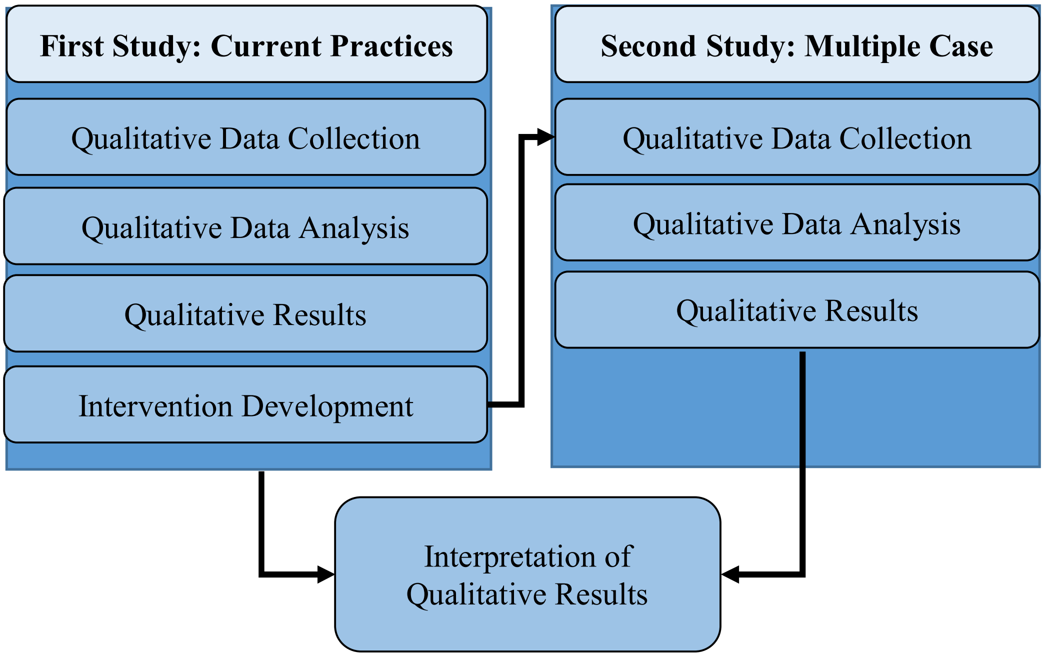


Figure 3.1 The research design of the study

For the two research questions of this study assigned as the *current practices study* of the research, the researcher aimed at understanding the science center educators' and science teachers' opinions regarding their science center experiences. Similarly, for the following questions assigned as the *multiple case study* of the research, the researcher aimed at investigating the interrelationships between the subject matter area, context, and the subjects. Because of the stated aims, the research methodologies based on the constructivist-qualitative ontology optimizes the understanding the central phenomena.

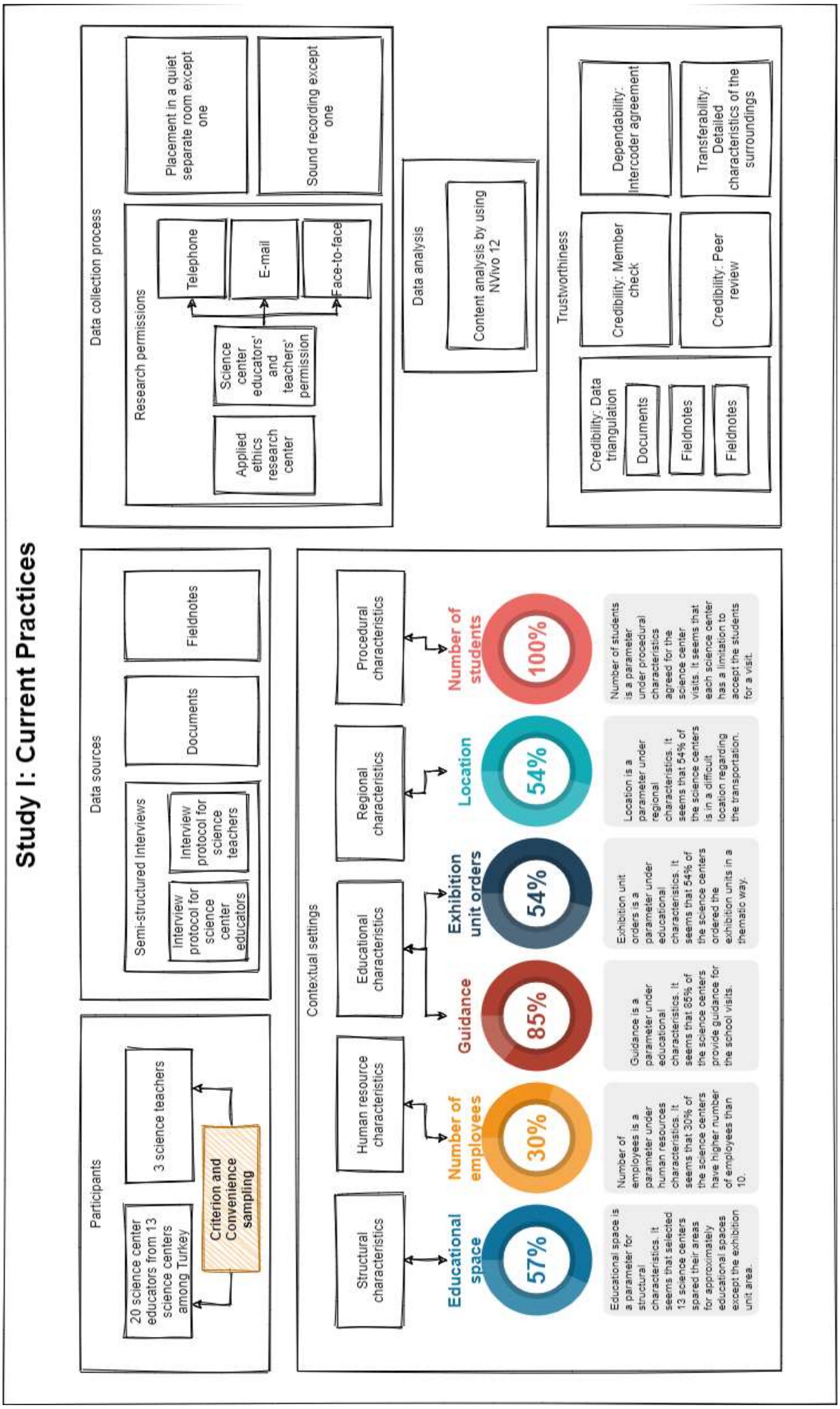


Figure 3.2 Methodological diagram of the current practices

Figure 3.2 shows the methodological details of the current practices study. This current practices study pinpointing the educational and organizational characteristics of the science centers. And, it gives insight on the elimination of the compounding variables before designing the subsequent research in science center context. Figure 3.3 shows the methodological diagram of the multi-case design which was designed based on the findings of the current practices study. In the multi-case study, selection process of the participants, lesson units, and the exhibition units; preparing worksheets considering the duration, number of questions, image selection and adaptation of the exhibition units for the design and development stage; organizational considerations as specifying the duration, timing of guided tour and collaborative activity, laboratory environment, and the transfer of students for organizational considerations; and role of the teacher, role of the science center educator, role of the students, timing for the distribution of conceptual diagnostic papers and science diaries, and timing for the free-exploration period and the guidance period were taken into consideration based on the findings and the researcher's insight from the current practices study.

Figure 3.3 Methodological diagram of the multicase design

Furthermore, unlike the structured process of quantitative methodology, the process is flexible and active as some aspects of qualitative study emerge during the study. Both *current practices* and *mutliple case* studies require flexible and dynamic processes since the known, and the knower construct the reality as stakeholders (Miles & Huberman, 1994). In this study, the *current practices* required the understanding of the current implementations of the science centers.

Table 3.1 Elements and Study Approach in the Study

Elements	Study Approach
Paradigm	Constructivist/Interpretivist
Ontology	Relativist
Epistemology	Subjectivist
Methodology	Naturalistic Inquiry
Qualitative Research Approach	Multimethod Study
Research Approaches of Multi-method Study	Descriptive/Interpretive Qualitative Study Descriptive/Interpretive Multicase Study

In addition to undertstanding the rationale for selecting qualitative research methodology, it is important to understand the rationale for selecting the appropriate methodologies for each phase of the research. Following headings includes the rationale for selecting current practices and multiple case study as research methodologies in this study.

Rationale for selecting multiple case study

A qualitative understanding of cases requires experiencing the activity of the case as it occurs in the contexts and in its particular situation. According to case studies, the situation is expected to shape the activity as well as the experiencing and the interpretation of the activity. The case is (a) dynamic, (b) operating in real-time, (c) acting purposively, and (d) interacting with other cases. In multiple case studies, an individual case is an interest of the study since it belongs to a particular collection of the cases (Merriam, 2009; Stake, 2010). Beside each individual case shares common characteristics and conditions since multicase studies promote particularization more than generalization, one can use multiple cases as a step toward theory. Also, the vital reason for doing a multiple case study is to examine how the phenomenon performs in different environments. This thesis study has three individual cases focusing on different science center settings and subject matters during the investigation of the verbal and nonverbal metacognitive accounts of the target learners. Since it is crucial to investigate the central phenomenon in different educational areas to understand the similarities and differences of the cases, the second phase has been conducted as a multiple case study.

The details about the design of the whole study, including research questions, data sources, data collection instruments, and data analysis are presented in Figure 3.4 to illustrate the timeline of the data collection process (For the tables associated with each research question, see Appendix H).

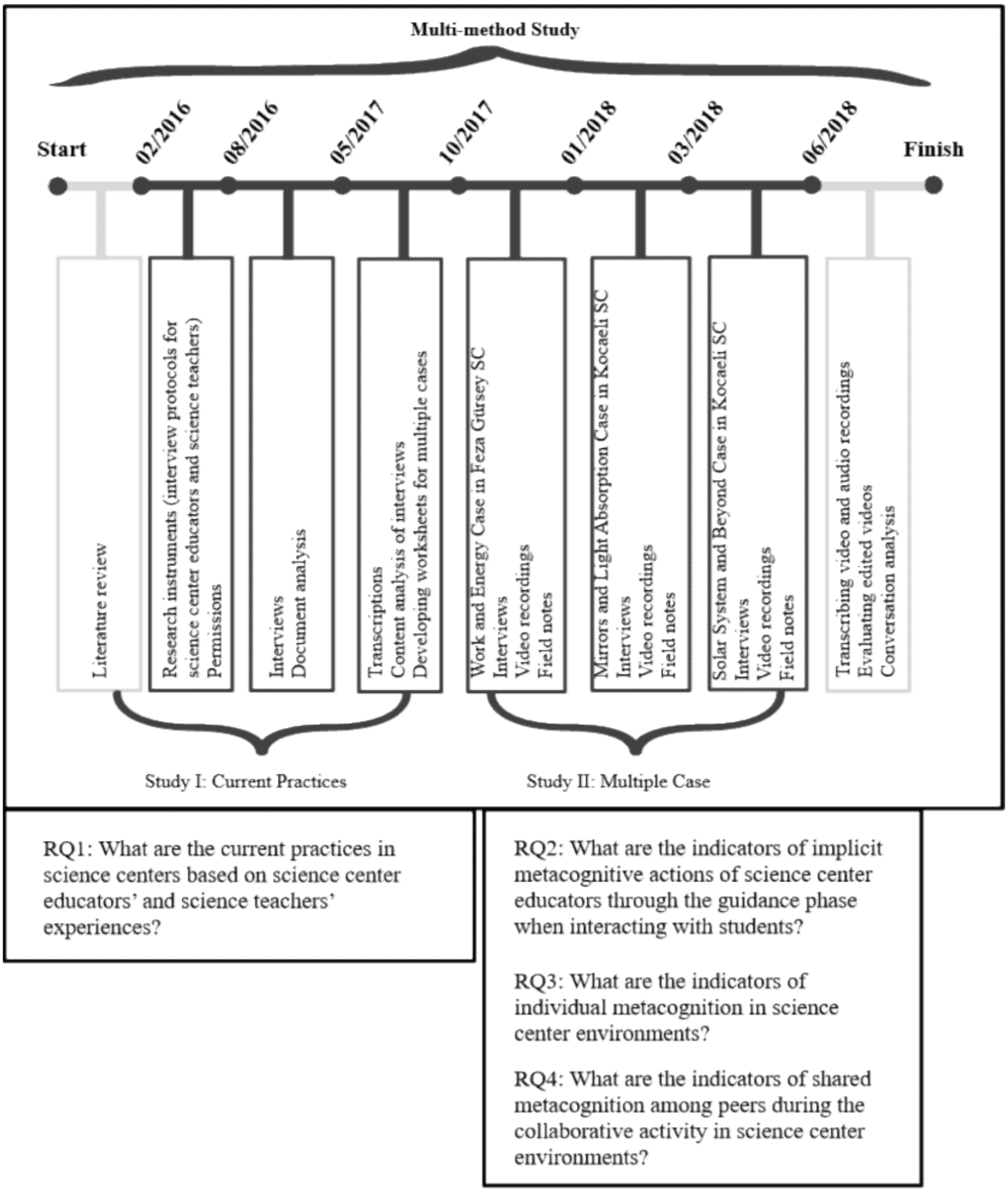


Figure 3.4 Multimethod study design timeline

3.3 STUDY I: Current Practices

In current practices study, a qualitative method was utilized to gather descriptive information about the science center practices focusing on organizational and educational issues to reveal instructional design issues of science centers in Turkey.

Investigating *Current Practices* also includes needs assessment and task analysis throughout the research process. Comprehensive needs assessment is one of the research methodologies in the constructivist-qualitative research approach. In this study, the researcher needed to understand the science center contexts in Turkey regarding their similarities and differences and the current implementations of the science centers based on the individual and organizational perspectives. It is aimed that by understanding the reality of the science center contexts in Turkey guides comprehensible and direct intervention processes. Hence, this thesis study began with the *current practices study* to provide a comprehensive outlook for the researchers, science center educators, science teachers, and learners as well as to govern the following research phase based on the findings.

Although *current practices study* of the study requires to investigate multiple cases in Turkey, since the researcher does not focus on each individual case separately and aimed at understanding the current implementations in general, a combination of needs assessment and task analysis has been selected as the research methodology rather than multiple case study.

3.3.1 Contextual Settings of the Study

This section described the visited science centers in each interview and their characteristics to give readers an idea about the actual context of these science centers in general. These characteristics are described via the journal kept by the researcher and the interviews with the science center educators. Although current practices study focuses on the science centers consisting of several cases located in Turkey, since the research questions focus on understanding the current practices by considering all dimensions of the implementations such as barriers, needs and solution attempts to enhance educational effectiveness among science centers, it is essential to describe the science center environments regarding their structural, functional, educational, regional and procedural characteristics.

In Turkey, science center educators are able to participate in the educational and organizational processes being held by science centers from the beginning of the construction period to the organization of the activities and designing instructional materials. 13 science centers, in Turkey, were observed, and educators in these centers were interviewed. Characteristics of science centers were reviewed under following headings as structural, functional, educational, regional, and procedural characteristics. Following characteristics are for descriptive purposes and providing in-depth information regarding the science centers in Turkey to hold a holistic viewpoint throughout the study.

Structuctural Characteristics

Structural characteristics of science centers refer to science centers' structural and infrastructural design issues. These are grouped under five main categories as the structure of the building, the largeness of building, the number of exhibition units, the educational spaces and the open area. Table 3.2 shows strucural characteristics (M: Mobile, NU: Not Unique, U: Unique, D: Duplex, O: One floor, T: Triplex, A: Available, NA: Not Available) of science centers.

Table 3.2 Structural characteristics of science centers in Turkey

	1	2	3	4	5	6	7	8	9	10	11	12	13
Structure of building	NU	NU	NU	NU	M	NU	U	NU	U	NU	U	NU	U
Largeness of building	D	O	T	O	M	D	O	D	T	D	D	D	T
Number of exhibition units	70	60	25	0	120	-	-	-	-	-	-	-	50
Educational spaces													
Conference hall	A	NA	NA	NA	M	NA	NA	A	A	A	NA	A	A
Library	NA	NA	NA	NA	M	A	NA	A	A	NA	NA	A	NA
Workshop	A	A	NA	NA	M	A	A	A	A	A	A	A	A
Laboratory	NA	A	A	A	M	A	NA	NA	A	A	NA	NA	A
Planetarium	NA	NA	A	NA	M	A	A	NA	A	A	NA	NA	NA
Open area	A	A	A	NA	M	A	A	NA	A	NA	A	A	A

M: Mobile, NU: Not Unique, U: Unique, D: Duplex, O: One floor, T: Triplex, A: Available, NA: Not Available

Structure of building refers to whether the science center's building is specially designed for an educational environment or it is settled on an existing building. Nine science centers have no unique design for educational infrastructure; whereas, four science centers designed the building of the science center according to educational needs. Besides, the largeness of building refers to how much the parts of the buildings are broad. While six science centers have duplex structure building, three science centers have triplex structure building for different educational spaces. These educational spaces consist of conference hall, library, workshop, laboratory, and planetarium areas for functioning specialized educational activities. Finally, nine science centers use open areas located outside the science center for their demonstrations and other scholarly activities as an alternative to inside educational space.

Human Resources Characteristics

Characteristics for human resources of science centers refer to how science centers function their regulations so that the number of employees and voluntary employees is essential factors in the determination of how effective regulations are sustained. Table 3.3 shows human resorces characteristics of science centers (A: Available, NA: Not Available).

Table 3.3 Human resources characteristics of science centers in Turkey

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Number of employee	6	1	4	11	6	5	4	11	50	7	5	4	11
Voluntary employees	A	NA	NA	A	A	A	A	A	A	A	A	A	A

A: Available, NA: Not Available

The number of employees differs among science centers. Whereas, SciCen.02 has one employee responsible for all duties, SciCen.09 has approximately 50 employees for distributed functions. Almost every science center has volunteer employees to meet human resource needs.

Educational Characteristics

Based on researchers' kept journals and interviews with science center educators, educational characteristics within science centers mainly divided into seven branches. Table 3.4 shows the educational characteristics of visited science centers (A: Available, NA: Not Available, M: Mobile, T: Thematic, U: Unordered, R: Relational). These characteristics are school visits, summer/winter schools, workshops, demonstrations, conferences, guidance during school visits and exhibition unit orders to satisfy instructional strategies.

Table 3.4 Educational characteristics of science centers in Turkey

	1	2	3	4	5	6	7	8	9	10	11	12	13
School visits	A	A	A	A	M	A	A	A	A	A	A	A	A
Summer/Winter Program	A	NA	A	A	NA	A	A	A	A	NA	A	A	A
Workshops	A	A	NA	A	NA	A	A	A	A	NA	A	A	A
Demonstrations	A	A	A	NA	A	A	A	A	NA	A	A	A	A
Conferences	A	NA	A	A	NA	A	NA	A	A	NA	A	A	A
Guidance	A	A	A	A	NA	A	A	A	A	NA	A	A	A
Exhibition unit orders	T	T	U	NA	NA	R	T	T	T	U	T	T	R

A: Available, NA: Not Available, M: Mobile, T: Thematic, U: Unordered, R: Relational

School visits refer to the group visits to the science center as an extracurricular activity for a voluntary class and their accompanying teachers. While school visits and demonstrations are available for all science centers, there are differences among the nature of visits. For instance, although SciCen.05 have school visits, and demonstrations, since it is a mobile science center its direction of implication is from science centers to schools rather than schools visit the science centers for experiencing demonstrations. 11 science centers have been observed as giving guidance during these school visits; whereas, two of them prefer not to give any guidance for visiting students.

10 science centers also provide summer and/or winter programs. In these activities, students are exposed to long-duration educational programs within the science center on a focused field of an area such as archeology, science learning through laboratory, and programming with robots. In addition to summer/winter schools, workshops being held throughout all year are conducted for a short-term educational activity. Ten science centers committed to prepared educational workshops for students on a variety of subjects related to both science concepts and other fields to make students gain skills in a diversity of the area.

Demonstrations, on the other hand, include display of one of the selected exhibition units or laboratory works focusing on a subject matter within the science lesson area. Eleven science centers state that they often use demonstrations to attract students' attention. In addition to demonstrations, nine science centers organize conferences for the benefit of students and the community. They state that these conferences are held to keep students and the society informed of current developments in science and to ensure the sustainability of the science center.

Finally, the order of the exhibition units is also covered by the educational characteristics of the science centers. The order of the exhibition units is divided into three main groups: unordered, thematic, and relational, both according to the declarations of the science center educators and the researcher's observation. Unordered exhibition units refer to random assignment of exhibition units within the science center settings without any consideration of thematic or conceptual contiguity. However, relational allocation of exhibition units within science center design considers the conceptual contiguity of exhibition units to provide connections during the transition from one exhibition unit to another within the guidance period. And, seven science centers were observed as having thematic groups on different fields of areas such as physics, chemistry, or biology. On the other hand, since SciCen.04 and SciCen.05 have either no exhibition units or a stable context, the order of the exhibition units under educational characteristics is not available for those science centers.

Regional Characteristics

Regional characteristics of science centers refer to secure access to the location of science centers, a socio-economic status where science centers are locating and accessibility of society for science center activities. Table 3.5 shows the regional characteristics of science centers (E: Easy, D: Difficult, M: Middle, L: Low, H: High, F: Free, NF: Not Free).

Table 3.5 Regional characteristics of science centers in Turkey

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Location	E	D	D	D	E	E	D	E	D	E	D	E	D
Socio-economic status	M	H	L	L	NA	M	L	M	M	M	M	M	M
Accessibility	NF	NF	F	F	NF	F	F	F	F	F	F	F	NF

E: Easy, D: Difficult, M: Middle, L: Low, H: High, F: Free, NF: Not Free

Location refers to the ease of access by public transportation the science centers. Since approximately seven science centers are not at the central areas or science centers have no free shuttle service, the location is in a hard place to reach. Besides, most of the science centers are located in a regional area having middle socio-economic status. Finally, nine science centers are free in-school visits and other kinds of educational activities. In addition, on to being free of charge, there are additional free offers for visitors to get the benefit from them.

Procedural Characteristics

Procedural characteristics of science centers refer to collaborations which science centers establish, school visit procedures, and limitations regarding the number of students for school visits per session. Table 3.6 shows procedural characteristics of science centers in Turkey per each visit.

Table 3.6 Procedural characteristics of science centers in Turkey per each visit

	Collaborations	School Visits	Number of students
SciCen.01	Teachers, Private and Governmental Organizations, Universities	Appointment	40
SciCen.02	Teachers	Appointment	20
SciCen.03	Teachers, Private and Governmental Organizations	Appointment	40
SciCen.04	Teachers, Private and Governmental Organizations, Universities	Appointment	20
SciCen.05	Teachers, Private and Governmental Organizations, Universities	Appointment	Certain grade levels from a school
SciCen.06	Teachers, Private and Governmental Organizations, Universities	Appointment	40
SciCen.07	Teachers, Private and Governmental Organizations, Universities	Appointment	60
SciCen.08	Teachers, Private and Governmental Organizations, Universities	Appointment	60
SciCen.09	Teachers, Private and Governmental Organizations, Universities	Ministry of Education	40
SciCen.10	Teachers, Private and Governmental Organizations, Universities	Appointment	40
SciCen.11	Teachers, Private and Governmental Organizations, Universities	Appointment	30
SciCen.12	Teachers, Private and Governmental Organizations, Universities	Appointment	60
SciCen.13	Teachers, Private and Governmental Organizations, Universities	Appointment	30

Except for one science center, 12 science center accepts school visits by appointment via telephone. However, since an exceptional science center establishes a collaboration with the provincial directorate of national education, each school class is given a date for a visit within one semester. Finally, the number of students accepted per session for a class is given.

3.3.2 Participants of the Study

Selection of science centers

A list of science centers was formulated after informal interview with an academician from the department of architecture in a public university an web-search. The first science center visited by the researcher offered another science center as well to interview with an informant from there. After visiting the science center to interview with the science center educator and observe the science center environment, the researcher was also further recommended for other science centers. Science centers were selected based on the availability and accessibility after getting suggestions from academicians, first few science center educators, and educational coordinators of the respondent science center for accessing the key informants.

Interview Participants

A total of 20 science center educators and three science teachers participated in the current practices study for a comprehensive needs assessment. Interview participants were selected through both criterion at first hand and convenience sampling techniques. The main research goal of the current practices study determined the criterion throughout the selection of participants to the study to focus on key informants for having in-depth interview purposes (Miles & Huberman, 1994). Also, the snowball sampling method (Miles & Huberman, 1994) was applied to select key informants who were experienced science center educators and teachers. Merriam (1998) assures that the purposive sampling technique is used firstly by determining the selection criteria of participants. For this reason, while selecting the participants, four criteria were employed. The first criterion was the involvement in instructional design, development and implementation processes for science center visits and recent science center visit experience for the science teachers. The second criterion was the diversity of participants including participants from different science centers and cities who could portray the different instructional design within science center settings were contacted. Also, science teachers from different schools who visited to various science centers recently were selected.

The third and fourth criteria were the accessibility and the willingness to participate in the study. In all interviews, contacted informants agreed to take part in the study, though one of them was reluctant about audio record during the interview. Science center educators and science teachers were interviewed to elicit the educational and organizational activities of science centers. In this way, interviews would help to understand the experiences of the science center educators and science teachers and what their experiences indicate (Bogdan & Biklen, 2007). Specifically, the participants in this *current practices* study were the science teachers of 7^{th}-grade students and science center educators experienced within educational processes held by the science center in Turkey.

The qualitative sample size needed to be large enough to adequately identify teachers' science center experiences and science center educators' opinions on science centers and provide sufficient data to address the research questions in this study. Data saturation is needed to be accessed for the determination of the sample size in qualitative research (Guest, Bunce, & Johnson, 2006). However, to provide data saturation, each study should specify the reasons on why the study selected that number of participants. The researchers should provide the final decision on reaching data saturation; although, Guest et al. (2006) assures it should be at least six interviews and Creswell (1998) affirms that approximately 30 interviews are needed. Likewise, Bernard, Wilhelm, Scherer, May, and Schreck (2012) ensures that the number of interviews is related to the continuation of data collection until the researcher receives all the answers.

Since this study is not aiming to generalize the results to a larger population and the qualitative methodology was employed to gain an in-depth understanding of the experiences and opinions of science teachers and science center educators. However, the required number of interviews to advance understanding of current practices was needed to be decided for sufficient data collection.

A total of 20 science center educators and three science teachers participated in the current practices. The following headings include the characteristics of the science center educators and the science teachers.

Science Center Educators

A total of 20 voluntary science center educators (N_{female}= 10, N_{male}=10) were selected among the science centers located in Ankara, Bursa, Eskişehir, Gaziantep, İstanbul, Kocaeli, and Konya who are actively participating in science center's educational activities or serving as the educational coordinator role who has broader knowledge on the foundation, interior design, activity design and evaluation processes as an active agent. The mean age of *SCE*s was 32.7, and they got their graduations from faculty of education (*N*=8), faculty of engineering (*N*=4), faculty of science and literature (*N*=9), and faculty of economics and administrative sciences (*N*=2). Table 3.10 shows the participant number, gender, age, degree of education, their role in *SC*s, educational status, science center number, *science center educators'* experience in year, and availability during the construction period.

Table 3.7 Science center educators as participants to current practices

Participant	Gender	Age	Work Experience	Science Center	Level of Education	Experience	Role	Department	Construction Period
Subj.01	Female	34	10	SciCen.01	Master	8	Education Coordinator	Faculty of Education	No
Subj.02	Male	33	9	SciCen.02	Bachelor	3	Education Coordinator	Faculty of Education	No
Subj.03	Female	28	3	SciCen.03	PhD	1	Education Coordinator	Faculty of Science and Literature	No
Subj.04	Female	29	8	SciCen.04	PhD	1	Education Coordinator	Faculty of Science and Literature	No
Subj.05	Female	25	8	SciCen.04	Master	3	Educator	Faculty of Education	No
Subj.06	Female	30	8	SciCen.04	Master	3	Educator	Faculty of Education	No
Subj.07	Male	30	8	SciCen.04	Master	3	Educator	Faculty of Science and Literature	No
Subj.08	Male	43	10	SciCen.05	Bachelor	8	Education Coordinator	Faculty of Science and Literature	Yes
Subj.09	Male	30	5	SciCen.06	Master	4	Education Coordinator	Faculty of Science and Literature,	Yes
Subj.10	Female	37	3	SciCen.07	PhD	3	Education Coordinator	Engineering, Faculty of Education	Yes
Subj.11	Female	26	3	SciCen.07	Bachelor	1	Educator	Faculty of Science and Literature	Yes
Subj.12	Male	29	3	SciCen.07	Bachelor	2	Educator	Faculty of Science and Literature	Yes
Subj.13	Male	31	3	SciCen.07	Bachelor	3	Educator	Faculty of Science and Literature	Yes
Subj.14	Male	38	2	SciCen.08	Bachelor	2 + 3	Education Coordinator	Engineering, Faculty of Education	Yes
Subj.15	Female	32	3	SciCen.09	PhD	3	Education Specialist	Faculty of Science and Literature	No
Subj.16	Female	56	6	SciCen.10	Master	6	Education Coordinator	Engineering	No
Subj.17	Male	35	12	SciCen.11	PhD	6	Education Coordinator	Faculty of Education	Yes
Subj.18	Male	31	4	SciCen.12	Bachelor	4	Organizational Coordinator	Faculty of Economics and Administrative Sciences	Yes
Subj.19	Female	31	4	SciCen.12	Master	4	Educator	Faculty of Education	Yes
Subj.20	Male	45	21	SciCen.13	Master	21	Education Coordinator	Engineering	Yes

Science Teachers

A total of three voluntary science teachers (N_{female}= 2, N_{male}= 1) participated in the current practices study. Science teachers were selected regarding the convenient sampling among *ST*s who visited one of the investigated science centers recently as a part of extra-curricular school activity. They were *science teachers* for 7th graders at different elementary schools with the mean age of 38.6, and they got their graduations from the faculty of education. Table 3.8 shows the participant number, gender, age, teaching experience in the year, and which *science center* they had attended as a visiting school group.

Table 3.8 Science teachers participated in current practices study

Teacher No	**Gender**	**Age**	**Experience**	**Region**	**Socioeconomic Neighborhood**	**Attended SC**
Teach.01	Male	45	19	Metropolis	High	Sci.Cen.13
Teach.02	Female	44	19	Metropolis	High	Sci.Cen.11
Teach.03	Female	27	3	District	Middle	Sci.Cen.06

3.3.3 Data Collection Instruments and Data Sources

The primary data collection instruments were the semi-structured interview protocols for key actors (science teachers and science center educators) within the science center context. Furthermore, field notes during the researcher visited the science center environment were kept. Additionally, documents such as teacher booklets, exhibition unit booklets, science curriculum, lesson plans, and worksheets were obtained from visited science centers. Table 3.9 shows the summary of the data sources and used instruments.

Table 3.9 Summary of Data Sources and Used Instruments for Current Practices

#	Data Sources	Definition	Purpose
1.	Interviews	Semi-structured interviews with the key actors (science teachers and science center educators).	In-depth understanding of the educational effectiveness within the science centers
2.	Fieldnotes	Fieldnotes after interviews with the science center educators were kept during the science center visit.	To support the interview data and understand the instructional design issues within science centers
3.	Documents	Teacher booklets, exhibition unit booklets, science curriculum, lesson plans, and worksheets were obtained from the visited science centers.	To verify the informants' data and field notes

3.3.3.1 Interview Protocol

The qualitative research interview is "a process in which knowledge is contructed between research and participant" having a structure and purpose related to the research suty (Brinkman & Kvale, 2015). The researcher conduct an interview to understand the subject's point of views which are actively engaged in meaning-making processes (Kvale, 1996; Bogdan & Biklen, 2007). Interview protocols are essential to use the allocated time for the interview effective and help to frame the interview questions and prioritization of question orders to organize the interviews in a focused manner and take the relevant answers.

Separate semi-structured interview protocols were prepared for *science center educators* and *science teachers* in Turkish. Based on the conceptual framework and literature review, the interview questions were generated under three themes *for science center educators* as *established collaborations, instructional design, and visitor tracking* (see Appendix A). The interview protocol for semi-structured interviews with science center educators was prepared in August 2016, and the interview questions were prepared in a way that addressed the research questions. After the interview questions were prepared, the interview protocol was sent for the evaluation and guidance of the instructional design expertand one science center educator. After the feedback period, the interview questions were re-organized. The questions and content of the protocols for participants were reviewed by two experts in the Instructional Technology and Science Education field. According to feedbacks, the researcher added prompts in case the informants have not a quick answer for his/her experience. Also, two of the questions for science center educators were rewritten due to the generation of "Yes/No answer" rather than being an open-ended question for the semi-structured interview. Also, research questions, the purpose, and a summary of the study were added in the protocols to gather more focused information from the participants. To collect descriptive data regarding *SCE*s' demographics, additional to 20 questions, their ages, years of experience, level of education, department, and the leading role in the science center was added at the beginning of each interview protocol.

The interview protocol for science teachers was generated under three themes as the *role of distribution, students' perceived metacognitive activities and student tracking* (see Appendix B). It was prepared in the 2017 March at Qualitative Research Method Course, and the interview questions were prepared in a way to address the research questions. After the interview questions were prepared, the interview protocol was sent for the evaluation and guidance of the thesis advisor, an academician and one science teacher. After the feedback period, the interview questions were re-organized. Similarly, one central question with three prompts about science teachers' demographics such as their ages and year of experience were added to the interview protocol.

Since the time-sequence regarding science center visit experience may reveal in-depth information for the interrelation between classroom level and science center level by considering the public and school policies, the questıons other than introduction and demographics, were grouped under three sections as prior to science center visit, during the science center visit and after the science center visit in both interview protocols.

Creswell (2009) emphasizes the importance of the pilot testing of the interview questions to make clarifications on the content of the interview and to understand whether it is feasible to be conducted or not. Cognitive debriefing technique was used to ensure that the interview protocol has no ambiguous or leading questions and there are adequately clear questions for science teachers and science center educations. The cognitive debriefing technique was applied to one person for each interview protocol. For the science center educator interview protocol, one female participated in the pilot testing. Similarly, for the interview protocol of science teachers, one male involved in the pilot testing.

To understand what the participants think about the questions, the researcher asked participants to think aloud while they are evaluating the questions. Thus, thoughts of the participants were easy to be tracked during their question evaluations whether they have any other questions regarding the existing one and whether the meaning of the questions was clear enough to understand and answer to them.

The interviews lasted approximately 35 minutes for each pilot study participant. After the cognitive debriefing process, some terms indicated in the questions were changed. For instance, the term "(öğrenme görevi) learning task" and "(etkinlik) activity" were clarified. Questions about the reason "why" the cooperations have been established by science centers with different institutions and individuals and the way "how" the implications have been changed were included. Also, to get more precious responses from the participants, the prompts were modified.

At the end of the pilot tests, the interview protocols were re-examined and finalized by the researcher and sent to one expert having researches related with the metacognition. After having reviews from the expert, the interview protocol was corrected again and was made ready for data collection process.

After all revisions, the final *SCE*s' interview protocol had two background questions, nine demographics questions, and 20 semi-structured interview questions (eight questions for prior to science center visit section, nine questions for during the science center visit section and three questions after the science center visit section). The final *SE*s' interview protocol had four background questions, two demographics questions, and 13 semi-structured interview questions (four questions for prior to science center visit section, six questions for during the science center visit section and four questions after the science center visit section).

3.3.3.2 Documents

O'Leary (2004) classified the documents under three categories as public records, personal documents, and physical evidence. Online and printed documents of science centers were collected within the bounds of possibility. Science center educators provided both online and printed documents. The documents include booklets for teachers, public information regarding exhibition units, pre- and post-tests, instructional stages for demonstration of the exhibition units, brochure response and sample workshop materials. Table 3.10 shows the available and given documents for analysis by science centers. However, not any document was obtained from the science teacher groups.

Table 3.10 Available Documents of Science Centers

Science Center	Available Documents
SciCen.01	Activities during the semester
SciCen.02	None
SciCen.03	Science educator booklet for demonstrations
SciCen.04	Laboratory program for the whole year
SciCen.05	Lists of exhibition units
SciCen.06	Brochure
SciCen.07	Exhibition unit brochure, Winter/Summer school program, Pre- and Post- Tests
SciCen.08	Exhibition unit demonstration plan
SciCen.09	Worksheet example
SciCen.10	Teacher booklet
SciCen.11	School visit programs
SciCen.12	Informative brochure
SciCen.13	Informative brochure, Website

Available documents provided valuable information on science centers' instructional design processes; also, provided a more extensive perspective regarding the science centers.

3.3.3.3 Field Notes

Although current practices study includes interviews and documents, to verify the data obtained from each informant, field notes were taken by the researcher regarding the orders of exhibition units, available exhibition units, group sizes visiting science centers and the role of science center educators and science teachers during the visits. Since the field notes were to verify the informants' data, they were not separately analyzed within the *current practices study*. However, they are mentioned under the lessons learned from the study section when it is necessary.

3.3.4 Data Collection Process

Data collection in current practices study includes data collection instruments as semi-structured interviews, field notes, and documents. The following headings presents the data collection process.

Research Permissions

After the data collection instruments were ready to conduct the study, the permission of the Ethics Committee was needed to take from the Applied Ethics Research Center of Middle East Technical University to start collecting the data. The interview protocols, voluntary participation forms, and information form regarding the details of the research were examined and the study has approved to be conducted by the Human Subject Ethics Committee (see Appendix C).

For deciding on intervieewes and interview date, the researcher listed the science centers and had a telephone call with each science center seperately. After the researcher had mentioned about her purpose in the study and requests from *science* *center educator*s, she sent the interview protocol, research permission from Human Subject Ethics Committee, and the purpose of the study to science center educators as electronic mail and confirmed the date and place for the interview.

Semi-structured interviews with *science center educators* were conducted between April 2017 and October 2017 as face-to-face sessions in six cities of Turkey as Ankara, Bursa, Eskişehir, Gaziantep, İstanbul, Kocaeli, and Konya (see Figure 3.3).. *For the location*, except for two interviews, the interviews were conducted in a private room. One of the exceptions was due to the time restriction of the researcher so that the interview was done as a distance interview via Google Hangout. The other exception was due to the time restriction of the interviewee so that this interview was held at a cafe in a quiet separate place. *For taking permission before the interview*, the interviewee was informed about the confidentiality and asked permission for the recording of the interview. Except for one science center educator, all participants accepted using a voice recorder. For no-permission of the voice record, the researcher took detailed notes during the interviews and sent it to the *science center educator* after the interview for the confirmation of the notes. For the consistency of data collection procedure, all interviews were conducted by the researcher in the Turkish language.

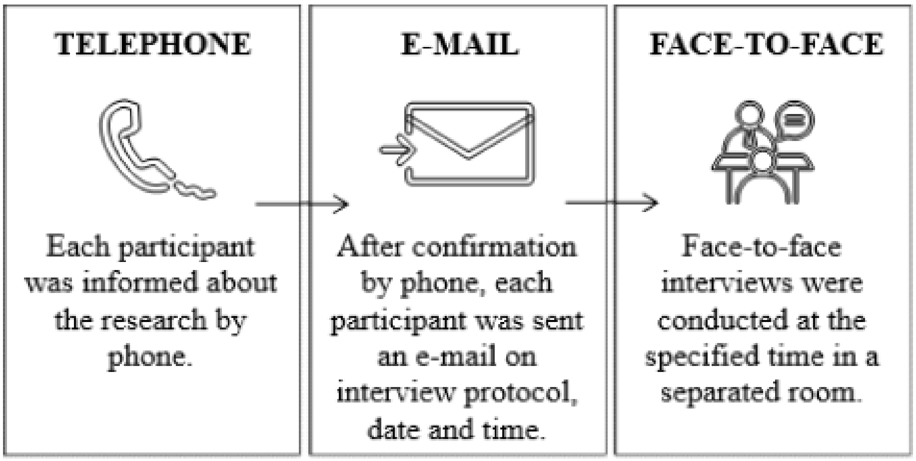


Figure 3.5 Interview process of science center educators

During the interview, the researcher conducted the interview protocol, and if it was needed, clarifications and further questions were asked to participants. Each interview lasted from 40 minutes to 75 minutes.

After the interviews, each *science center educator* was accompanied by the researcher for the science center visit and provided guidance and the available documents for the researcher. Later, the researcher sent a pen to each science center educators as a memory of their voluntary participation in the interviews.

Semi-structured Interviews with Science Teachers

Semi-structured interviews with *science teachers* were conducted between 2017 April and 2017 May as face-to-face sessions in two cities of Turkey as Ankara and Manisa (as a visitor school group to SciCen.06). *For deciding on intervieewes and interview date*, the researcher had a telephone call with each school separately. After the researcher had mentioned about her purpose in the study and requests from *science teacher*s, she sent the interview protocol, the research Human Subject Ethics Committee permission form and the purpose of the study to *science teacher*s as electronic mail and confirmed the date and place for the interview.

Each interview was conducted individually in a quiet and separate place at school environment (laboratory, counseling room, and teachers' lounge during the class hour) and lasted from 30 minutes to 45 minutes. For the consistency of the data collection procedure, all interviews were conducted by the researcher in the Turkish language.

3.3.5 Data Analysis

Content analysis was carried out by the researcher (Strauss & Corbin, 1998). During the data analysis process, three stages of analysis in coding as open coding, axial coding, and selective coding were used (Strauss & Corbin, 1999; Neuman, 2009). Open coding is a procedure in this data analysis technique to develop conceptual categories; whereas, axial coding is a procedure to investigate the relationships between the categories. Finally, selective coding is a procedure to build a story among the categories and find the core categories for offering theoretical propositions.

Data analysis was performed after each interview. The voice records were transcribed, and a clean copy was made for the taken notes (for one science center). After each interview was transcribed, they were sent to the interviewees for the member checking phase. After the interviewees confirmed the transcribed interviewees, the coding was performed. During the data analysis, the coding process was iterative, and it was coded around the concept of *educational effectiveness.* Therefore, current practices created categories related to having a relationship to educational effectiveness.

During the open coding, the transcribed text was examined for salient categories, and the codes were applied to the text to label the phenomena. The data were conceptualized with more abstract terms such as "Lack of pedagogical knowledge". Then, the concepts were grouped, and a category was defined for each concept so that categories were developed by the grouped concepts. Categories were named as using broad in vivo codes. Also, a sentence by sentence coding approach was used during the open coding procedure. After the categories were created, the hierarchies between the categories were specified. And, the memos kept by the research during the open coding were reviewed so that the momentary thought while creating the codes were revisited (Glaser, 1978). Figure 3.6 shows the open coding process.

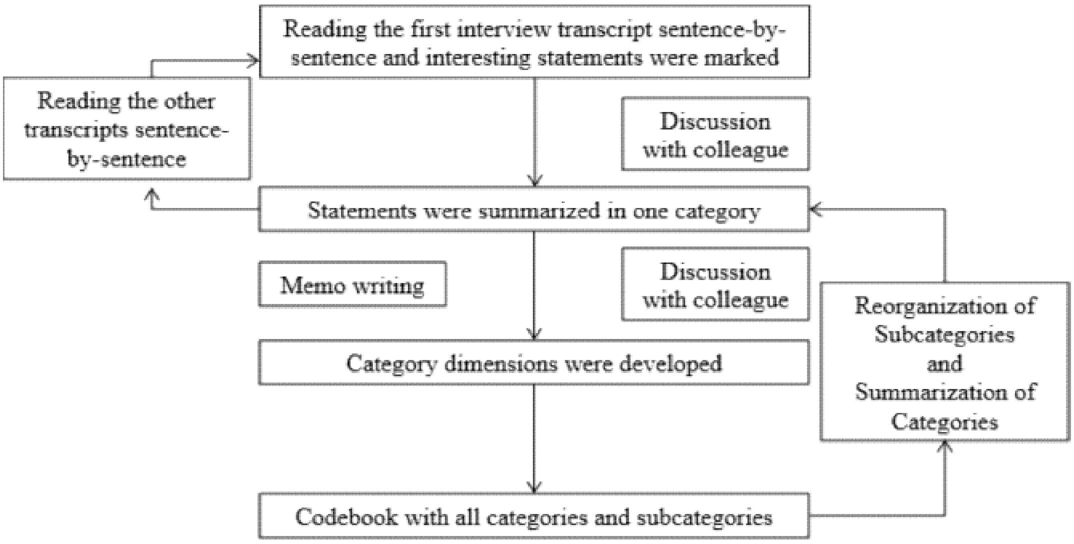


Figure 3.6 Open Coding Process (Adapted from Strauss & Corbin, 1998)

During the axial coding, all data was coded to develop a model regarding the educational effectiveness within the science centers. First of all, causal conditions were taking the influencing factors of the central phenomenon, events, and incidences into account to identify the points for the occurrence of educational effectiveness. Secondly, the data was identified regarding its central idea. Third, the context and specific conditions were identified. Fourth, intervening conditions were determined. Fifth, action-oriented verbs were identified, and finally, consequences were identified. Figure 3.7 shows an example axial coding process.

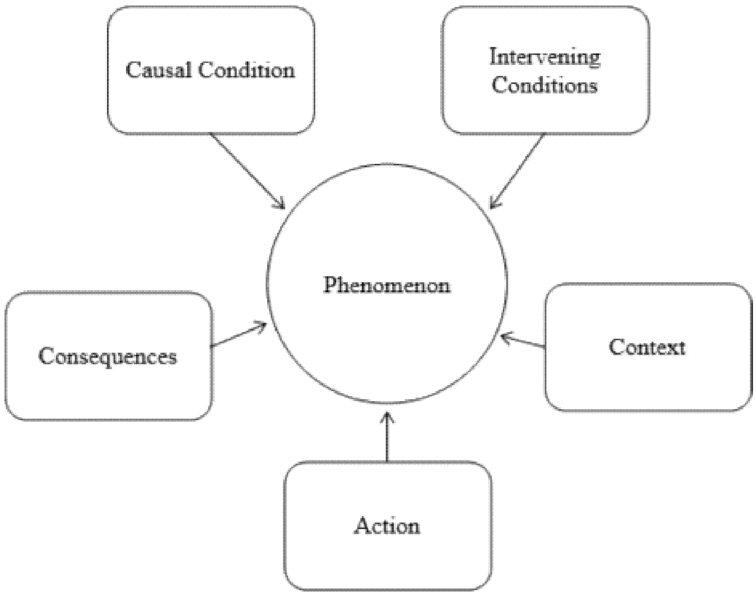


Figure 3.7 An example axial coding process

Finally, the selective coding procedure was applied to identify one or two categories as the central phenomena. The story around the educational effectiveness category was conceptualized, and the core category was related to other categories.

After the coding process, a comprehensive report about the data by interpreting the findings and the conclusions was generated. Also, related quotations were selected as examples to categories, themes, and subthemes.

3.3.6 Trustworthiness

Marshall & Rossman (2016) states that trustworthiness or goodness of qualitative research, including reliability and validity, is derived from quantitative approaches to restrict the limitations on contextually and personally interpretive nature. On the other hand, Denzin and Lincoln (1994) define a set of criteria for trustworthiness, which are credibility, transferability, dependability, and confirmability. In this study, to ensure the trustworthiness of qualitative findings, these four criteria were used.

Credibility

The credibility of the *current practices study* was enhanced by using data triangulation, member check, and peer reviews. Data triangulation was applied to collect pieces of evidence from different individuals (Creswell, 2007). Therefore, this allowed investigating the phenomenon from different perspectives (Bogdan & Biklen, 2007).

In current practices study, the researcher obtained a clear and comprehensive understanding of educational effectiveness within different science center settings based on science center educators' and science teachers' experiences through data triangulation process. Besides, different types of data sources including interviews, field notes, and documents for enhancing the validity of the study. In addition to the data triangulation process, the member check strategy was used to strengthen the credibility of the study (Miles & Huberman, 1994). After each interview, transcriptions were sent to the participants via e-mail to satisfy this strategy to get their feedback (see Appendix D).

Finally, the peer review strategy was applied to enhance validity, including the individuals who are familiar to the phenomenon and studied area taking the role as an external controller of the data (Creswell & Poth, 2016). The advisor was considered as a peer reviewer of this study, and the researcher had to present the findings through collected data so that this process was to ensure the researchers' findings.

Transferability

Creswell (2017) emphasized the importance of providing a detailed description of the phenomenon in reference to the methodology and the context to allow the reader to make their judgment regarding transferability. For this purpose, the researcher provided a detailed description of each step in the research process for a clear understanding of the conditions and consequences by the readers. In this *current practices study*, the visited science centers and their characteristics with the participants' characteristics were provided to illustrate the surroundings of the study for the readers.

Dependability

Consistent and repetitive findings are essential to establish the dependability (or reliability) within the research process (Miles & Huberman, 1994; Creswell, 2007). Intercoder agreement is one of the most preferred strategies to ensure dependability. With the intercoder agreement, more than one coder analyzed the collected data to see whether the same codes are generated from the same excerpts of the document (Creswell, 2007). In this study, the intercoder agreement was applied to eliminate the bias of the researcher when analyzing the text-based data.

Miles and Huberman (1994) recommended a reliability score between .80 and .90 on an excellent reliability check after the first calculation of intercoder agreement. During the inter coding process, after coding the data consisting of 10 percent of the transcripts, the coders discussed the codes and reached a consensus on the precise definition of the codes (Hodson, 1999). This procedure was repeated until the required intercoder agreement score was obtained. The most informative interview transcript of science center educators was selected to be coded by another researcher. The independent intercoder was a researcher in the Department of Computer Education and Instructional Technology at Middle East Technical University. She conducted qualitative studies in both her master's thesis and research studies.

Before the coding process, the intercoder was briefly informed about the purpose, the research questions and the methodology of the study. The researcher as the main coder and the intercoder also agreed about the procedure of the coding to ensure reliability. This procedure included coding independently, assuring reconciliation of different codes, deciding on all codes and re-coding if it was necessary. After the first cycle of the coding, the two coders came together to discuss and comment on the similarities and differences between the codes to form a consensus and create a standard coding table. Since the score of the intercoder agreement was found as .74, the necessity of re-coding occurred. After the second cycle of the coding, the score was .90.

Since the satisfactory score obtained from the second cycle of the coding, the researcher continued the coding by herself. However, during the coding process, in case a possibility to change any code was also consulted to the intercoder.

Confirmability

Confirmability (also refers to objectivity) is the degree of the neutrality of the findings. Miles and Huberman (1994) pointed out the possibility of objectivity in case the researcher states his/her prejudices and tendencies.

In this study, the researcher kept a journal and reflecting the notes on interviews, participants, attitude, and thoughts to avoid misinterpretations of the data. With the help of the kept journal and applied triangulation method, the researcher tried to ensure that the interpretations and findings derived from the actual data collected from informants rather than produced through the effect of the researcher's imagination or biases.

3.3.7 Ethical Considerations

Throughout the research process, ethical principles were taken into consideration carefully. The research permission from the Human Ethics Committee at METU was taken. Later than the research permission process, before the interviews begin, each participant was informed about the study purpose and the research process in a deliberate manner. Participants were told to be able to stop the interview when they felt like it.

The anonymity of the data was provided to ensure confidentiality, and the interview data and documents were not shared with any third party, and the names of the participants were not mentioned in the data report.

3.4 STUDY II: Multiple Case Study

In *multiple case study*, a qualitative method was utilized to understand the aspects of both individual and inter-individual metacognitive processes through 7th-grade students' interaction within a science center context.

3.4.1 Determination of the cases

The research study was formulated by selecting three cases as different lesson units from 7th graders' science lesson curriculum (Work and Energy, Mirrors and Light Absorption, and Solar System and Beyond). For each of the lesson units, the level of comparison was both individual and inter-individual.

The reason that the research study focused on both individual and inter-individual levels of comparison was due to practical and theoretical issues. For example, the selected lesson units have varying exhibition units as a result of their different nature of concepts, lesson objectives and learning goals in the science curriculum. However, the description of similarities and differences in practice may reveal the actual context and implementation of the scientific context within science center environments. Thus, multiple cases were selected and investigated in a comparative setting to discover and explain differences and similarities between cases.

Major components of the research design and related justifications are presented as follows (Merriam, 1998; Yin, 2009):

(1) ***Bounded system**:* A case can be seen as a phenomenon of constructed reality by individuals in a bounded context (Merriam, 1998; Stake, 1995). Depending on what the purpose of the study is and what the rationales behind the decisions are, a science concept may be defined as a case, a group of people, a unit or a case study itself (Gerring, 2004). Cases in this study were bounded by (a) *nature of concepts of the related science lesson units,* (b) *characteristics of exhibition units*, (c) *guidance and*

collaborative activities within science center environment, (d) *time period –only three weeks- field research for separated learning objectives* and (e) *conceptual framework of the study* (metacognitive processes within science center environments).

Science center as the metacognitive context in selected science lesson subjects was the phenomenon investigated, science centers were the bounded system, and their educational effectiveness in reference to students' metacognitive processes was the context. The purpose was to propose the whole picture of metacognitive processes which can be separated from neither the entire system nor the unique characteristics of the selected science lesson units. The comparison of how metacognitive processes occur throughout educational processes was limited to multiple actors within the science centers about selected exhibition units.

***(2) Unit of Analysis & Unit of Observation**:* Units of analysis are not necessarily required to be the same as the units of observation (di Gregorio & Davidson, 2008). Because, while "unit of analysis" refers to an entity that is being studied and a level at which results are determined, "unit of observation" is a level at which data is collected to understand the "unit of analysis". Concordantly, the unit of analysis is formed by the research questions, while the "unit of observation" is determined by the data collection methods.

In the research study, the "unit of observation" was the multiple actors (science center educators and students) in reference to three science lesson units and corresponding exhibition units who were interviewed and observed in their respective guidance and collaborative stages of science center environments. The observations supported the researcher in gaining an understanding of the science center events. It is difficult to draw a clear line between the units in the context of qualitative research since it is tough to find a definitive distinction between the unit of analysis and unit of observation.

(3) ***Nature of phenomenon:*** In the research study, not all of the potentially important aspects of metacognitive processes were known in advance in each context. Additionally, complex differences between participants' metacognitive processes would reveal different findings within and in-between cases. Participants' *science conceptual understanding* and *metacognitive processes* could not be separated from the context of the study. Thus, a research design that allowed to keep an open mind within a given research parameter was required to understand the complex phenomenon as students' individual and inter-individual metacognitive processes in its real-world context where it is found and functioned. As Merriam (1998) claimed that "the case study offers a means of investigating complex social units consisting of multiple variables of potential importance in understanding the phenomenon" (pp. 41), the nature of the phenomenon within the current study indeed required a case study design.

(4) ***Nature of research questions:*** According to Yin (2009), case studies are favorable when "how" or "why" questions are being asked. The research study explained differences and similarities in science concepts that exist at the science center level, and illustrates how students' metacognitive processes occur at individual and inter-individual levels in science center context in reference to concepts related to "work and energy", "mirrors and light absorption", and "solar system and beyond".

(5) ***Nature of event:*** Case studies are suitable when contemporary events are investigated, and when behavior cannot be controlled (Yin, 2009). Case studies can provide a broad range of data collection, such as observation or interviews with people currently involved in the event. Experiments are a suitable research strategy if the researcher can control the behavior of the investigated events/people in general. When conducting the research study, the researcher did not have any control over the action or conduct

of the multiple actors (students, science center educators, and teachers) throughout the observations and interviews.

(6) Multi-case design: The scope of a comparative study may cover a range including more than one lesson unit, or it could be arranged to compare the conditions of one specific lesson unit but at different times and/or having different exhibition units. Within the studies employing a methodology of a comparative approach, as Ragin (1987) stated, a case-oriented research is used. As further noted in the study of Ragin (1987), cases given within the qualitative research are regarded as configurations that are formed by the combined characteristics, and they can be treated as a whole. The study approach that is referred to as multiple cases has the purpose of observing the processes and outcomes derived through several cases or sites. This approach also helps to comprehend how these processes and outcomes get qualified by the local conditions and lead the development of more sophisticated and more powerful explanations" (Miles & Huberman, 1994). Among the purposes of shaping and guiding this study, a comparison of the cases took its place.

As the research study was built on three cases in different science lesson units, it was classified as a multiple-case (cross-case) study (Merriam, 1998; Yin, 2009). Multi-Case study design was conducted, which comprises the comparison of cases that differ on specific crucial characteristics. Moreover, it was helpful to identify essential patterns formed by the data collection. It aimed to provide a comparison of metacognitive processes at individual and inter-individual levels within the borders of the cases. The levels of comparison were conceptual in work and energy, mirrors and light absorption, and solar system and beyond lesson units. Units of comparison were the aspects of individual and inter-individual metacognitive processes of students within the three chosen lesson units. Metacognitive processes in terms of conceptual understanding within science center environments were analyzed, described and illustrated using qualitative research methods.

3.4.2 Contextual Settings of the Study

This section described the research environments (exhibition units in relation to science lesson units and the associated science centers and schools) for each case and their characteristics to give readers an idea about the actual context of these cases in general. These characteristics are described via the journal kept by the researcher, the interviews with the science center educators, and obtained online and printed documents.

Research environment selection is one of the substantial issues in multiple case studies. Since the researcher focuses on the central phenomenon as "science centers as metacognitive contexts" and investigated different subject matter areas with varying units of exhibition in science centers as in with three cases, the research environments were selected considering the available exhibition units matched with the science concepts. In a nutshell, research environment micro-selection criteria include (a) balance between the science concepts, (b) variety between the science concepts, (c) balance between the contextual settings of three cases, and (d) variation between the contextual settings of three cases.

The balance between science concepts refers to the balance between the selected science lesson units. Although selected science lesson units were mentioned as in different levels in theoretical aspects, they all require interactivity during the meaning-making process. As mentioned, a variety between the science concepts was also provided as in theoretical aspects to have opportunities for learning about complexity and contexts. Besides the criteria related to science concepts, context-related criteria were provided. First of all, the balance between the contextual settings of three cases governed regarding the number and the characteristics of the contextual materials. Second, the variety between the contexts was provided as the different exhibition units in different interactivity levels.

In addition to micro-selection criteria, macro-selection criteria were performed during the final decision to selecting the science centers. Since current practices study feedforwarded the rest of the study, interviewed science center educators allowed portrait drawing of each science center. Two of them were selected for the exhibition units which are matched with the investigated science concepts.

Selected contextual settings of each case, including science concepts and their related exhibition units and selected science centers with their historical, cultural and physical characteristics, were indicated at the following headings.

3.4.2.1 Case I: Work and Energy (conducted in Feza Gürsey Science Center)

Work and energy was the first science lesson unit in this study. It was carried out in Feza Gürsey Science Center, which is one of the early founded science centers in Turkey located in Ankara. Following headings mentioned the contextual setting of Feza Gürsey Science Center, used exhibition units for the work and energy case, assigned learning objectives to these cases, and explanations of the exhibition units.

Feza Gürsey Science Center

"Work and Energy" unit was carried out in one of the early founded science centers in Turkey located in Ankara. It has six science center educators for a variety of roles, which are preparing educational materials, guiding for exhibition units, serving to school for demonstration experiments and conducting workshops. Besides science center educators, *Feza Gürsey Science Center* has two organizational personnel who are taking appointments for the visiting groups. *Feza Gürsey Science Center* was established in 1993 and has 50 exhibition units. These exhibition units are belonging to physics and biology related subject matter areas (Table 3.11). This science center is open each day with the exception of religious and national holidays for individual or group visitors. Requested group visits may include kindergarten, elementary, secondary and high school group levels. For the guiding process, visiting school groups have been taking guidance for five exhibition units which are appropriate to their educational level.

Figure 3.8 First floor of Feza Gürsey Science Center

Figure 3.9 Second floor of Feza Gürsey Science Center

Table 3.11 Exhibition units and educational areas in Feza Gürsey Science Center

Floor	Type	Category or Function
Sub-ground Floor	Workshop area	Doing wet-laboratory experiments Conducting workshops for supplying the units Conducting membership activities for enjoying
Ground Floor	Demonstration area	Experiment demonstration Group preparation for science center experience Sitting area for a rest
	Exhibition unit area	Units under physics concepts Units under perception concepts
First Floor	Exhibition unit area	Units under biology concepts Units under physics concepts

Exhibition Units and Assigned Objectives

Table 3.12 shows the associated exhibition units in Feza Gürsey Science Center and assigned learning objectives with these exhibition units. The assigned objectives were taken from the 7th-grade science lesson curriculum, and they were assigned to the related exhibition units.

Table 3.12 Exhibition units and assigned learning objectives for Work and Energy Case in Feza Gürsey Science Center

Week	Exhibition Units	Assigned Objectives
FIRST WEEK	Sand Pendulum Press Test Pedal Force	*Mass and Weight Relationship* Defines the weight as a force and measures its magnitude with a dynamometer, denoting the gravitational force acting on the mass as weight. Compares the concepts of mass and weight.
	3d Sand Pool Air Bubble Race Bernoulli's Ball Hot Air Balloon	*Force-Solid Pressure Relationship* Explores the variables affecting the solid pressure by experimenting and analyzes the relationship between these variables. Discovers the variables affecting fluid pressure by trying and analyses the relationship between these variables. a. It is emphasized that gases exert pressure in a similar manner to liquids. b. Variables and mathematical equations affecting liquid and gas pressure are not mentioned. Gives examples of pressure properties of solids, liquids, and gases in daily life and technology

Table 3.12 (Cont.) Exhibition units and assigned learning objectives for Work and Energy Case in Feza Gürsey Science Center

Week	Exhibition Units	Assigned Objectives
SECOND WEEK	Guess who wins 3d Sand Pool	*Force, Work and Energy Relationship* Understands that the work done in the physical sense is directly proportional to the applied force and the path taken and indicates the unit. Associates energy with work concept, classifies it as kinetic and potential energy. a. Potential energy is classified as gravitational potential energy and elasticity potential energy, but mathematical relations are not mentioned.
	Guess who wins 3d Sand Pool Pedal Force Measure your power	*Energy Transformation* Explains the transformation of kinetic and potential energy types with examples and concludes that energy is conserved. Explains the effect of friction force on kinetic energy with examples. a. Friction surfaces, air resistance, and water resistance are taken into account in exemplifying the effect of friction force on kinetic energy. b. It is inferred that the loss of kinetic energy is converted to heat energy by a simple experiment showing that the friction surfaces are heated.

In addition to educational spaces selected for each learning objective of work and energy unit, associated exhibition units and their explanations were mentioned in Table 3.13.

Table 3.13 Exhibition units and explanations in Feza Gürsey Science Center

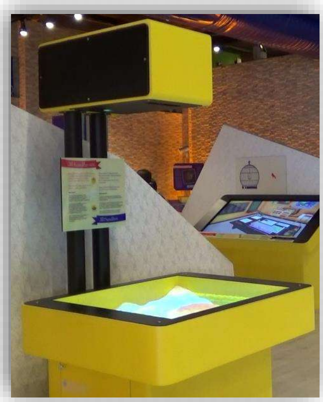
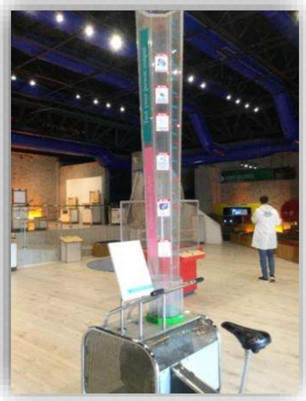
Exhibition Units	**Images**	**Explanation**
Sand Pendulum		The sand pendulum was to make students remember the *force* concept, especially *resultant* and *friction forces*. It consists of a long, and two short ropes joined in a V-shape above. It works by filling sand in a box with holes at the end of the long line.
3d Sand Pool		The 3d Sand Pool was used to describe the solid pressure and the variables to which the solid pressure depends. It consists of sand in different colors projected as various landforms.
Air Bubble Race		Air Bubble Race was to make students observe the velocity and size of the air bubbles in the fluids after applying force with the help of a pump. It consists of three tubes with different density liquids as water, water and glyserin mixture and glyserin.

Table 3.13 (Cont.) Exhibition units and explanations in Feza Gürsey Science Center

Exhibition Units	**Images**	**Explanation**
Hot Air Balloon		Hot Air Balloon was to make students observe the balloon aeration. The exhibition unit fires through a button. It reduces the gas density by heating the air inside the balloon.
Bernoulli's Ball		Bernoulli's Ball has a funnel, a ventilation unit and a ball. In the device which is opened with the help of the button, after the air is blown, the ball rests on the moving air which has lower pressure.
Pedal Force		In Pedal Force, the dynamo connected to the pedals operates as the pedals of the bicycle are turned, and it operates the radio and the bulb connected to the dynamo.

Table 3.13 (Cont.) Exhibition units and explanations in Feza Gürsey Science Center

Exhibition Units	Images	Explanation
Guess Who Wins		In Guess Who Wins, two discs with different weight distribution are released from the same height and with equal force, which can be observed before completing the race.
Measure Your Power		In Measure Your Power, the pedals of the bicycle are turned, and the propeller is operated, and the air is blown, and the ball is raised. Thus, it can be observed that kinetic energy is converted to gravitational potential energy.

3.4.2.2 Case II: Mirrors and Light Absorption (Conducted in Kocaeli Science Center)

Mirrors and light absorption was the second science lesson unit in this study. It was carried out in Kocaeli Science Center. Following headings mentioned the contextual setting of Kocaeli Science Center, used exhibition units for the work and energy case, assigned learning objectives to these cases, and explanations of the exhibition units.

Kocaeli Science Center

Mirrors and light absorption was carried out in one of the biggest science centers in Turkey located in Kocaeli. It has eight science center educators, two technological support employees and one communication employee who is responsible for preparing, conducting and evaluating educational activities. This science center is open each day with the exception of national holidays for individual or group visitors. Even though, the requested group visits may include kindergarten, elementary, secondary, and high school group levels, the science center educators guide kindergarten and elementary students rather than secondary and high school group levels. For the guiding process, visiting school groups have been taking guidance for pre-determined exhibition units which are selected among the highest interactivity levels. Table 3.14 shows the exhibition units and educational areas in *Kocaeli Science Center.*

Table 3.14 Exhibition units and educational areas in Kocaeli Science Center

Floor	Type	Category or Function
First Floor	Exhibition unit area	Dynamical World
		Perception and Reality
		Sultans of the Science
Second Floor	Demonstration area	Experiment demonstration Group preparation for science center experience Sitting for a rest
	Workshop area	Material production Technical skill acquisition
	Library area	Studying Sitting for a rest Solving puzzles

Exhibition Units and Assigned Objectives

Table 3.15 shows the associated exhibition units in Kocaeli Science Center and assigned learning objectives with these exhibition units. The assigned objectives were taken from the 7^{th}-grade science lesson curriculum, and they were assigned to the related exhibition units.

Table 3.15 Exhibition units and assigned learning objectives for mirrors and light absorption in Kocaeli Science Center

Exhibition Units	Assigned Learning Objectives
Monochrome Room Shadow Play Countless Color	*Light Absorption* Discovers that light can be absorbed by matter as a result of its interaction with matter Concludes that white light is a combination of all light colors Relates the reason why objects appear black, white, and color, with the reflection and absorption of light as a result of observations Gives examples of innovative applications of solar energy in daily life and technology Discusses the ideas about how to make use of solar energy in the future
Touch the Spring Infinite Views	*Mirrors* Observes mirror types and gives examples of usage areas Compares the images formed in flat, concave and convex mirrors: a. Image drawing by special rays is not mentioned b. Mathematical relations are not mentioned c. The properties of the image of the object (large / small, inverse / straight) in the concave mirror may vary according to the distance of the object from the mirror can be mentioned
Color Removal	*Light Refraction and Lenses* By observing the path of light changing the environment, it relates the cause of refraction to the change of environment Observes the refraction of light by experiment using thin and thick-edged lenses Give examples of the use of lenses in daily life and technology Designs an imaging tool using mirrors or lenses

In addition to educational spaces selected for each learning objective of mirrors and light absorption unit, associated exhibition units and their explanations were mentioned in Table 3.16.

Table 3.16 Exhibition units and their explanation for mirrors and light absorption in Kocaeli Science Center

Exhibition Units	**Images**	**Explanation**
Monochrome Room		Monochrome Room was to make students observe the results in the difference of the lights. In this room, there is no red light to reflect objects and make them look red, and there is no blue or green light. The objects in this room look odd because a single color light illuminates them. Usually, light with many color illuminate the world around people. For example, a sweater looks red because it reflects red.
Colored Shadows		Colored Shadows was to make students observe different tones of the colors. By mixing the lights in different colors, new tones are obtained. For example, when you block the blue light, you make a shadow with Red and Green light. The shade formed by the combination of red and green light is yellow.

Table 3.16 (Cont.) Exhibition units and their explanation for mirrors and light absorption in Kocaeli Science Center

Exhibition Units	**Images**	**Explanation**
Touch the Spring		Touch the Spring was to make students observe the image of the spring by considering the large curved mirror. The exhibition unit consists of a large curved mirror, spring and two observation holes at front and right sides. The large curved mirror helps to create the image of the spring. The light from the real spring is reflected in the mirror to form the image.
Infinite Views		Infinite Views was to make students observe the unlimited image formation and how many mirrors are needed to form this image. When an object is placed between two mirrors placed parallel to each other, the image of this object is formed separately in both mirrors, depending on their distance from the mirrors. Then, these images are formed in the reverse mirror image. For example, a new image is formed by the reflection of the image formed in one mirror to the other mirror, and this event continues successively, and infinite image formation takes place.

Table 3.16 (Cont.) Exhibition units and their explanation for mirrors and light absorption in Kocaeli Science Center

Exhibition Units	**Images**	**Explanation**
Color Removal		Color Removal was to make students observe the colors in rainbow from the white light. Each filter blocks some of these colors and passes some of them. The prism separates the remaining colors and allows us to see which colors pass through the filter.

3.4.2.3 Case III: Solar System and Beyond (conducted in Kocaeli Science Center)

Solar System and Beyond was the third science lesson unit in this study. It was carried out in Kocaeli Science Center. Following headings mentioned the used exhibition units for the solar system and beyond case, assigned learning objectives to these cases, and explanations of the exhibition units.

Exhibition Units and Assigned Objectives

Table 3.17 shows the associated exhibition units in Kocaeli Science Center and assigned learning objectives with these exhibition units. The assigned objectives were taken from the 7th-grade science lesson curriculum, and they were assigned to the related exhibition units.

Table 3.17 Exhibition units and assigned learning objectives for the solar system and beyond in Kocaeli Science Center

Exhibition Units	Assigned Learning Objectives
Turk-Islamic Astronomy World Moving Through Space	*Space Investigations* Explains space technologies Explains the causes of space pollution and predicts the possible consequences of this pollution Explains the relationship between technology and space investigation Explains the structure of the telescope and what it does a. Telescope types are mentioned. b. Light pollution is mentioned. Makes inferences about the importance of telescope in the development of astronomy a. The selection of observatory places and the conditions of these places are mentioned. b. The contributions of Western astronomers and Turkish Islamic astronomers are mentioned. Presents a simple telescope model
Summer Sun Winter Sun Constellation Viewer Solar System Model Gravity Well	*Solar System and Beyond: Celestial Bodies* Becomes aware of star formation process a. The concept of nebulae is mentioned. b. Examples of nebulae are given. c. The concept of the black hole is mentioned. Explains the concept of star a. Types of the star are mentioned. b. Constellations with the nomenclature of star groups seen from Earth are referred to. c. The distance between celestial bodies expressed in light-years is mentioned. Explains the structures of galaxies a. Types of galaxies are mentioned. b. Examples of galaxies include the Milky Way and Andromeda galaxies. Explains the concept of the universe

Besides, Table 3.18 shows associated exhibition units and their explanations on how they were used for satisfying the learning objectives needs.

Table 3.18 Exhibition units and their explanations for the solar system and beyond in Kocaeli Science Center

Exhibition Units	**Images**	**Explanation**
Turk-Islamic Astronomy World		Turk-Islamic Astronomy World was to make students observe ancient astronomical investigations in Anatolia. Mapping of stars andsky sphere were selected to discuss the Turk-Islamic Astronomy World which was related to the lesson objective.
Summer Sun Winter Sun		Summer Sun / Winter Sun was to make students observe the changes affected by the rays coming from the Sun to planets at different distances such as Earth or Mars. By keeping the panel fixed on the Earth and observing the changes in the sun rays falling into the Earth due to the shape of the Earth.

Table 3.18 (Cont.) Exhibition units and their explanations for the solar system and beyond in Kocaeli Science Center

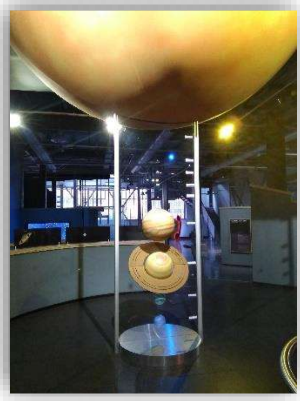
Exhibition Units	**Images**	**Explanation**
Constellation Viewer		Constellation Viewer was to make students observe the constellation and the change of the brightness and the position of stars depending on one's point of view. The stars, which are very close to each other when viewed from the earth, may be very far from each other in space. We perceive nearby stars as if they were brighter, but nearby stars may be pale. Distant stars may also be pale or golden. Its position has nothing to do with how bright the star is. The mass decides how bright the star will be and what stages it will pass through.
Solar System Model		Solar System Model was to make students investigate the properties of the sun and eight planets that make up the solar system.

Table 3.18 (Cont.) Exhibition units and their explanations for the solar system and beyond in Kocaeli Science Center

Exhibition Units	**Images**	**Explanation**
Gravity Well		Gravity Well was to make students observe he complete turn of the planets around the sun and the sun around the black hole. The planet closest to the sun is the fastest, and the distant planet is the slowest. Since the discovery of Neptune, one complete cycle has not been observed. Similar turns occur in the satellites around the planets. Also in the center of our galaxy is full of stars that revolve around the black hole.

3.4.3 Participants

Selection of Science Centers

Science centers were selected among the science centers who were participated in the Current Practices: Study I. During Study I, the researcher had an opportunity to see the science center environments and available units, which associated with the selected learning objectives. Based on the available units that are associated with the selected learning objectives and willingness of *SCE*s were the important factors on selecting the science centers in multiple case study. *SCE*s willingly involved in the study due to their point of view to support the researchers and researches within the science center.

Selection of Exhibition Units

The researcher either took a list of exhibition units from the science centers or took photos of the exhibition units which are available for the selected science lesson units. Table 3.19 shows the summary of selected units including the timing and the match of the curriculum subjects; teacher's requirement, and science center educators' advice from their previous experiences. Although science centers have exhibition units matched with the selected concepts, in case there is no specific exhibition unit for the concept, physical appearance of the exhibition units was taken into consideration as a selection criterion. For instance, since 3d Sand Pool provides a sand-surface environment, it can be selected to observe the differences in surface area and solid pressure by referring to daily life examples. In addition to aforementioned criteria, exhibition unit information which are close to associated exhibition units were the last selection criteria for the exhibition units during preparing instructional sequence.

Table 3.19 Sumary of selected exhibition untis for each case

Curriculum Subject	**Exhibition Units**	**Timing**	**Notes**
Force and Pressure	Sand Pendulum	5 min	• Teacher's requirement: Sand pendulum should be used to make students recall force concept. Air friction force should be mentioned. • SCE's advice: Students should observe different oscillatory movements regarding a variety of applied forces. • Timing issue: Since the oscillatory movemets may be diversed by applying a variety of forces, the time duration separated for the sand pendulum is enough to recall previous knowledge.
	Press Test	2 min	• Teacher's requirement: Press test should be used to make students recall force concept. • SCE's advice: Students should observe what kind of fixed variables affect the forces during press. • Timing issue: Since press test is to recall previous knowledge and quickly connect it with daily life example, the time duration spared for this exhibition unit is shorter compared to others.

Table 3.19 (Cont.) Sumary of selected exhibition untis for each case

Curriculum Subject	**Exhibition Units**	**Timing**	**Notes**
Force and Pressure	Pedal Force	3 min	• Teacher's requirement: Pedal force should be used to make students recall the force concept and a quick information regarding energy transformation should be given to prepare them for the second part of the subject matter. • SCE's advice: Students should observe how different forces applied to pedals result in difference within the level of light and sound of the electrical devices. • Timing issue: Since pedal force is to recall previous knowledge, quickly connect it with daily life example, and prepare students for the second part of the subject matter, the time duration spared for this exhibition unit is shorter compared to the time duration spared for focused concepts.
	3d Sand Pool	6 min	• Teacher's requirement: 3d Sand Pool (since it provides a sand-surface environment) should be used to make students recall both the force and introduce solid pressure. Examples of solid pressure should be given by referring to surface area. • SCE's advice: Students should also observe the landforms and air pressure in the sea level should be mentioned. • Timing issue: Since 3d sand pool is to introduce the pressure concept to students, it needs longer time.

Table 3.19 (Cont.) Sumary of selected exhibition untis for each case

Curriculum Subject	**Exhibition Units**	**Timing**	**Notes**
Force and Pressure	Air Bubble Race	5 min	• Teacher's requirement: Air bubble race should be used for the liquid pressure and connect the liquid pressure concept with the force. • SCE's advice: Students should see the difference between the sizes of the bubbles in different liquid tubes and they need to try it in a competitive way. • Timing issue: Since air bubble race is to introduce the liquid pressure concept to students and make them understand the variables affecting the liquid pressure, it requires longer time.
	Bernoulli's Ball	5 min	• Teacher's requirement: Bernoulli's ball should be used for air pressure concept. • SCE's advice: Students should state the differences between the moving air and static air. • Timing issue: Since Bernoulli's ball is to introduce the air pressure conept to students and make them understand the variables affecting the air pressure, it requires longer time.
	Hot Air Balloon	5 min	• Teacher's requirement: Hot air balloon should be used for air pressure concept. • SCE's advice: Students should state heated air and the air pressure inside and outside the air. • Timing issue: Since hot air balloon is to inform students about the air pressure in regard to heat, it needs longer time to observe.

Table 3.19 (Cont.) Sumary of selected exhibition untis for each case

Curriculum Subject	Exhibition Units	Timing	Notes
Energy and Energy Transformation	Guess Who Wins	8 min	• Teacher's requirement: Guess who wins should be used for energy transformation. The difference between kinetic and potential energies should be mentioned. • SCE's advice: Students should obseve two of the discs and they need to guess what kind of factors affecting their speed and travel-time. • Timing issue: Since "Guess who wins" requires competition between two discs and theoretical discussions on the results of the exhibition unit, it needs longer time to observe.
	3d Sand Pool	6 min	• Teacher's requirement: 3d sand pool should be used for energy transformation to discuss the kinetic and potential energies and make connections with the previous concepts, air and solid pressure. • Timing issue: Since students should be shown balls with a variety of weight falling down to sand surface, it needs longer time to observe and discuss from the example.
	Pedal Force	8 min	• Teacher's requirement: Pedal force should be used for energy transformation to discuss the kinetic energy and electrical energy. • SCE's advice: Students should apply a variety of force by pedalling and see the transformed energy. Also, energy conservation should be mentioned in regard to radio and light. • Timing issue: Since students should pedal and discuss the energy transformation and recall the types of energies by the help of previous exhibition units, it needs longer time.

Table 3.19 (Cont.) Sumary of selected exhibition untis for each case

Curriculum Subject	Exhibition Units	Timing	Notes
Energy and Energy Transformation	Measure Your Power	8 min	• Teacher's requirement: Measure your power should be used for energy transformation to discuss the kinetic energy and potential energy. • SCE's advice: In addition to kinetic and potential energies, applied air force concept can be mentioned. Besides, each transformed kinetic energy should correspond to a tool using electricity. Students should be informed regarding a social factor by using the concepts such as savings. Also, each student can try the exhibition unit after discussing the concepts. • Timing issue: Since students should discuss on the applied air force, and energy transformation, it needs longer time.
Mirrors and Light Absorption	Monochrome Room	6 min	• Teacher's requirement: Monochrome room should be used for the "white light" concept. • SCE's advice: Students should discuss the differences between white and yellow lights. • Timing issue: Since students should discuss the types of lights and question the results of the exhibition unit, it needs longer duration.
	Colorful Shadows	5 min	• Teacher's requirement: Colorful shadows should be used for the tones of mixed colors. • SCE's advice: Students should question the differences between different mixed colors. • Timing issue: Since students should discuss the tones of mixed colors, it needs longer duration.
	Countless Color	3 min	• Teacher's requirement: Countless color should be used to reinforce the prediction of the tones of the mixed colors. • Timing issue: Since students discuss the tones of the colors and strengthen their understanding regarding them, it needs shorter duration.

Table 3.19 (Cont.) Sumary of selected exhibition untis for each case

Curriculum Subject	**Exhibition Units**	**Timing**	**Notes**
Mirrors and Light Absorption	Color Removal	5 min	• SCE's advice: Color removal can be shown by extracting the main colors within the white light with a help of a prism. • Timing issue: Since students discuss and connect this exhibition unit with the previous ones and discuss daily life issues such as rainbow, it takes longer duration.
	Touch the Spring	6 min	• Teacher's requirement: Touch the spring should be shown and the prediction regarding the types of mirrors should be taken from the students by referring the exhibition unit. • SCE's advice: Each student should observe the spring individually. • Timing issue: Since each student observes the spring individually and then discuss what kind of mirrors reflect the images how, it takes longer time duration.
	Infinite Views	5 min	• SCE's advice: Each student should observe the flat mirrors individually and be asked how many flat mirrors construct an infinite view. • Timing issue: Since each student observes the infinite view, it takes longer time duration.
Solar System and Beyond	Turk-Islamic Astronomy World	5 min	• Teacher's requirement: In order to satisfy the objective related with the astronomical issues in Anatolia, Turk-Islamic Astronomy World should be indicated.
	Moving Through Space	5 min	• Teacher's requirement: Moving throung space should be shown to make students observe the space components.
	Summer Sun / Winter Sun	5 min	• Teacher's requirement: Sun clock should be mentioned in relation to the seasons. • Timing issue: Since students should observe the clock regarding different seasons and different planets, the time takes longer.

Table 3.19 (Cont.) Sumary of selected exhibition untis for each case

Curriculum Subject	**Exhibition Units**	**Timing**	**Notes**
Solar System and Beyond	Constellation Viewer	5 min	• Teacher's requirement: The star formation should be mentioned. Also, students should observe different stars in different distance and discuss how they form the constellation. • Timing issue: Since after observation, students need to discuss on star-related issues, it takes longer duration.
	Solar System Model	5 min	• Teacher's requirement: Solar system model should mention the planets in the solar system, their largeness, and their order regarding the distance to the Sun. • Timing issue: Since the model is based on hypothetical exhibition unit, it takes longer to recall the previous knowledge, inform them about the solar system, and discuss on the solar system components.
	Gravity Well	5 min	• Teacher's requirement: Gravity well should mention the turning velocity of the planets around the Sun and the Sun around the Black Hole. • SCE's advice: Students should observe the ball during it is falling into the gravity well. • Timing issue: Since gravity well is based on hypothetical exhibition unit, it takes longer to recall related concepts and discuss on the gravity, black hole and the movements of the planets and the Sun.

Selection of Schools

The schools for each case were selected through both convenience and purposeful sampling technique. The technique was determined in parallel to the main objective of the multiple case study. Thus, criterion specified rather than random sampling was employed. A purposeful sampling focuses on selecting information rich cases and key informants (Miles & Huberman, 1994; Patton, 2002; Ritchie, Lewis, Lewis, Nicholls, & Ormston, 2013). Among the school list of the ministry of education, available elementary schools were specified and they were contacted for the convenience. Among the convenient schools referring to their teachers' workload, and willingness to participate in a research study, the schools having low to middle socio-economic status level were selected for three cases. In addition, since during the first case, the school was located at a distance to the science center; for the mirror and light absorption, and solar system and beyond cases, the distance at a school was specified as another criterion for the selection. Table 3.20 shows the participants of each case for the selection of schools.

Table 3.20 Participants of each case including contextual settings, level and size of the classroom(s), and associated science teacher

Case #	**Contextual Settings**		**Other Parameters**		
	Science Center	**School**	**School Distance to Science Center**	**Level and Size of the Classroom(s)**	**Associated science teacher**
Case 1. Work and Energy	Feza Gürsey	Public Elementary School	30 km	7th-grade, two classrooms, a total of 42 students (16 + 26 students)	One science teacher
Case 2. Mirrors and Light Absorption	Kocaeli	Public Elementary School (A)	2 km	7th-grade, one classroom, a total of 16 students	One science teacher
		Public Elementary School (B)	1 km	7th-grade, one classroom, a total of 26 students	One science teacher
Case 3. Solar System and Beyond	Kocaeli	Public Elementary School	4 km	7th-grade, one classroom, a total of 26 students	One science teacher

Participants of the Study

A total of four elementary schools including 7th-grade students (N_{guided}=105, $N_{collaborative}$=72), four science teachers, and four science center educators, participated in the multiple case study for three cases. Table 3.21 shows the participants of the schools, students, science teachers and science center educators.

Table 3.21 Participants of the schools and science centers during multiple case study

	Contextual Settings		**Participants**			
	Science Center	**School**	**Guided Tour**			**Collaboration**
			Students	Science Center Educators	Science Teachers	Students
Case 1. Work and Energy	Feza Gürsey	Public Elementary School	39	2	1	16
Case 2. Mirrors and Light Absorption	Kocaeli	Public Elementary School (A)	24	1	1	20
		Public Elementary School (B)	16	1	1	12
Case 3. Solar System and Beyond	Kocaeli	Public Elementary School	26	1	1	24

Case 1: Work and Energy was performed during the 2017-2018 fall semester at Feza Gürsey Science Center in Ankara. Feza Gürsey Science Center had an appropriate environment for this lesson unit due to its matched exhibition units, which could

cover the objectives of the lesson unit. Since this lesson unit endures for six weeks within the science curriculum, due to massive demand, the science center visits divided into two stages for three weeks. The first visit focused on the learning objectives related to force and pressure, and the second visit focused on the learning objectives related to force and energy. The participated Elementary School, was located at Çankaya district of Ankara, which had approximately 30 km distance to Feza Gürsey Science Center having low to middle socio-economic status level. Each case had three phases, including (a) guided tour, (b) collaborative activity, and (c) video editing phases.

(a) *Guided Tour:* For the guided tour, a total of 39 students, one science teacher, two science center educators and two classrooms from the Public Elementary School was participated in the science center visit. Since the total size of two classes was 42 and 39 students parents permitted to participate in the guided tour, the convenient sampling method was used. Also, the science teacher who was responsible for these 7th-grade classes was volunteer actively participating in the study. Besides, two science center educators were offered by the science center education coordinator to guide the visiting students.

(b) *Collaboration:* Moreover, the collaboration phase of work and energy case consisted of a total of 16 volunteer students by including seven matched-pairs (N_{female}=6, N_{male}=8) and two individual students (N_{female}=1, N_{male}=1) among the students who participated in the guidance phase of this case. Matched-pairs were selected among the students who are closer as a friend to each other within the classroom. Students were motivated to participate in the study in terms of three issues: (a) answering scientific questions by using exhibition units in science center environment, (b) generating their own videos during answering the questions, and (c) editing self-generated videos to create a video database for other students who have limited opportunities to visit science centers. Table 3.22 shows the matched pairs of work and energy case participated in the collaborative activity phase.

Table 3.22 Students in the Work and Energy Case

	Students			
	Pair One		Pair Two	
	StuName	Gender	StuName	Gender
StuWecInd.01	StuWecInd.1	Male	-	
StuWecInd.02	StuWecInd.2	Female	-	
StuWecPair.01	StuWec1	Female	StuWec2	Female
StuWecPair.02	StuWec3	Female	StuWec4	Female
StuWecPair.03	StuWec5	Female	StuWec6	Female
StuWecPair.04	StuWec7	Male	StuWec8	Male
StuWecPair.05	StuWec9	Male	StuWec10	Male
StuWecPair.06	StuWec11	Male	StuWec12	Male
StuWecPair.07	StuWec12	Male	StuWec14	Male

StuWecPair: Pair of Students for Work and Energy, StuWecInd: Individual Student for Work and Energy, StuWec: Student for Work and Energy

Case 2: Mirrors and Light Absorption case was performed during the 2017-2018 spring semester at Kocaeli Science Center in Kocaeli. Kocaeli Science Center had an appropriate environment for this lesson unit due to its matched exhibition units, which could cover the objectives of the lesson unit.

Two schools participated in this case. The first school, Public Elementary School (A), was located at the central Kocaeli, which had approximately twokm distance to Kocaeli Science Center having middle socio-economic status level. Similarly, the second school, Public Elementary School (B), was located at the central Kocaeli which had approximately one km distance to Kocaeli Science Center having low to middle socio-economic status level. Each case had three phases, including (a) guided tour, (b) collaborative activity, and (c) video editing phases.

(a) *Guided Tour:* From the two selected public schools, a total of 40 students, two science teachers (one teacher for each school), and one science center educator participated in the guided tour. The convenient sampling method was applied for the participant selection of this phase. The class size from the first Public Elementary School (A) was 24 and from the second Public Elementary School (B) was 16, and each parent of the students permitted to take participation in the study for the guidance phase. Also, the science teachers who were responsible for these 7th-grade classes was volunteer actively participating in the study. Besides, one science center educator was offered by the science center education coordinator to guide the both visiting students.

(b) *Collaboration:* Moreover, collaboration phase of mirrors and light absorption case consisted of a total of 32 students by including 16 matched-pairs (N_{female}=16, N_{male}=16). After taking permissions from the parents for the collaboration phase of the study, a total of 20 students (10 pairs) from the Public Elementary School (A) and a total of 12 students (6 pairs) participated in the study. Therefore, student-pairs were established based on the convenience sampling method. Matched-pairs were the students who are closer to each other within the classroom environment. However, their performance levels in science course were varying. Students were motivated to participate in the study in terms of three issues: (a) answering scientific questions by using exhibition units in science center environment, (b) generating their own videos during answering the questions, and (c) editing self-generated videos to create a video database for other students who have limited opportunities to visit science centers. Table 3.23 shows the matched pairs of mirrors and light absorption case participated in the collaborative activity phase.

Table 3.23 Students in the Mirrors and Light Absorption Case

	Students				
	Pair One		Pair Two		
	StuName	Gender	StuName	Gender	School
StuMlaPair.01	StuMla1	Male	StuMla2	Male	School A
StuMlaPair.02	StuMla3	Female	StuMla4	Female	School A
StuMlaPair.03	StuMla5	Male	StuMla6	Male	School A
StuMlaPair.04	StuMla7	Female	StuMla8	Female	School A
StuMlaPair.05	StuMla9	Male	StuMla10	Male	School A
StuMlaPair.06	StuMla11	Female	StuMla12	Female	School A
StuMlaPair.07	StuMla13	Male	StuMla14	Male	School A
StuMlaPair.08	StuMla15	Female	StuMla16	Female	School A
StuMlaPair.09	StuMla17	Male	StuMla18	Male	School A
StuMlaPair.10	StuMla19	Female	StuMla20	Female	School A
StuMlaPair.11	StuMla21	Male	StuMla22	Male	School B
StuMlaPair.12	StuMla23	Female	StuMla24	Female	School B
StuMlaPair.13	StuMla25	Male	StuMla26	Male	School B
StuMlaPair.14	StuMla27	Female	StuMla28	Female	School B
StuMlaPair.15	StuMla29	Male	StuMla30	Female	School B
StuMlaPair.16	StuMla31	Female	StuMla32	Male	School B

StuMlaPair: Pair of Students for Mirrors and Light Absorption, StuMla: Student for Mirrors and Light Absorption.

Case 3: Solar System and Beyond was performed during the 2017-2018 spring semester at Kocaeli Science Center in Kocaeli. Kocaeli Science Center had an appropriate environment for this lesson unit due to its matched exhibition units which could cover the objectives of the lesson unit. One school, Public Elementary School, was participated in this study which had approximately 4 km distance to Kocaeli Science Center having middle socio-economic status level. This case had three phases as well, including (a) guided tour, (b) collaborative activity, and (c) video editing.

(a) ***Guided Tour:*** A total of 26 students, one science teacher and one science center educator participated in the guided tour. The convenient sampling method was applpied for the participant selection of this phase. The class size from this public elementary school was 26 and each parent allowed to conduct the study in the custody of their science teacher and the researcher. Also, the science teacher who were responsible for the 7th-grade classes was volunteer actively participating in the study. Besides, one science center educator was offered by the science center education coordinator to gudie the visiting students.

(b) ***Collaboration***: Solar system and beyond case included a total of 24 students by including 12 matched-pairs (N_{female}=12, N_{male}=12). Therefore, matched-pairs were established based on the convenience sampling method. Matched-pairs were the students who are closer to each other within the classroom environment and they were assigned by the science teacher. Students were motivated to participate in the study in terms of three issues: (a) answering scientific questions by using exhibition units in science center environment, (b) generating their own videos during answering the questions, and (c) editing self-generated videos to create a video database for other students who have limited opportunities to visit science centers. Table 3.24 shows the matched pairs of solar system and beyond case participated in collaborative activity phase.

Table 3.24 Students in the Work and Energy Case

	Students			
	Pair One		Pair Two	
	StuName	Gender	StuName	Gender
StuSsbPair.01	StuSsb1	Male	StuSsb2	Male
StuSsbPair.02	StuSsb3	Female	StuSsb4	Female
StuSsbPair.03	StuSsb5	Male	StuSsb6	Male
StuSsbPair.04	StuSsb7	Female	StuSsb8	Female
StuSsbPair.05	StuSsbc9	Male	StuSsb10	Male
StuSsbPair.06	StuSsb11	Female	StuSsb12	Female
StuSsbPair.07	StuSsb13	Male	StuSsb14	Male
StuSsbPair.08	StuSsb15	Female	StuSsb16	Female
StuSsbPair.09	StuSsb17	Male	StuSsb18	Male
StuSsbPair.10	StuSsb19	Female	StuSsb20	Female
StuSsbPair.11	StuSsb21	Male	StuSsb22	Male
StuSsbPair.12	StuSsb23	Female	StuSsb24	Female

StuSsbPair: Pair of Students for Solar System and Beyond, StuMla: Student for Solar System and Beyond

3.5 Data Collection Instruments and Sources of Data

3.5.1 Overview of the Instruments

Case studies require a wide range of evidence such as direct observation results, interviews with participants, documentary records, artifacts, and secondary analysis of others' research (Yin, 2009) to be able to provide a holistic and detailed descriptipn of a phenomenon or to answer the questions why and how something happened. Due to this requirement and in terms of the purpose of the study, the main data source for data collection was the observations, retrospective interviews and documents from the key actors (students and science center educators) within science center context.

Data collection instruments of multiple case study includes retrospective interviews with students, documents (conceptual diagnostic paper and science diaries), field notes and observations of science center educators, observations of students and think alouds of students during guided tour and students during their collaborative activities. Moreover, video recordings from the first and the third point of views provided the observation data. First point of view videos were recorded via eye-tracking so that eye movements of each collaborative partner was recorded as well. Then, these self-generated videos during the recording of eye-movements were given to students so that their videos construct a different source for the data collection.

Note: This multiple-case study was designed within three phases for each case including video edition phase. Although the researcher conducted this phase from data collection to data analysis, since metacognitive processes of students were not observable by this phase, it needs modifications to include in further studies. In this phase, students edited generated videos during the collaborative phase which were extracted from the eye-tracking video data. During video edition phase, students were given their produced videos and guidance by the researcher regarding the video edition. These edited video materials were examined regarding the use of conceptual words within transitions and on each separated parts. You may find the details under data collection and data analysis sections for the edited videos; although the products were not included in the results.

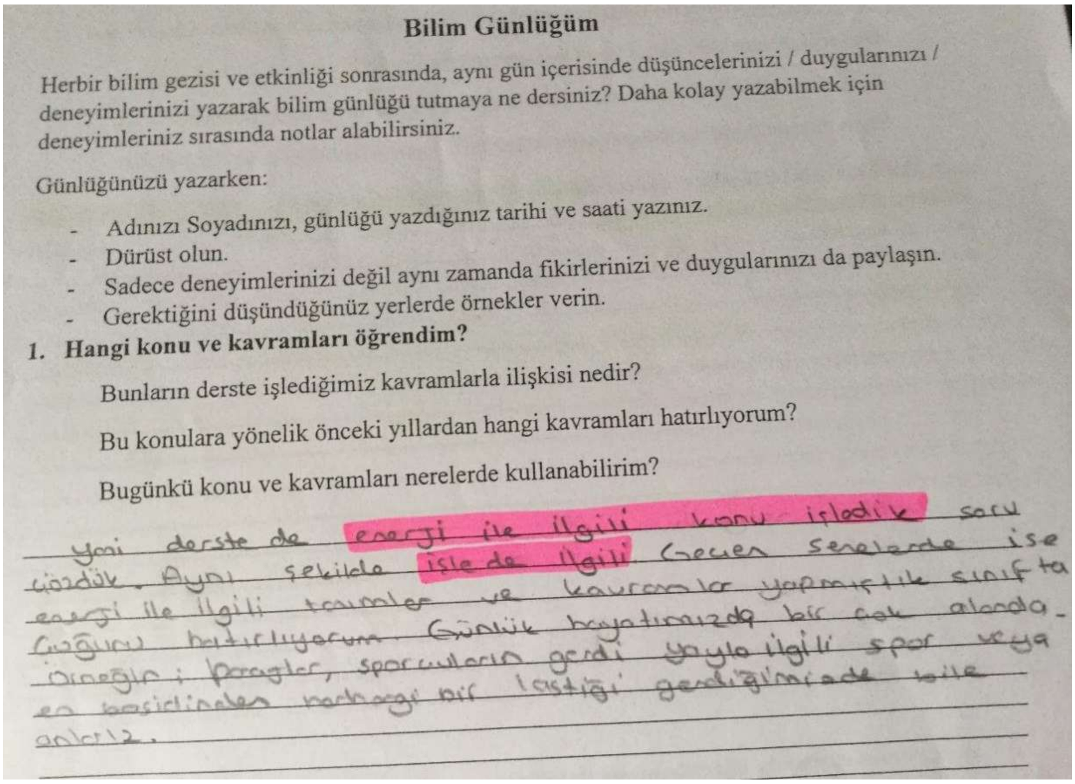
3.5.2 Documents

After each guided tour, students were given the science diaries to reflect their self-experiences during science center visit as a whole class with their science teachers by the guidance of a science center educator. In addition, students were given a conceptual diagnostic paper for in-depth understanding of how science center educators' guidance to whole class was effective on students' conceptual understanding.

Science Diaries

Science diaries are reflective papers which are for in-depth undetsanding of students' science center visit experience and their conceptual understanding regarding the scientific concepts. Many studies have been using science diaries by focusing on students' experiences. In the scope of this study, students' interaction between exhibition units, artifacts, science center educators, science teachers and their friends is an important issue for understanding their self-experiences during the guidance phase. Therefore, science diaries were given to students after the science center visit.

In this study, science diaries include a total of six questions (see Appendix E). Questions were grouped under three stages as prior to science center visit, during the science center visit and after the science center visit. Students' background knowledge and relation of science center visit with the concepts among their science lesson units were asked. Figure 3.10 shows one of the students' science center visit reflection based on the questions from science diaries.



Bilim Günlüğüm

Herbir bilim gezisi ve etkinliği sonrasında, aynı gün içerisinde düşüncelerinizi / duygularınızı / deneyimlerinizi yazarak bilim günlüğü tutmaya ne dersiniz? Daha kolay yazabilmek için deneyimleriniz sırasında notlar alabilirsiniz.

Günlüğünüzü yazarken:

- Adınızı Soyadınızı, günlüğü yazdığınız tarihi ve saati yazınız.
- Dürüst olun.
- Sadece deneyimlerinizi değil aynı zamanda fikirlerinizi ve duygularınızı da paylaşın.
- Gerektiğini düşündüğünüz yerlerde örnekler verin.

1. **Hangi konu ve kavramları öğrendim?**

   Bunların derste işlediğimiz kavramlarla ilişkisi nedir?

   Bu konulara yönelik önceki yıllardan hangi kavramları hatırlıyorum?

   Bugünkü konu ve kavramları nerelerde kullanabilirim?

Yeni derste de enerji ile ilgili konu işledik soru çözdük. Aynı şekilde işle de ilgili. Geçen senelerde ise enerji ile ilgili terimler ve kavramlar yapmıştık sınıfta olduğunu hatırlıyorum. Günlük hayatımızda bir çok alanda örneğin: boraglar, sporcuların gerdi yayla ilgili spor veya en basitinden herhangi bir lastiği gerdiğimizde bile anlarız.

Figure 3.10 Example of a students' answer for one of the questions on science diary

Conceptual Diagnostic Paper

This study used conceptual diagnostic paper for in-depth understanding of students' science conceptual understanding about selected scientific concepts (work and energy, mirrors and light absorption, solar system and beyond) after science center visit. This paper was given to students in order to provide a coplementary information on students' conceptual understanding regarding the scientific concepts related with their science lesson units.

In the conceptual diagnostic paper, students were asked questions on the exhibition units that they had taken the guidance during the science center visit. The images of the exhibition units were included in the papers with three sub-questions (see Appendix F). These sub-questions focused on the relationship of the exhibition units with the scientific concepts, relationship of the exhibition units with the science lesson unit, and relationship of the working principle of the exhibition unit with the science lesson unit and scientific concepts.

3.5.3 Interview Protocols

Interview protocols are important to make use the allocated time for the interview effective and help framing the interview questions and prioritization of question orders to organize the interviews in a focused manner and take the relevant answers.

Interview protocols for students were prepared in Turkish to be conducted just after their experience regarding collaborative activity and video editing session. A separate interview protocol was prepared for students for both collaborative activity and video edition session. The questions and content of the protocols for students were reviewed by two experts in Instructional Technology and Science Education field. According to feedback, the researcher added prompts in case the students have not a quick answer for their experiences (see Appendix G).

Concurrent Interviews

Concurrent interviews focus on the questions which participants are asked on a specific objective. This objective is to unveil the steps of problem solving during the students are engaging in problems. The proccessing steps including encoding, attending, selecting, manipulating, applying, translating and generating a response are beliebed to exist for each student and do not interfere with the nature of their problem solving (Leighton & Gierl, 2007, p.152). For conducting concurrent interviews, in this study, during the collaboration phase of the study, students were asked when it was necessary to verbalize their problem solving steps.

Retrospective Interviews

Retrospective interviews focus on the questions which participants were asked on a specific objective. This objective is to confirm what participants said during the concurrent session of the interviews. If a student is asked for solving steps of a specific problem and students' verbalizations do not match with the answers giving at retrospective interview; then, it may show that concurrent interview is invalid (Leighton & Gierl, 2007). In addition, retrospective interviews also provide an opportunity for students to mention on higher-level or metacognitive processes on solved problems which they may not verbalized during the concurrent sessions. However, the time lapse between the concurrent session and retrospective interview should be sufficiently short in order to validate the concurrent session and make students verbalize their expreiences which is not just localized with problem solving strategies (Leighton & Gierl, 2007).

In this study, retrospective interviews were conducted just after the collaboration and video edition phases. After the collaboration phase, students were asked questions regarding their general experience obtained by their collaborative actions by showing their filled question-cards and made them memorize regarding their observed actions.

Secondly, After the video edition phase, students were asked questions on their video editing experience related to their science center visit. This experience includes their recall of exhibition units, connection of exhibition units and science lesson and improvement suggestions for this phase (see Appendix G).

3.5.4 Observations

A case study should be conducted in the natural context of the case and this allows collection of relevant data through direct observations in the natural setting (Yin, 2009). The need of the observation in the study is based on two differentiated natures of the observational studies. The first one is that the observation provides a way to investigate the phenomenon in the natural setting and the second one is that researcher (observer) has the opportunity to experience the phenomenon at first hand (Merriam, 2009).

In this study, the researcher observed the stituation as a participant-observer. The main concern of the observation was identifying the collaborative units of students focusing on their individual and inter-individual metacognitive processes during science conceptual understanding. The researcher took voice or written memos when it was needed during and after each collaborative activity.

As observational instruments, the researcher used external video recordings of collaboration phases for each case from two view points at a distance to students' collaborative activities as dynamic agents. In addition, since each student wear a mobile eye-tracking glass, video recordings of each student at each case were also taken in align with the gaze patterns.

Video Recordings

Video recordings of collaboration phases for each case were taken by the researcher from two viewpoints at a distance to students' collaborative activities as dynamic agents. Besides, since each-student wore an eye-tracking glass, video recordings from the first viewpoints were also obtained. Figure 3.11 shows the equipment for video recordings in the collaboration phase.

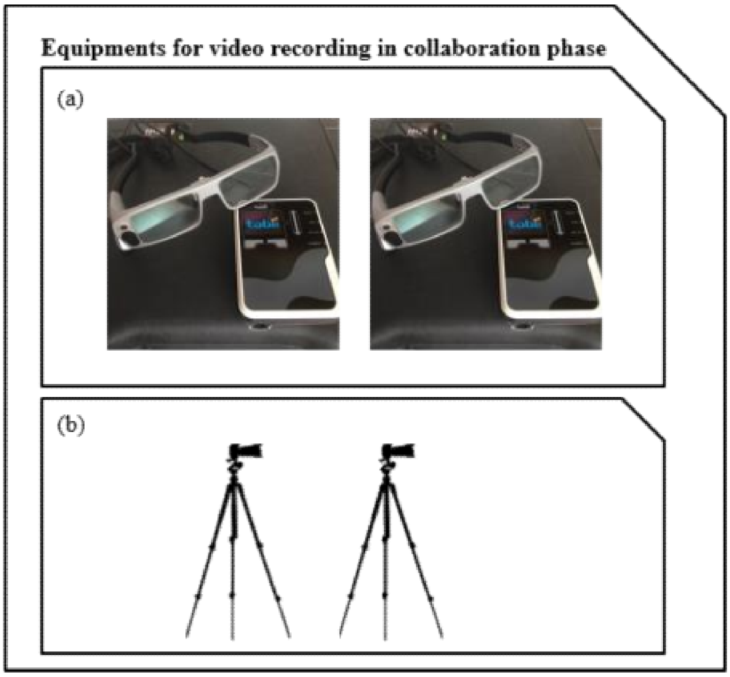


Figure 3.11 Demonstration of Tobii Glass 1 and Videos with Tripod. (a) shows two Tobii Glass 1; when (b) shows two cameras with tripods to use in third-view of video recordings

Eye-tracking Glass

The eye-tracking methodology allows researchers to record participants' eye movements on wherever the user focuses (Holmqvist et al., 2011). Hence, eye-tracking was used to examine students' metacognitive processes, and two Tobii Glass 1 were used during the collaboration phase.

During the collaboration phase each student wear an eye-tracking glass which provided the freedom of movement as an ecologically valid instrument. Tobii Glasses I was used as eye-tracking instrument which records eye movement data from one eye and provided the gaze patterns of the agents.

3.6 Data Collection Procedure

Data collection procedure in *multiple case* study includes data as mentioned earlier collection instruments as semi-structured interviews, eye tracking and third point of view video cameras as on-line observation instruments, conceptual diagnostic paper and science diary, and student-edited videos as indirect observation instruments. Since conducting both quantitative and qualitative data collection instruments have been complementary processes for research questions regarding metacognitive processes, in the following headings, they were presented as intricated procedures under each of the phases. Furthermore, although it was not stated in the data collection instruments, off-line records of teachers' perceptions regarding their students were reported as a part of the data collection procedure.

Guidance Phase

The guidance phase of multiple case study includes six sub-processes. These are analyzing content, specifying events of instruction, arranging available slots for science center for the science course hour, taking guidance from the selected science center educator on specified events of instruction, allowing time to students to free-explore the environment and asking students to write a science diary and fill the conceptual diagnostic paper. Figure 3.12 shows the guidance process for each case.

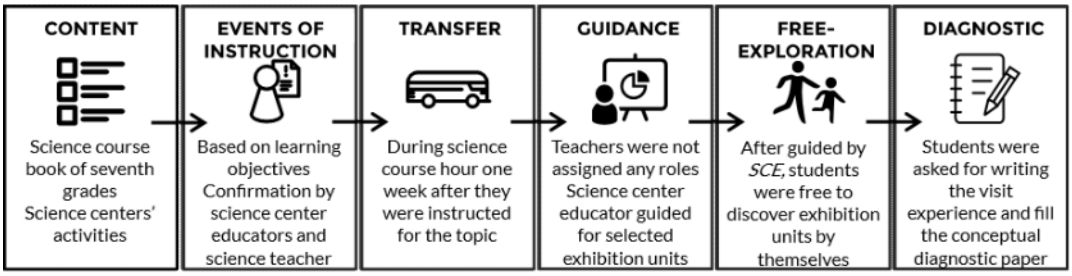


Figure 3.12 Guidance process for each case

For ***work and energy case***, the selected school was located at Çankaya district of Ankara, which had approximately 30 km distance to the Feza Gürsey *Science Center*. For the guidance phase, students were transferred to Feza Gürsey Science Center for having science center experiences. Students were transferred via school buses. The researcher contacted school management, students' families and students' teachers throughout transferring periods. Each classroom visited to science center with their science teacher within the classroom hour as a part of their classroom activity.

Beforehand, the researcher identified the objectives and the available exhibition units in science center and prepared instructional sequence referring to prepared lesson plan to be delivered by *SCE* by taking confirmation from two *ST*s (one of them was *ST* of two classrooms) and two science center educators regarding the lesson plan (for detail see 3.4.2.1.). A different *SCE* guided each classroom group with the same *ST*. After *SCE* guided students on selected exhibition units referring to *WE* lesson unit for the first 25 minutes, 20-minute duration was given for the free-exploration stage so that after students were guided, they were also allowed to familiarize the science center environment.

Throughout the guidance and free-exploration stage, the video recordings were taken by the researcher from two points of view. The researcher and one *SCE* adjusted the video cameras throughout the guidance phase and throughout the free-exploration period, two cameras were stabilized into the environment. After the visiting school group completed the planned instructional sequence within a lesson hour (see Table 3.13), they were transferred to their school environment by school bus as well.

After the guidance stage, they were given the conceptual diagnostic paper and science diary questions to perform them individually. The participated science teacher distributed the conceptual diagnostic paper and science diaries to each student who took guidance at the science center as a whole class group. After the school visit experience, students filled the conceptual diagnostic paper having the image of the related exhibition units and asking the relationship between the exhibition unit and the scientific concept. Moreover, they answered individually to the questions on paper-based science diary by reflecting their science center visit experience as a whole class.

For ***mirrors and light absorption case***, the schools were located at the central Kocaeli which had approximately two km distance to the Kocaeli *Science Center*. For guidance, students were transferred to Kocaeli *Science Center* for having science center experiences Students were transferred to science center via school busses for each phase. The researcher contacted with school management and students' teachers throughout the transferring periods. Guidance phase of mirrors and light absorption case included 36 students, two science teachers, two science center educators and two classrooms each from two different schools located at approximately two km-distance to science center. Each classroom visited to science center with their science teacher within the classroom hour as a part of their classroom activity. Beforehand, the researcher identified the objectives and the avaible exhibition units in science center and prepared instructional sequence referring to prepared lesson plan to be delivered by *SCE* by taking confirmation from two *ST*s and two *SCE*s regarding the lesson plan (for detail see 3.4.2.2.).

Each classroom group was guided by a different *SCE*. After *SCE* guided students on five selected exhibition units referring to *MLA* lesson unit for the first 30 minutes, 15-minute duration was given for free-exploration stage so that after students were guided, they were also allowed to familiriaze the science center environment. Throughout the guidance and free-exploration stage, the video recordings were taken by the researcher from two point of views. The researcher and one *SCE* adjusted the video cameras throughout the guidance phase and throughout the free-exploration phase, two cameras were stabilized into the environment.

After the guidance phase, students were given the conceptual diagnostic questions and science dairy questions to be filled. Each science teacher distributed the conceptual diagnostic papers and science diaries to students to perform individually. After students reflected their science center visit experience via answering to questions on science diary and filled the conceptual diagnostic paper, they returned back them to their teachers and the teachers passed to the researcher.

For ***solar system and beyond*** case, the school was located at the central Kocaeli which had approximately four km distance to the Kocaeli *SC*. For the guidance phase, students were transferred to Kocaeli *SC* for having science center experiences. Students were transferred to science center via school busses. The researcher contacted with school management and students' teachers throughout the transferring periods.

A total of 24 students (N_{boy}= 12, and N_{girl}= 12) participated in the guidance phase of *solar system and beyond case.* The instructional sequence in the guidance phase of *solar system and beyond case* was determined by the available exhibition units which are matched with the lesson objectives and the researcher took approval from the *ST* and *SCE*. One *ST* and one *SCE* accompanied with the students for the guidance phase (for detail see 3.4.2.3.).

After the guidance phase, students were given the conceptual diagnostic questions and science dairy questions to be filled. Each science teacher distributed the conceptual diagnostic papers and science diaries to students to perform individually. After students reflected their science center visit experience via answering to questions on science diary and filled the conceptual diagnostic paper, they returned back them to their teacher and the teacher passed to the researcher.

Collaboration Phase

Collaboration phase includes sub-phases as transferring student to science center via school bus, arranging eye-tracking glasses, informing about the study process, collaborative pairs' work and conducting retrospective interviews.

For the work and energy case, participant students were transferred as matched-pairs to science center via school bus on available time slots for them. They were transferred to the science center on the availability. Since each collaborative work endured approximately one hour, two or three student groups were transferred to the science center at a time to prevent a long wait. The researcher accompanied with the students throughout their transfers between the school and Feza Gürsey *SC.* For Feza Gürsey *SC,* the researcher asked for free-slots which provided a quiet environment for the students during they were answering the questions. When matched pairs and the researcher arrived at *SC,* the researcher set up the environment for video cameras and eye-tracking glasses. After the location of video cameras was arranged, eye-tracking glasses and their working principle were briefly introduced to students and they wear glasses as not to close the camera viewpoint. The glasses were adjusted to students' heads as in providing a degree of freedom in their movements. After students wear the glasses, each student's glass was calibrated in front of a white wall. Later than, matched-pairs were given their question sheets at the entrance of the science center and their glasses were activated. Students were asked for concurrent think-aloud during they were answering to the questions.

Figure 3.13 Students' collaboration during their engagement with exhibition units and worksheet

The researcher was available for the students when they needed any clarification or hint and she was at the backside of the video camera for the direct observation. After students felt they had over the questions, the session ended. Later than the session ended, students were asked questions for retrospective interviews.

For ***mirrors and light absorption case,*** a total of 32 students participated in the collaboration phase. For the collaboration phase of *mirror and light absorption,* questions related with five exhibition units which were presented as a sequence of instructional objectives to the students at the guidance phase.

Each pairs of the students were transferred to science center for collaborative activity. Students wear eye-tracking glasses and the calibration was made for each student. Later then, students were informed about the collaboration process as "You will answer a set of questions and the glasses on your eyes will record what you are doing while you are answering them. Please think aloud as much as possible during you are answering the questions."

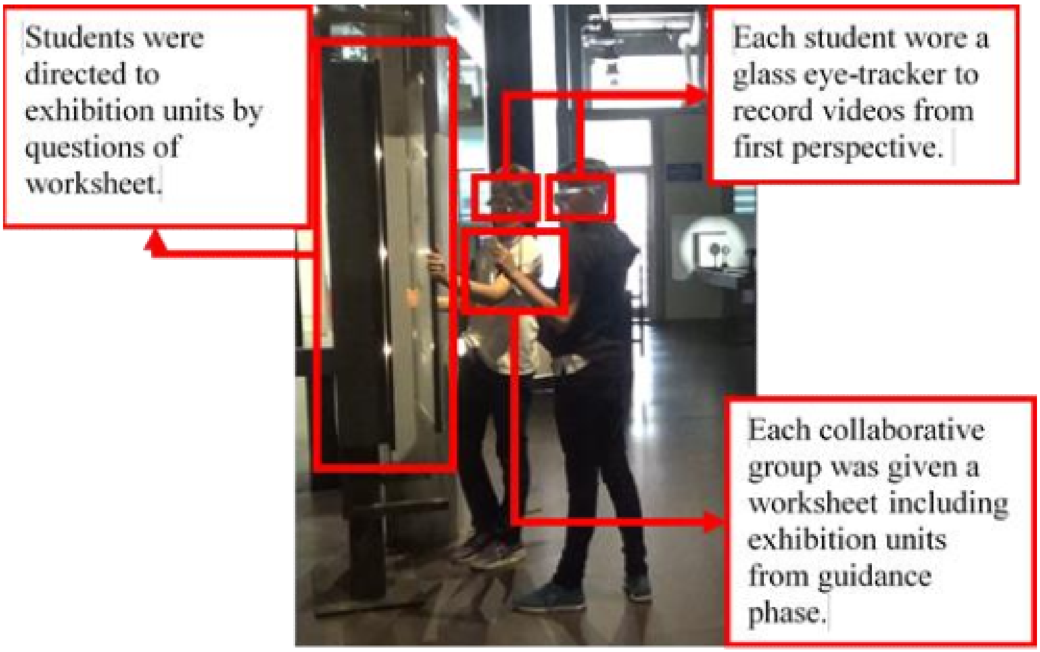


Figure 3.14 Students' collaboration during their engagement with exhibition units and worksheet for Mirror and Light Absorption lesson unit

After students answer the questions, they were asked questions regarding their experience as a part of retrospective interview. Later then, students were transferred to their school.

For ***solar system and beyond*** case, a total of 24 students (N_{boy}= 12, and N_{girl}= 12) participated in the collaboration phase. The question-answer sheet was prepared aligned with the instructional sequence in guidance phase.

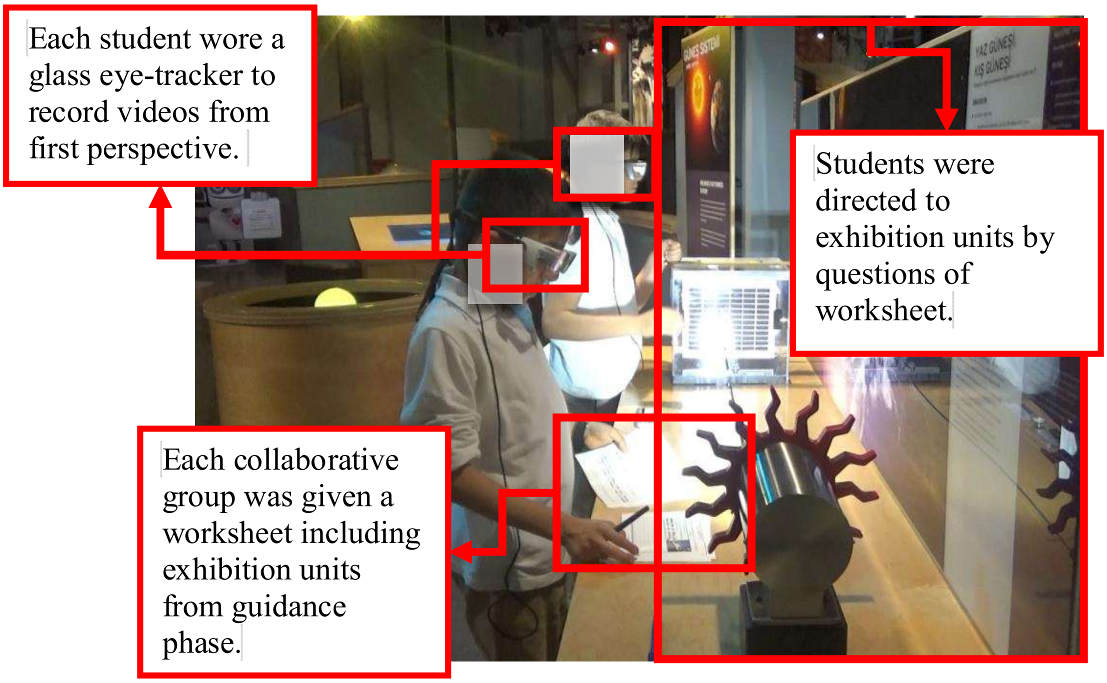


Figure 3.15 Students' collaboration during their engagement with exhibition units and the given worksheet for SSB lesson unit (The exhibition unit in the image: Summer Sun Winter Sun)

After students answered the questions, they were asked questions as a part of retrospective interview process.

Video Edition Phase

Video edition phase was performed in a computer laboratory area with students who had participated in the collaboration phase. For the work and energy case, students were trasferred to a computer laboratory of a public university; wherease, for the mirrors and light absorption, students were transferred to the computer atelier of the science center. Finally, for the solar system and beyond case, students used the computer laboratory of their elemantary school. Students' self-generated videos through eye-tracking tool were extracted and given to each groupfor the editing. The researcher accompanied with the students to assist for video edition software which was Movie Maker. For any technical issues with computers, the researcher and an other computer staff were available.

Students were given to their own self-generated videos and filled answers within worksheet and they were directed at the beginning of the video edition phase. The directions were as follows:

1. Write the purpose of each exhibition unit at the beginning of the related one.
2. Write about your experience and how other students can get benefits from these exhibition units.
3. Write questions to your friends that you have thought that can be beneficial for them in understanding the lesson concepts.

Students who were participated in the collaboration phase attended to video edition phase as well to edit their own self-generated videos extracted from eye-tracking glasses recordings. For work and energy case, and mirrors and light absorption case, students were transferred to another computer laboratory out of school due to computers' technical problems. The researcher accompanied students throughout the transfer and helped them in editing their videos. Whereas, for solar system and beyond case, students were transferred to the computer laboratory which was available in their school and the school computer teacher provided technical help if there existed any problems.

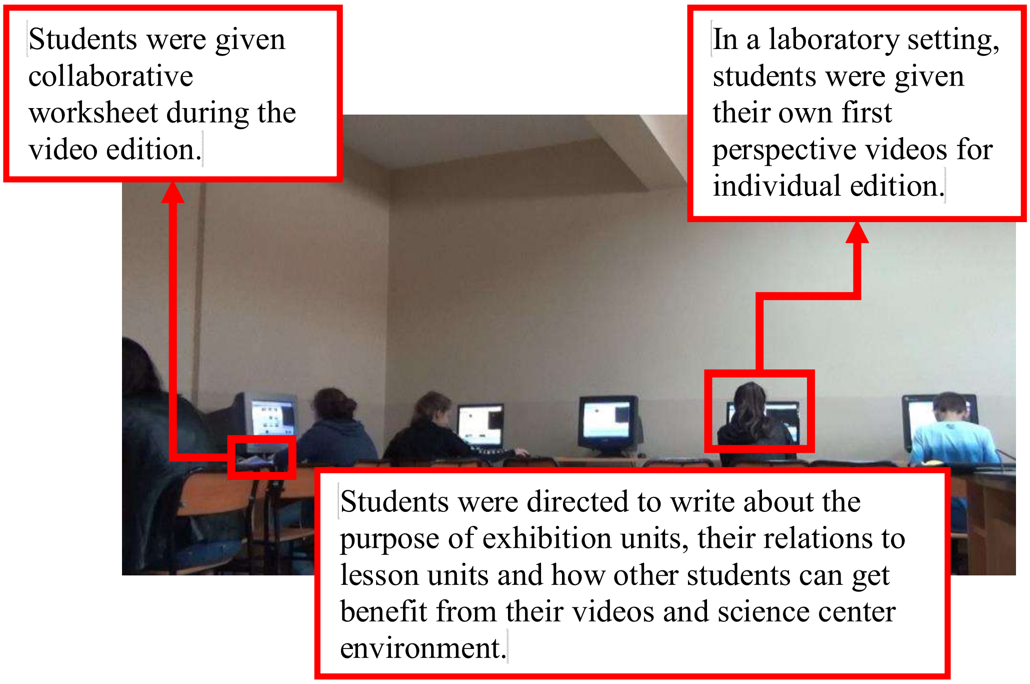


Figure 3.16 Students' video edition phase during the edition of their self-generated videos.

At the end of the video editing phase, the edited videos were saved to be examined. However, this phase of the multicase study was not included in the results due to its effectiveness on detecting metacognitive actions of the students. Different design settings for video edition to detect metacognitive actions or experiences were discussed and suggested at the final chapter.

3.7 Data Analysis

Data analysis included three sub-phases as data analysis for guidance phase, data analysis for collaboration phase and data analysis for edited video phase. The researcher performed the analysis by using Tobi Studio, Transana Professional 3.0, and Nvivo 12. Following paragraphs included the data source and the analysis step for each phase.

(a) ***Data Analysis for Guidance Phase:*** The guidance phase of the study included video recordings (two videos from the third point of views) throughout the science center educator's guidance to school visit groups, and documents (conceptual diagnostic paper and science diary) filled just after the science center visit. Two video recordings from the third point of view were analyzed by using content analysis method. During content analysis, qualitative data were transcribed and then coded. Then, codes were assigned to themes and categories. The researcher used Transana Professional 3.0 (Woods & Fassnacht, 2007) based on the initial coding scheme. The coding scheme targeted at the science center educator's metacognitive regulatory processes adapted by using two source coding schemes on metacognitive processes (Liesje De Backer, Keer, & Valcke, 2016; Meijer, Veenman, & van Hout-Wolters, 2006). Table 3.26 shows the initial coding scheme for science center educators' metacognitive processes.

Table 3.25 Initial coding scheme of science center educators' metacognitive regulation process

Category	Theme	Sub-Theme
Orientating	Content Orientation	Activating prior knowledge
		Hypothesizing
	Guide Orientation	Providing turn-taking
		Relocating
	Task Analysis	Establishing task demands
		Informing task subjects and constitution
		Structuring task instruction
Planning	Considering alternatives for conceptual understanding	
	Developing action plan	
Monitoring	Monitoring of strategy use	Component structuring
		Repeating question
		Selective attention
	Monitoring of progress	
	Comprehension monitoring	Noticing lack of comprehension
		Claiming (Partial) understanding
		Demonstrating comprehension by repeating
		Demonstrating comprehension by elaborating
Evaluating	Checking	
	Reflecting	

Document data collected by conceptual diagnostic paper and science diaries were analyzed by using content analysis method as well. Before analysis process, answers and reflections of each student were transferred to computer environment. A deductive approach was used to code students' science diary and conceptual diagnostic papers for in-depth understanding their experience of taking guidance during the science center visit. Conceptual diagnostic paper was coded regarding students' conceptual understanding of each scientific concept. An evaluation rubric was used for coding the levels of conceptual understanding which are misconception, no understanding, emergent understanding, partial understanding and sound understanding (see Appendix K).

(a) ***Data Analysis for Collaboration Phase:*** The collaboration phase of the study included videos from the first and second points of view, worksheets, and retrospective interviews for each collaborative student.

First-eye videos by eye-tracking glasses

First, first-eye videos by eye-tracking glasses were analyzed for each collaborative pair. Qualitative data from eye-tracking was extracted by using Tobii Studio as a video file. Then, videos of each collaborative pair were coded synchronously at Transana Professional 3.0 environment. Data of each phase for all gathered data were analyzed seperately for the multiple case study. Eye-movement patterns of each collaborative pair were transcribed regarding each student's looking direction (pair's eyes, exhibition unit, worksheet, and science center environment) and type of eye movements (transitions, and visual search).

Video data acquired by Tobii Glasses 1 for each student in the collaborative unit were analyzed after synchronization. Transana Professional 3.0 was used to synchronize and conduct the conversational analysis. Students' verbal utterances and eye movement patterns were coded during the analysis in a timeline-based manner.

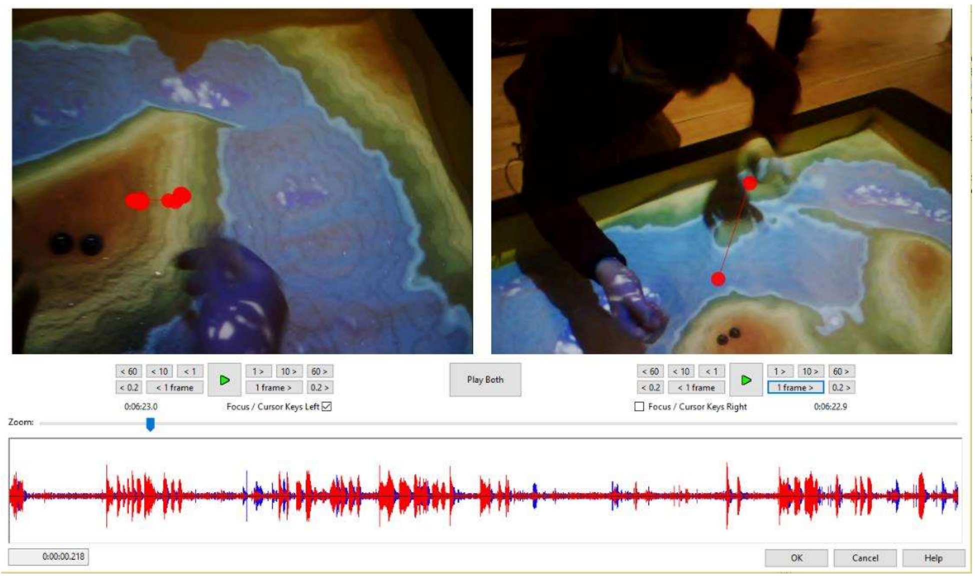


Figure 3.17 Synchronizing collaborators' self-generated videos

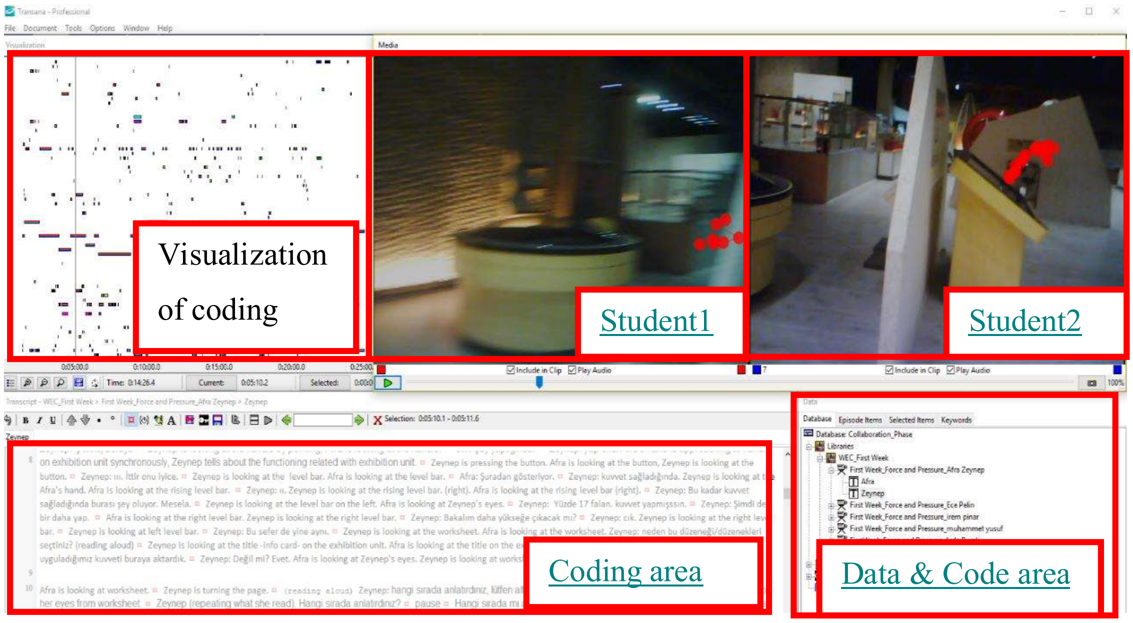


Figure 3.18 Coding of collaborative students' data

Worksheets

Second, worksheets were used within document analysis to detect students' level of scientific conceptual understandings for each case. An evaluation rubric was used to determine the level of science conceptual understanding (see Appendix). Data from worksheet also helped to expose the issues and challenges, and needs for the revisions in the embedded instructional design.

Retrospective interviews

Third, qualitative data from the retrospective interviews were analyzed to examine how 7th-grade students' individual and inter-individual processes occur within science center context during answering to questions on the worksheet. Qualitative data were analyzed by using content analysis and conversation analysis method.

During content analysis, qualitative data were coded, and codes were assigned to themes and categories (Berg, 2001; Maxwell, 2013; Merriam & Tisdell, 2016). Before analysis process, voice records of interviews and retrospective reviews were transcribed to prepare data for analysis. An initial codebook with several initial codes and categories/themes related to metacognitive processes within science center context during conceptual understanding was also created based on the literature (Meijer, Veenman & van Hout-Wolters, 2006; De Backer, Van Keer, Valcke; 2016).

Table 3.26 Initial coding scheme of collaborative students' metacognitive process

Metacognitive Process (Category)	Main Theme	Sub-theme
Orientating		
	Content Orientation	
		Activating prior in-class knowledge
		Activating prior experience from guidance session
		Hypothesizing
	Task Analysis	
		Detecting task demands
		Exploring task subjects and constitution
		Becoming aware of task perceptions
	Structuring task instructions	Pointing to (underlining) core concepts
		Schematizing task instructions
Planning	Planning in advance	Planning solving task approach
		Distributing role of duties
	Interim planning	Planning solving task approach
		Distributing role of duties
Monitoring		
	Monitoring of strategy use	
		Text structuring
		Component structuring
		Selective component navigation
		Re(reading)
		Adapting strategy use
	Monitoring of progress	
		Reflecting on strategy use
		Reflecting on the proposed solution
		Reflecting on the quality of the progress made

Table 3.26 Initial coding scheme of collaborative students' metacognitive knowledge and regulation process

Metacognitive Process (Category)	Main Theme	Sub-theme
Evaluating	Comphrension monitoring	Reflecting on the collaborative activity
		Noticing lack of comprehension
		Claiming understanding
		Demonstrating comprehension by repeating
		Demonstrating comprehension by elaborating
	Evaluating learning outcomes	Checking correctness of the conceptual understanding
		Checking completeness of the conceptual understanding
		Checking effectiveness of the conceptual understanding
		Recapitulating answers
	Evaluating learning process	Reflecting on personal efficiency
		Reflecting on task difficulty
		Reflecting on self-efficacy

(b) ***Data Analysis for Video Edition Phase:*** The video edition phase of the study included students' edited videos as their products and retrospective interviews just after then the video editing session.

Students' Edited Videos

Each edited video was analyzed by using the content analysis method. The main questions being asked during the analysis were:

(i) How did each student separate the associated concept?

(ii) What kind of questions did each student asked to other potential students?

(iii) What kind of experiences did each student write on the edited video?

(iv) How did each student get benefit from their filled worksheets?

Retrospective interviews

The researcher conducted an interview individually with each student. The interviews were transcribed and content analysis method was used to pinpoint students' perceptions regarding both their video edition phase and the whole process.

3.8 Trustworthiness

Marshall & Rossman (2016) states that trustworthiness or goodness of qualitative research, including reliability and validity, is derived from quantitative approaches to restrict the limitations on contextually and personally interpretive nature. On the other hand, Denzin and Lincoln (1994) define a set of criteria for trustworthiness, which are credibility, transferability, dependability, and confirmability. In this study, to ensure the trustworthiness of qualitative findings, these four criteria were used.

The *credibility* of the *multiple case study* was enhanced by using data. Data triangulation was applied to collect pieces of evidence from different individuals (Creswell, 2007). Therefore, this allowed investigating the phenomenon from different perspectives (Bogdan & Biklen, 2007).

For the *transferability,* the characteristics of the science centers, students, schools and the teachers were provided to illustrate the surroundings of the study for the readers for each case.

For the *dependability,* coder based repeated coding was applied to provide an agreement for the analyzed data.

For the *confirmability,* the researcher kept both audio and written journal and reflecting the notes on the video recordings. Also, eye tracking device provided a methodological instrument for triangulation method. So, researcher's bias were tried to be eliminated.

CHAPTER 4

RESULTS

The purpose of this study was to investigate and analyze the metacognitive processes during and after collaborative learning activities amongst 7th graders of Turkish students visiting science centers in terms of the aspects contributing to metacognitive processes in science centers within a holistic perspective. This thesis includes two separated but connected studies. The first study questioned the current practices affecting educational effectiveness within multi-dimensional characters of science centers incorporating educational practices (instructional design process) and organizational practices (infrastructural issues, regulations, and collaborations). A qualitative research design guided this first study based on the comprehensive needs assessment study approach. The science center educators and science teachers' perceptions of educational effectiveness within science centers were disclosed with the help of semi-structured interviews. Additional data to support the interviews and direct observations were provided by the examination of the related documents. Finally, in order to draw a conclusion, the themes and sub-themes that emerged from qualitative data analysis that were key to the research questions were categorized and brought together according to their interrelatedness.

On the other hand, the second study, whose design was proposed based on the results of the first study, probed the aspects revealing metacognitive regulation and knowledge processes based on individual and inter-individual perspectives. The study was guided by a multiple-case study approach. The science center educators' and students' metacognitive activities during conceptual transfer and conceptual understanding of selected scientific concepts were disclosed with the help of direct, indirect observations, documents, and interviews. Finally, in order to draw a conclusion, the codes were generated from qualitative data analysis that was key to the research questions were categorized and brought together according to their interrelatedness.

The findings were stated in the following structure: Firstly, for the study of the current practice, each category and emerging themes related to that category was summarized individually under educational and organizational practices. Secondly, for the multiple case study, each theme was summarized separately, and then each context within science center regarding “Work and Energy”, “Mirror and Light Absorption” and “Solar System and Beyond” units respectively was explained with the help of the quoted statements and looking patterns of the participants under each code. Also, at the beginning of each level and theme, a compare and contrast paragraph was provided to demonstrate a holistic view of the contexts. Thus, differences and similarities between contexts were intended to be revealed more clearly. Additionally, at the end of each level of issues, a table showing similarities and differences was also presented. Lastly, a figure showing the relationships between the themes and sub-themes that the findings indicated was drawn.

Moreover, the findings regarding metacognitive knowledge and regulation processes are presented in the individual and inter-individual perspectives within macro, meso and micro levels. The macro level includes such themes and codes regarding selected scientific topics; whereas, meso level includes such themes and codes regarding environmental factors such as exhibition units, used hand-materials, and educational areas. Finally, the micro-level includes issues at the level of the individuals. Micro-level is also presented by the codes and themes about the conceptual understanding of scientific topics.

The findings were reported with deductive reasoning. For this reason, the narration of this deductive report moved from the general aspects to the specific aspects of metacognitive processes. In this sense, it was primarily aimed at drawing the big picture and later looking at metacognitive processes closely.

4.1 Results for Study I: Current Practices in Science Centers

Current practices study of this thesis study centralized the main research question as "What are the current practices of science centers according to science center educators and science teachers' experiences?" and focused on the following research questions for founding the basis of the multiple case study:

1. How are current educational practices within science centers?
2. How are current organizational practices within science centers?

Data analysis provided one main category under current educational practices as *current educational practices*, and four main categories under organizational practices as *barriers*, *expectations*, *needs*, *solution attempts*.

4.1.1 Educational Practices

Category I: Current Educational Practices

This category relieved current practices focusing on educational aspects within science centers. Current practices (n_{SC}=13, n_{SCE}=20, f=561) held by science center educators to enhance educational effectiveness emerged two main themes as (a) *designing instruction* and (b) *enhancing collaboration*. *Designing instruction* emerged as one of the main themes for current educational practices category (n_{SC}=13, f=480). This main theme was an essential part of the delivery of the instruction to the target groups and stated sub-themes as including analyzing, designing-developing, implementing, and evaluating. These sub-themes were written as a part of the cyclic process in the rest of the paragraphs.

Analyzing

The analyzing phase, as a sub-theme, was stated in the first phase of the designing instruction process (n_{SC}=13, n_{SCE}=20, f=131). This phase included the elements which *science center educator*s take into consideration throughout designing the instruction as an initial stage to ground the instruction with content analysis, learner analysis, and need analysis. Table 4.1 illustrates the sub-themes and associated codes regarding designing instruction. First, ***content analysis*** was stated as being conducted regarding school curriculum, other science centers' activities, and other aspects. First of all, *science center educator*s reported that they are taking the school curriculum as a baseline before preparing and adapting field-trips and workshop activities. SCE.19 from SciCen.12 said following excerpt:

> *"Discovery time (which is a prepared educational activity time during field-trips) is especially covering exhibition units which are including lesson objectives in the school curriculum."* [Q2, Appendix I]

Table 4.1 Analyzing sub-theme of Designing instruction theme under Current Educational Practices

Sub-Themes	Number of *SC* (n)	Frequency of being told (f)
Content Analysis	***13***	***43***
Curriculum	12	30
Other science center's activities	6	10
Other aspects	3	3
Learner Analysis	***13***	***49***
Age characteristics	12	36
Cultural characteristics	2	2
Learner's interest	7	11
Context analysis	***13***	***39***
Available educational space	6	8
Material characteristics	8	15
Timing	9	16

n_{SCE}=20

Second, ***learner analysis*** was stated to comprise learners' ages, cultural characteristics, and their interest to set the foundation of design and development processes. This analysis was stated as necessary for not only to provide instruction regarding students' cognitive levels but also not to have a feeling of failure. SCE01 from SciCen.01 said following excerpt:

> *"We are not preparing workshops which are above students' cognitive levels stated in the school curriculum. We want to make them discovery, but we do not want that they have a feeling of failure."* [Q3, Appendix I]

In the *analyzing* phase, finally, ***context analysis*** was stated as being conducted regarding available educational space, material characteristics and timing (visit duration). While available educational space specifies visiting group sizes, material characteristics found the basis for how a subject in the curriculum should be treated in consideration with the selected material characteristics. In addition to these, timing (visit duration) for that specific workshop or field-trips was taken into account as a need so that *SCE*s prepare the educational activities regarding visit duration of each school group to enhance educational effectiveness. SCE.11 from SciCen.07 said following excerpt:

> *"Some exhibition units are an appeal to the eye so that they are drawing more attention at first glance, such as experiments like turbulence or bicycle. But, other exhibition units may require much theoretical information so that students have less interest in them."* [Q4, Appendix I]

Designing and Developing

Designing-Developing, as the second phase, was stated as being carried out simultaneously by science center educators (n_{SC}=13, n_{SCE}=20, f=52). Table 4.2 presents the sub-themes and associated codes regarding the designing-developing phase. Designing-Developing phase divided into three sub-themes as specifying instructional methods, material arrangement, and activity design process. ***Specifying instructional methods*** was reported as a sub-phase for the designing-developing phase. It was stated that learner, topic, and material characteristics are taken into consideration for the specification. Thus, *SCE*s diversify activities regarding different age groups, subject matters, and materials.

Table 4.2 Designing-Developing sub-theme of Designing Instruction theme under Current Educational Practices

Sub-Themes	**Number of *SC* (n)**	**Frequency of being told (f)**
Specifying instructional methods	***7***	***23***
Learner characteristics	6	13
Material characteristics	4	8
Topic characteristics	2	2
Material arrangement	***6***	***9***
Activity design process	***9***	***20***
Activity diversification	5	7
Brainstorming on draft activity	5	7
Draft activity preparation	6	6

n_{SCE}=20

Material arrangement in educational space, on the other hand, was seen as an essential sub-phase implemented by *SCE*s for designing-developing processes. Since the material arrangement was reported as critical to facilitate transitions between the exhibition units being presented to visiting school groups as well as essential to provide links between subjects in exhibition units and workshops. SCE18 from SciCen.12 said following excerpt:

"For instance, we have an educational space on pendulums for exhibition unit area. There were four to five exhibition units for them, but we see that they are constituting a complete subject. Then, with feedback, we thought that they inform about similar subjects, but they are located in different places and when one was going to a similar subject which was located at a distance needed to pause, and this was resulting in a disruption in subject integrity. After this kind of feedback, we brought exhibition units about pendulums as a single exhibition unit. For now, you can see small rooms and plus signs while you are entering the

educational space, which is related to pendulums, and just by turning around, you are exposing to all exhibition units on pendulums." [Q6, Appendix I]

Besides, during the ***activity design process***, to enhance educational effectiveness through the conducted activities, *SCE*s diversify activities, prepare draft activities and brainstorm on draft activities by coming together. SCE.09 from SciCen.06 said following excerpt:

"We organize workshops in many different areas. For instance, we are excavating for archeology workshops with which we have a kit, and we are describing archeology processes in our excavation area. We have approximately 40 to 45 workshops, and they are all different." [Q5, Appendix I]

Implementing

Implementing phase revealed three themes as sequencing instruction, use of instructional methods, and use of sequencing instruction methods (n_{SC}=13, n_{SCE}=20, f=204). The distinction between these three categories was made regarding how science centers sequence their instruction in practice and what the theoretical background of sequencing instructions are in terms of both use of instructional methods and use of sequencing instruction method. Table 4.3 shows revealed sub-themes for implementing phase with the number of frequency.

Sequencing instruction, as a sub-theme, included three main stages respectively, as the preparation stage for science center experience, guidance and free-exploration stage (n_{SC}=13, f=135). After *SCE*s prepare visiting school groups for science center experience, they guide selected groups and finally, they do not interfere with the groups by providing them a free-exploration chance to explore the science center environment by their own will. Although these stages show variety among science centers, shared understanding of school visits was stated as in the following order:

The preparation stage is the first stage of the science center visit program offered to visit school groups. At this stage, first of all, teachers are informed by *SCE*s before the school visit via e-mail by sending brochures or pre-prepared forms of questions. Secondly, students are arranged based on the group-sizes to use the educational space efficiently and finally, students are informed about the science center and its regulation to adapt students to context. In brief, the preparation stage was stated as including informing teachers, arranging group-sizes and adapting to the context before the guidance stage. SCE19 from SciCen.12 said following excerpt:

> *"Students in school visit groups are very excited. We begin by saying our slogan to them: 'We have a regulation here'. When we are saying 'regulation', they start to stay in order. 'Our regulation is keeping off exhibition units are forbidden' Students cannot believe this, for the first time, they cannot understand since students have been told as they should not do. Firstly, they like this idea and this is motivating for them. Then, we give short information about the science center, including how many exhibition units there are inside, what they will see, what they can do and they may come here with their families as well."* [Q7, Appendix I]

Guidance stage, on the other hands, *SCE*s activate students' prior knowledge, demonstrate on exhibition units about subject matters, ask questions regarding the subject matters, get responses from students in verbal or non-verbal cues, give roles to students based on material characteristics, provide feedback for them and finally connect the subject matter with another exhibition unit or daily life examples. Since *SCE*s mentioned the interchangeable sequence of guidance stage regarding *SCE*s instructional strategy and characteristics of exhibition unit, instructional sequence stated under the guidance stage is not typical for all learning resources within different science centers.

The free-exploration stage, as the third sub-phase, was stated as a period in which students are able to explore the science center environment or exhibition units following their own will. During this period which can last up to 20 minutes, students are able to discover the science center individually or in groups and interact with their teachers, friends or *SCE*s. *SCE*s who were observing students' behaviors during this period stated students get preliminary information by reading the information written on exhibition units and set the goals for those units to discover it. Moreover, *SCE*s observed that students show up help-seeking behaviors and they are trying to drive a conclusion by trial and error method. Finally, educators stated that students track their progress and assess whether they could achieve their goals or not. However, the frequencies of planning, monitoring and evaluating activities were rarely mentioned by *SCE*s. This may refer to science centers may not implement direct observations throughout students' engagement with exhibition units or science centers may not have adequate knowledge to verbalize students' metacognitive activities.

In addition to sequencing instruction, the *use of instructional methods* was revealed as a theme under the implementing phase. *SCE*s stated that instructional methods that are used during implementation are collaborative learning, inquiry learning, learning by doing and meaningful learning. *SCE*s believed that implementing the aforementioned instructional methods enriches the educational activities. Although these instructional methods were stated as mostly being used for the guidance phase, it was also assured that the science center environment led to students apply this kind of instructional methods as well. In addition to use of instructional techniques, *use of sequencing instruction methods* was also revealed as a sub-theme which included that *SCE*s sequence the instruction in accordance with abstract to concrete and simple to complex and also they assured that they give mental breaks during the period when students' cognitive load increase by making them do physical work (such as placing laboratory equipment in place). SCE.05 from SciCen.04 said following excerpt:

"Sometimes, we make students collaborate during doing experiments. For instance, a skeleton cannot be done by one student so that we bring three students together, and they construct that model. And, they perceive this as 'This work belongs us, we did it.' Also, they engage in group works having a product at the end of the work period. On the other hand, for doing a telescope, a student can do it individually. Therefor this (selection of instructional methods) depends on the students' readiness and content." [Q8, Appendix I]

Table 4.3 Implementing sub-theme of Designing Instruction theme under Current Educational Practices

Sub-Themes	Number	Frequency
Sequencing instruction	***13***	***135***
Preparation stage	8	23
Preparing teachers	3	8
Arranging group-sizes	5	7
Adapting to context	4	8
Guidance stage	11	85
Activating prior knowledge	5	10
Connecting	3	3
Demonstrating	9	18
Getting responses	8	19
Giving examples	2	2
Giving feedbacks	2	5
Giving roles	4	7
Questioning	10	21
Free-exploration stage	6	27
Planning	3	5
Goal setting	1	1
Reading information	2	3
Acquiring needed prior knowledge	1	1
Monitoring	6	20
Help-seeking	5	10
Note-taking	2	3
Trial-error	4	5
Evaluating	1	2
Goal assessment	1	1
Tracking progress	1	1
Use of instructional methods	***12***	***61***
Collaborative learning	7	10
Inquiry learning	8	18
Learning by doing	7	19
Meaningful learning	9	14
Use of sequencing instruction methods	***5***	***8***
Abstract to concrete	2	3
Mental break	2	3
Simple to complex	2	2

Evaluating

Table 4.4 shows the sub-themes and associated codes regarding the evaluating phase. *Evaluating phase,* as the final phase of the instructional design process cycle, revealed two sub-themes as process and student evaluation which are referring to summative evaluation (n_{SC}=13, *f*=93). *SCE*s stated *process evaluation* and *student evaluation* have been developing their insights regarding the instructional design and they can adjust the activities and materials based on these insights. For process evaluation, it was revealed that *SCE*s observe the target group during implementation and adapt activities and materials. The observations made by *SCE*s during the implementation are divided into two groups as either direct or indirect observations. While direct observation considers the students' questions and examples, indirect observation takes students' mostly non-verbal responses or reactions into account. In addition to process evaluation, student evaluation was also made by *SCE*s for long-term activities implemented in the science center environment. Under student evaluation, *SCE*s track students' progress and inform parents or teachers for student's progress-difference. SCE.14 from SciCen.08 said following excerpt:

> *"Students' reactions. Exhibition units or instructional sequence for that exhibits can show changes according to students' reactions to that exhibit since there are differences between their feedbacks and applications that we have provided."* [Q9, Appendix I]

Table 4.4 Evaluating sub-theme of Designing Instruction theme under Current Educational Practices

Sub-Themes	Number of *SC* (n)	Frequency of being told (f)
Process evaluation	***14***	***82***
Observing during implementation	11	36
Direct observation	5	9
Indirect observation	11	27
Adjusting activities and materials	13	46
Availability of materials	5	8
Level of difficulty	2	2
Level of satisfaction	12	20
Level of understanding	5	14
Security	2	2
Student evaluation	***5***	***11***
Tracking student's progress	4	8
Informing for student's progress-difference	3	3

n_{SCE}=20

Enhancing Collaboration

It was revealed that ***having a substantial funding for expansion*** facilitates to *adapt educational activities* and *to have an impact on society*. In the scope of adaptation of educational activities to obtain materials regarding workshops and exhibition units from either science centers in Turkey or abroad, it was reported that science centers cooperate with private companies or state institutions. Moreover, by having substantial funding for expansion to adapt educational activities, science centers provide financial support for training *SCE*s by sending them for being exposed to other national and international science centers. In addition to adapting educational activities, having an impact on society can be provided by having a substantial funding for expansion by advertising and doing projects in collaboration with various institutions.

*Science center educator*s mentioned that preparing educational activities can be done within the scope of enhancing collaboration to enhance educational effectiveness. ***Preparing educational activities*** was stated to include both enhancing knowledge and facilitating access to desired target groups. It was seen that enhancing knowledge is essential for two reasons, which are having a higher impact on society and enhancing *SCE*s' knowledge. To have a higher influence on society, science centers prefer to give conferences on specific topics and give training for development for either teachers, students or public. On the other hand, enhancing *SCE*s' knowledge by collaborating with outsider *SCE*s, professionals or institutions is seen as an essential factor for preparing educational activities. In the scope of *SCE*s' knowledge, decision-making processes on further implementations, sharing culturally-adapted knowledge, taking advice on content, taking feedback on instructions and taking inspirations on enhancing educational activities were stated as current practices regarding preparing educational activities. In addition to enhancing knowledge, facilitating access to people with disabilities, students, voluntary workforce and public people were indicated as being provided by preparing educational activities in the scope of enhancing collaborations.

Table 4.5 Enhancing collaborations that enhances the effectiveness of educational processes according to SCEs

Sub-Themes	**Number of *SC* (n)**	**Frequency of being told (f)**
Having substantial funding for expansion	***9***	***30***
Adapting educational activities	6	11
Obtaining materials	4	6
Training employees	4	5
Facilitating to have an impact on society	6	19
Advertising	2	4
Doing projects	6	15
Preparing educational activities	***10***	***45***
Enhancing knowledge	7	22
Having a higher impact on society	4	10
Increasing *SCE*s' knowledge	5	12
Facilitating access	9	23
To the disabled people	1	1
To the public people	2	2
To the students	8	11
To voluntary workforce	5	9
Setting the ground for science center	***6***	***6***

n_{SCE}= 20

Finally, ***setting the ground for science center*** was seen as a beneficiary result of practices in enhancing collaborations by taking advice on grounded information such as science center employees, exhibition units and their explanation to students regarding their culture and ages, and the main theme of the science center. SCE10 from SciCen.07 said following excerpt:

> *"Advisor instructors explain each exhibition unit regarding the explanation to students such as 'Students should ask that in that stage and learn that you need to try these and students should know these before they leave the science center'."* [Q1, Appendix I]

4.2 Current Organizational Practices

This issue relieved current organizational practices focusing on organizational aspects within science centers. Current organizational practices (n_{SC}=13, n_{SCE}=20, f=561) held by science center educators to enhance educational effectiveness emerged four categories as *barriers*, *expectations*, *needs*, and *solution attempts*.

4.2.1 Barriers

Considering problematic factors which are seen as barriers (n_{SC}=13, n_{SCE}=20, f=99) on enhancing the effectiveness of the science center education processes; four main themes are revealed under barriers category as (a) *lack of administrative support*, (b) *lack of long-term reciprocal agreement on an annual plan with schools*, (c) *lack of knowledge*, and (d) *lack of financial budget*. Table 4.6. shows themes, sub-themes, and frequency of being told.

Table 4.6 Barriers that prevent effectiveness in educational process

Themes and Sub-Themes	Number of SC (n)	Frequency of being told (f)
Lack of administrative support	***4***	***10***
Lack of knowledge	***6***	***9***
On cultural differences	4	6
On maintaining sustainability	3	3
Lack of financial budget	***10***	***31***
Lack of structural details in building	5	5
Lack of human resource	7	17
Lack of renovations	5	9
Lack of long-term reciprocal agreement	***13***	***49***
Everlasting permission process	2	2
Lack of opportunity to access to students	4	4
Lack of reciprocal agreement with teachers	11	41
Uncontrollable demanding requests	2	2

n_{SCE}=20

Lack of administrative support includes lack of support in decision-making processes for the professional development of science center employees and the preparation of infrastructure that can take part in these developmental processes. The unsustainable management approach is an obstacle towards providing an opportunity to SCEs for enhancing their collaborations, which may also provide advanced educational activities to create learning environments based on their observations, for increasing impact on society of educational activities by mentioning the activities on social media accounts. SCE.17 from SciCen.11 and SCE.04 from SciCen.04 told following utterances respectively as barriers for lack of administrative support:

> *"We cannot say that we are attending conferences. As administrations change, approaches change as well."* [Q10, Appendix I]

> *"We will not have any YouTube channel since the administration is not permitting this."* [Q11, Appendix I]

Lack of knowledge was revealed as a barrier that prevents the effectiveness of educational processes with two sub-themes, which are lack of knowledge on cultural differences and lack of knowledge on maintaining sustainability. It is seen that the lack of knowledge on cultural differences is an obstacle for the adaptation of educational processes, including educational activities, from the first steps of the instructional design process to the renewal period. During the foundation of science centers, SCEs were informed about how the educational activities were structured regarding the local culture in that specific region where the science centers located; however, the absence of the culturally adapted knowledge for the educational activities for Turkey context during these pieces of training was noted as the lack of knowledge on how SCE would adapt the acquired educational activities into Turkish culture. Subj.09 from SciCen.06 said following utterance as a barrier for lack of knowledge on cultural differences:

> *"Newly-established science centers send their staff abroad, but children in Turkey are not similar to children there. Children who are visiting a science center in Sweden are not showing similar behaviors with children who are visiting a science center in Eskişehir or Elazığ. We need to prepare our national training for science communicators."* [Q12, Appendix I]

Lack of knowledge on maintaining sustainability was also revealed as another issue for barriers to enhancing educational effectiveness in science centers. It was reported that science centers do not know about how they will maintain sustainability for science center visitors. Subj.09 from SciCen.06 told the following utterance as a barrier for lack of knowledge on maintaining sustainability:

> *"When someone arrived here, they came for once or twice or brought their guests for the third visit; however, the question of why they should come for the fourth time is still searching an answer."* [Q13, Appendix I]

The third emerged sub-theme as a barrier to enhancing educational effectiveness in science centers is *shoestring (lack of) financial budget*. Shoestring financial budget was stated as mostly focusing on the contextual factors which prevent enhancing educational effectiveness such as the inconvenient structure of the building (lack of structural details in the building) for educational activities, lack of human resource for maintaining diverse work branches and lack of renovations for providing diverse educational activities. Shoestring financial budget was stated as a preventing factor for the renovation of the building, and this results in noise pollution when big student groups have arrived at the science center. Moreover, lack of human resource was reported as a barrier which increases the workload of available personnel so that assessment and evaluation, which are essential in enhancing educational effectiveness cannot be conducted efficiently. Finally, due to the expensiveness of exhibition units, it was stated that renovations for diversifying educational activities are prevented. Subj.19 from SciCen.12 and Subj.09 from SciCen.06 said following excerpts respectively on the inconvenient structure of the building, lack of human resource and lack of renovations:

> *"There exists noise pollution due to intensive people. And, since the structure of the building is inconvenient, this cannot be prevented."* [Q14, Appendix I]

> *"It is not possible to follow visitors. There may need 100 personnel here for assessment and evaluation."* [Q15, Appendix I]

> *"It is difficult to renovate the interior sides of the science center's environment. There is no science center in Turkey which has been renovating its capacity by 50% since it is costly. Of course, it is a demotivating factor that you have been informing on the same exhibition units. When exhibition units are replaced, other educational issues may be renovated as well."* [Q16, Appendix I]

Lack of long-term reciprocal agreement with schools on an annual plan emerged as the last barrier having the highest number of frequency. Lack of long-term reciprocal agreement also emerged the barriers as everlasting permission processes, lack of opportunity to access to students, lack of reciprocal agreement with teachers, and uncontrollable demanding requests. Beside everlasting permission processes as the lack of collaboration with schools caused a barrier, unexpected activity requests might not be satisfied due to the unavailability of the permission. SCE.09 from SciCen.06 and SCE.01 from SciCen.01 said following excerpts on everlasting permission processes respectively:

> *"Formal procedures may take more time. For instance, an important person has come to Turkey, and sudden activity is organized. We need to invite a school to bring students with them (important visitors). However, we have difficulty in taking permission in a short time."* [Q17, Appendix I]

> *"We have no long-term agreement with them (schools). We have been establishing project-based collaborations; however, we have no long-term collaboration based on an annual plan."* [Q18, Appendix I]

In addition to everlasting permission processes, the lack of reciprocal agreement with teachers was seen as a barrier that might result in getting involved in the educational processes by interfering with them. Furthermore, this barrier was seen to cause that teachers cannot take an active role before, during and after the science center visit. Many SCEs stated teachers' passive role and reluctant attitude towards having an active role without interfering with the educational processes during science center visit. This passive role was stated as having negative aspects affecting both students and science center visit sides. SCE09 from SciCen.06 and SCE15 from SciCen.09 said following utterances respectively:

“Sometimes, when we asked students, teachers also respond, and we do not want this.” [Q19, Appendix I]

“Most of the visiting teachers go to cafeterias after they brought the students into the exhibition areas.” [Q20, Appendix I]

Moreover, since there is a lack of reciprocal agreement with teachers, during the school visits, the effective timing allocation of the science center visit duration might not be provided. Also, logistics issues due to visit duration in the science center and distance to the science center have emerged as a barrier caused by the lack of reciprocal agreement with teachers. Due to the distance between school and science centers, school busses are set for transferring the students to science centers. However, as the distance increases, the visit duration in the science center decreases during the school hours so that this was noted as a barrier that prevents the effective involvement of students and teachers into the educational processes. Due to the limited visit duration, students are quickly informed about the exhibition units, and after this stage, they are expected to self-explore the science center environment. and SCE.15 from SciCen.09 said following utterance:

“Visiting school groups are coming with school buses from a distance so that they do not stay too long. They want to go. If there are groups who have time, we are conducting pre-prepared extra workshops for them.” [Q21, Appendix I]

Due to a lack of long-term reciprocal agreement with schools on an annual plan, it was stated that science centers find a lack of opportunity to access to the students. SCE.10 from SciCen.07 said following excerpt:

“Few teachers from the ministry of national education were a volunteer for giving advice; however, we could not receive support. We needed to struggle with all the things so that I hesitated about the willingness of national education in the science center. Although we signed a protocol with national

education, requested for at least ten thousand students as a visiting group, ensured the transportation as a free of charge, and took the responsibility of each child, we could not bring the students here." [Q22, Appendix I]

Uncontrollable demanding requests were also featured as a barrier under lack of long-term reciprocal agreement with schools on an annual plan was stated as causing that group sizes to get bigger when satisfying the requests or there exists unavailability in time-slots for school visits. Furthermore, these were mentioned as resulting in limited interaction between students and teachers. Subj.19 from SciCen.12 said following excerpt:

"Interactive time-slot is a time that students can select exhibition units to explore them actively. However, this is not possible for a long time due to the demanding requests of the school groups to the end of the semester, and it is difficult to implement this." [Q23, Appendix I]

4.2.2 Expectations

Expectations (n_{SC}=12, n_{SCE}=20, f=64) revealed two main themes as (a) *enhancing collaboration* and (b) *transforming students' attitudes* (see Table 4.7). *Enhancing collaboration* was revealed as *SCE*s' expectation, including establishing science center dynamics and involving teachers within educational processes. Establishing science center dynamics was revealed as the core expectations with building an effective team-work environment, maintaining sustainability, and producing national materials. Moreover, involving teachers within educational processes were also stated as a sub-theme of enhancing collaboration and declared the *SCE*s' expectations from school teachers. Teacher's initiation for organizing science center visits, teacher's interaction with students during visits and teacher's participation in science center activities were also stated under the expectations from the teacher's involvement. *Transforming students' attitudes* were also stated as expectations of *SCE*s from students, and these expectations included arousing interest in science, endearing science and encouraging students to improve their inquiry skills. SCE.19 and SCE.18 from SciCen.12 said following excerpts respectively:

> *"Interactive time-duration is a period in which we want to have interaction between students and their teachers."* [Q24, Appendix I]

> *"Many families say 'my child is having breakfast as s/he is listening to the radio that s/he made'. This is the message that we want to give in workshops. We are trying to enter into the houses. As well as the student feels "I could do." and shows it to mother, father, or friend since it is a reflexive attitude. If s/he has questions related to it on the mind, be curious about it and continue discovering."* [Q25, Appendix I]

Table 4.7 Expectations from others that enhances the effectiveness of educational proesses

Themes and Sub-Themes	Number of *SC* (n)	Frequency of being told (f)
Enhancing collaboration	***11***	***36***
Establishing science center dynamics	5	8
Building effective team-work environment	2	2
Maintaining sustainability	3	3
Producing national materials	3	3
Involving teachers within educational processes	10	28
Initiation for organizing *SC* visits	7	12
Interaction with students during visits	6	8
Participation in *SC* activities	5	8
Transforming students' attitudes	***11***	***28***
Arousing interest	4	7
Endearing science	6	12
Inquiry skills	6	9

n_{SCE}=20

4.2.3 Needs

Needs (N_{SC}=12, N_{SCE}=20, $N_{frequency}$=38) as a category has emerged with four main themes, which are (a) *expanding human resource*, (b) *expanding educational space*, (c) *expanding collaboration*, and (d) *improving evidence-based educational processes*. Table 4.8 shows themes and sub-themes with their frequencies.

Expanding human resource was mentioned as a need which is expected to lead positive benefits for science center functionality. By expanding the human resources, the workload can be distributed among science center employees so that *SCE*s can allocate more time and energy to educational activities. Hence, it can be said that expanding human resources may also constitute the basis of factors that improve the effectiveness of educational processes.

Expanding educational space was stated as a need, including four sub-themes as building a wet-ground laboratory, building virtual platforms, forming subject-specified stations, and national materials. Building a wet-ground laboratory is stated as an essential educational space for *SCE*s since it provides the necessary environment to learn the concepts which cannot be covered by exhibition units while learning the science concepts. Moreover, based on *SCE*s' perceptions, lack of equipment related to the laboratory hands-on activities results that students can be missed out on the connected lesson objectives. To fill this gap, it was stated that science centers need wet-ground laboratories. Subj.10 from SciCen.07 said following excerpt:

> *"The most important educational space is laboratories since students starve for those. When we conduct experiments, they surprise and like them. Students have laboratories in their schools; however, they are not in use. For example, when we needed equipment such as a magnet for an experiment, the school could not find even the key to the laboratory."* [Q26, Appendix I]

Table 4.8 Needs that enhances the effectiveness of educational processes

Themes and Sub-Themes	Number of *SC* (n)	Frequency of being told (f)
Expanding human resource	***5***	***9***
Expanding educational space	***5***	***10***
Building a wet ground laboratory	1	3
Building virtual platforms	1	4
Forming subject-specified stations	1	1
National materials	2	2
Extending collaboration	***7***	***9***
Adjusting activities	2	2
Accessing to the target group	2	2
Gaining benefits on facilities	2	2
Increasing impact on society	2	3
Grounding evidence-based educational activities	***7***	***10***
Recording educational processes	1	3
Testing the effectiveness of educational activities	3	4
Understanding students' attitudes and behaviors	2	3

N_{SCE}=20

Forming subject-based stations were also stated as a need for expanding educational space. *SCE*s said that these kinds of stations are needed to eliminate the cognitive load of students by hiding the exhibition units which are not related to the lesson objectives and diversify the sequence of instruction. Subj.11 from SciCen.07 said following excerpt:

> *"We may show different exhibition units in parts so that students have a perception like 'There are different experiments!'."* [Q27, Appendix I]

Extending collaboration was represented as a need for adjusting educational activities, access to the target group, gaining benefits on collaborators' facilities and increasing impact on society. *SCE*s said that for increasing impact on society, science centers need to collaborate with institutions such as non-governmental organizations, universities, schools, and private companies. Distribution of the collaborated institutions was indicated as providing many more benefits to science centers for different areas. SCE.09 from SciCen.06 said following excerpt:

> *"Universities are not adequate for science centers since they are unable to go beyond the academic perspective. We are doing something here with people and children. Therefore, we are working with non-governmental organizations such as the search and rescue team, the red crescent in Turkey, schools, private institutions, and private companies."* [Q28, Appendix I]

In addition to increasing impact on society, by extending collaboration, accessing to students can be provided. *SCE*s overemphasized bounding partnerships with teachers who were stated as key characters of accessing to students are needed. SCE.09 from SciCen.06 said following excerpt:

> *"Our purpose is here to access to students, and we need to access to teachers for the first step. If we cannot gain teachers, we cannot bring students here."* [Q29, Appendix I]

Gaining benefits on collaborators' facilities was also explained as an essential need under extending the collaboration theme. Thus, the science center can reach equipment which is not existed in the science center environment. SCE.04 from SciCen.04 said following excerpt:

> *"We brought students to faculty of pharmacy and faculty of medicine. We are getting help from there. For instance, we need cell culture, but we do not have it. We brought students to there. For instance, we do not have an operation device; we brought students there."* [Q30, Appendix I]

Grounding educational activities were also connotated as a need by *SCE*s to emphasize the need for preparing educational activities regarding evidence-based researches. Grounding educational activities revealed three sub-themes as recording educational processes, testing the effectiveness of educational activities, and understanding students' attitudes and behaviors. Continuing students who are involved in educational activities in the science center are needed to be followed by recording the educational progress of the students while they are producing so that it was stated as a facilitator for tracking that specific educational process. Subj.04 from SciCen.04 said following excerpt:

> *"We want videos that can project whole educational processes. After the project finished and we produced, a video will show us that specific students got through those educational processes."*
> [Q31, Appendix I]

Testing the effectiveness of educational activities was also highlighted as a need for grounding educational processes. Scientific studies conducted on educational processes can form the basis of the subsequent educational programs during designing instruction and trying to maintain sustainability. SCE.17 from SciCen.11 said following excerpt:

> *"We tried to apply and think that we get efficiency. But, we do not have any scientific research for this."* [Q32, Appendix I]

4.2.4 Solution Attempts

Solution attempts (n_{SC}=13, n_{SCE}=20, f_y=102) which were applied by *SCE*s for enhancing educational effectiveness in science centers revealed five main themes as (a) *compensating infrastructural limitations*, (b) *evaluating implemented activities*, (c) *extending collaboration,* (d) *having an impact on society* and (e) *maintaining sustainability*. Table 4.9 shows themes and sub-themes with their frequencies.

Attempted solutions for ***compensating infrastructural limitations*** were pointed out as arranging educational space and limiting group-size. By limiting group-size, science centers separate the visiting school groups based on their ages to use educational space efficiently. In other words, in parallel with the educational space width, groups are separated based on their ages so that *SCE*s are trying to provide efficiency during the visit by limiting group sizes.

> *"We are trying not to accept kindergarten students with elementary school groups at the same time. They all have different days to visit since kindergarten students are unguarded; they may occur problems."* [Q33, Appendix I]

> *"We can take 20 students for one group since it is not convenient when it is more than 20 students."* [Q34, Appendix I]

Table 4.9 Solution attempts to barriers that strengthen the effectiveness of educational processes

Themes and Sub-Themes	**Number of *SC* (n)**	**Frequency of being told (f)**
Compensating infrastructural limitations	***3***	***7***
Arranging educational space	3	3
Limiting group-size	2	4
Extending collaboration	***12***	***42***
Establishing strong relationships with key agent	4	8
Expanding human resource	4	5
Gaining benefits on facilities	2	2
Integrating teachers in educational processes	8	17
Satisfying demanding requests	6	10
Maintaining sustainability	***9***	***21***
Preparing workshops	4	5
Renewing demonstrations	3	3
Student-membership program	3	8
Training employees for interchangeable roles	4	5
Having an impact on society	***13***	***21***
Using social media for sharing activity news	13	17
Using the website for informing about exhibition units	4	4
Evaluating implemented activities	***3***	***11***

n_{SCE}=20

In addition to limiting group-size, arranging educational space was stated as a solution attempt of science centers. Even though science centers have shoestring financial budget, with established collaborations and provided supports, additional building and mobile spaces were stated as constituted. SCE.18 from SciCen.12, SCE.19 from SciCen.12 and SCE.10 from SciCen.07 said following excerpts respectively:

> *"There are different plans for the new building. A building will arise to the backside and we will have a more organized educational program there."* [Q35, Appendix I]

> *"We had difficulties at earlier times. Each child within a group having 30 students wants to be at the forefront and wants to see before others. We solved this problem. We prepared stickers on the ground and we are warning students as 'Now, we are out of the circle.' They are standing out of it and they can all observe without losing communication."* [Q36, Appendix I]

> *"We have plans to bring a temporary exhibition here. We are currently exchanging correspondence with the institutions. After the temporary exhibition, if we structured laboratory to there and widen the science center, we will remove the 60-student obstacle."* [Q37, Appendix I]

Moreover, ***extending collaboration*** was also indicated as a solution attempt to remove the obstacles in front of enhancing educational effectiveness in science centers. By extending collaboration, it was revealed that science centers establish strong relationships with key agents, expanding human resources, gaining benefits on facilities, integrating teachers in educational processes and satisfying demanding requests. To satisfy the science center visit requests of school groups, it was stated that science centers could limit the science center visit count and prepare additional activities. SCE.10 from SciCen.07 said following excerpts:

> *"Classroom teacher takes the appointment for science center visit. We are taking especially their names and telephone*

numbers, and we are following this. If an appointment would be canceled, we want to replace it with another demanding group." [Q38, Appendix I]

"We are drawing the line for the appointments and trying not to give more than two or three appointments." [Q39, Appendix I]

Under extending collaboration theme, integrating teachers in educational processes was revealed as a sub-theme which means that *SCE*s provide informative documents to teachers before the visit and make them participate in the workshop when the time is available for them during the visit. SCE.19 from SciCen.12 and SCE.15 from SciCen.09 said following excerpts respectively:

"We wanted to conduct a study on the integration of teachers. Last year, we sent a document including related exhibition units and questions to teachers before they visited science center as a school group." [Q40, Appendix I]

"We will involve teachers in science center visits for more efficiency. For instance, while we are conducting workshops, we are taking teachers in and asked for help during the workshop. They are helping us and doing with us." [Q41, Appendix I]

Finally, *SCE*s reported establishing strong relationships with key agents so that they are trying to remove the barrier, which was stated as everlasting permission processes. SCE.09 from SciCen.06 said following excerpt:

"Formal protocols take many more times sometimes; for instance, a sudden visitor has come to the city or come to Turkey. We need to invite a school since we need to meet the students with the guests. Government correspondence takes forever and it is difficult to take permission for us. It is easier to get permission for teachers so that we are calling teachers whom we are working together. That teacher can get permission in a short time

and bring students to activity. Since we are out of these processes, it takes approximately 15 days for us to get permission and reciprocal relationship is important." [Q42, Appendix I]

Establishing strong relationships with key agents who were stated as a provincial directory of national education and teachers was reported as providing benefits on science centers' procedural and functional regulations, such as arranging group sizes or visiting school groups. SCE.15 from SciCen.09 said following excerpt:

"This system took time to get back on the rails. When the science center was first opened, we suffered a lot regarding appointments. There were problems in school group visits since they might come when they approved or the group size might get bigger than the agreement. It was difficult to see 300 people at the same time since you had inadequate personnel numbers. But, it has been getting back on the rails by working with provincial, national education." [Q43, Appendix I]

Having an impact on society has emerged as another main theme. To provide this dissemination effect, science centers use social media for announcing new activities and sharing information regarding exhibition units through their websites. SCE.15 from SciCen.09 said following excerpt:

"We are conducting workshops, for instance, we have an exhibition unit named "Our Universe" including all planets in the solar system. However, we don't know whether the student connects this with her daily life or not. For this reason, we are making students do sundial in the workshop and both she is learning sun movements in the workshop, and she saw sun movement and moon and earth rotation around the sun in exhibition unit hall so that student makes sense of the concepts." [Q44, Appendix I]

4.3 Results for Study II: Multiple Case Study

This *multiple case study* had the central phenomenon as "science centers as metacognitive concepts". This phenomenon assures the main research question as "How should be the instructional design for different science lesson units regarding metacognitive processes?". And, the main issue focused on the following research questions:

2. What are the indicators of implicit metacognitive actions of *SCE*s through the guidance phase interacting with students through the guidance phase?
    a. Is there any change in scientific conceptual understanding levels for selected concepts of students in alignment with *SCE*s' implicit metacognitive actions?
        i. ***Baseline question for 2a.*** *What are the students' experience of science center visit during their science lesson hours?*
3. What are the indicators of shared metacognition during peers' collaborative works?
4. What are the indicators of students' metacognition within science center environments?

Data analysis of each phase, including guidance, and collaboration (since video edition phase was extracted, the findings of that phase was not included) was contended within the following titles.

4.3.1 Guidance Phase

Reminder: The guidance phase is the first phase of the multiple case study. It refers to the guidance of seventh-grade students by SCEs on pre-defined events of instruction focusing on the target concepts. Students were brought to the science center within their class hours via school bus and their science teachers accompany with them. They took guidance from one of the SCEs for approximately 30 minutes and then freely explored the exhibition units. Then, students were given both a *science diary and a conceptual diagnostic paper to reflect their experiences and fill the questions to relate the concepts to the guided exhibition units.*

Seven guidance sessions occurred in the guidance phase within three cases. They are the lesson units, which are “Work and Energy”, “Mirrors and Light Absorption”, and “Solar System and Beyond”. Table 4.10 shows associated science center educator’s characteristics regarding the guidance video data. Firstly, “***work and energy unit”*** divided into two weeks due to its demanding lesson objectives. Two classes participated in the guidance phase with the same science teacher from the same school. Thus, the guidance phase occurred four times. Second, for “***mirrors and light absorption unit***”*,* two classes from two different schools with their science teachers participated in the guidance phase so that two guided tours occurred for this unit. Finally, for “***solar system and beyond unit***”*,* one guided tour occurred targeting one class and the science teacher of that class. However, due to technical problems, the guidance video for the solar system and beyond lesson unit was not accessible. Therefore, this analysis, including the guidance phase focusing on implicit metacognitive actions, includes a total of six videos for both work and energy and mirror and light absorption units.

Table 4.10 SCE’s characteristics and associated video data

Video #	SCE #	Gender	Age	Science Center	Science Teacher	Lesson Unit
1	1	Female	28	Feza Gürsey SC	ST1	Work and Energy (*Force and Pressure*)
2	1	Female	28	Feza Gürsey SC	ST1	Work and Energy (*Energy and Energy Transformation*)
3	2	Female	29	Feza Gürsey SC	ST1	Work and Energy (*Force and Pressure*)
4	2	Female	29	Feza Gürsey SC	ST1	Work and Energy (*Energy and Energy Transformation*)
5	3	Male	28	Kocaeli SC	ST2	Mirrors and Light Absorption
6	3	Male	28	Kocaeli SC	ST3	Mirrors and Light Absorption
7	4	Female	27	Kocaeli SC	ST4	Solar System and Beyond

The indicators of implicit metacognitive actions of SCEs interacting with students through the guidance phase (RQ2)

The coding of the video data of this guidance phase investigated the indicators of implicit metacognitive regulatory actions of *SCE*s. The results revealed four categories: *orientating, planning, monitoring,* and *evaluating.* Six SCEs' video data built these categories during separate guidance phases. Table 4.11 shows the themes and sub-themes, including the frequencies of being uttered by *SCE*s to imply their metacognitive regulatory actions during guidance.

Table 4.11 SCEs' implicit metacognitive regulatory actions during guidance

Sub-Themes	Number of guidance (n)	Frequency of being uttered (f)
Orientating	***6***	***248***
Content Orientation (CO)	*6*	*72*
Activating prior knowledge (APK)	6	47
Hypothesizing (H)	6	25
Guide Orientation (GO)	*6*	*78*
Providing turn-taking (PTT)	6	32
Relocating (RL)	6	46
Task Analysis (TA)	*6*	*98*
Establishing task demands (ETD)	6	21
Informing task subjects and constitution (ITSC)	6	50
Structuring task instruction (STI)	6	27
Planning	***6***	***66***
Considering alternatives for conceptual understanding (CACU)	*6*	*13*
Developing an action plan (DAP)	*6*	*53*
Monitoring	***6***	***387***
Monitoring of strategy use (MSU)	*6*	*60*
Component structuring (CS)	6	6
Repeating question (RQ)	6	34
Selective attention (SA)	6	20
Monitoring of progress (MP)	*6*	*47*
Comprehension monitoring (CM)	*6*	*233*
Noticing a lack of comprehension (NLC)	6	64
Claiming (Partial) understanding (CU)	6	118
Demonstrating comprehension by repeating (DCP)	6	5
Demonstrating comprehension by elaborating (DCE)	6	46
Evaluating	***6***	***230***
Checking (CH)	*6*	*200*
Reflecting (RF)	*6*	*30*

Orientating: This category refers to the orientation of students to the guidance session for setting the ground to understand the selected concepts. *SCE*s' utterances targeting orientation of the students had 248 frequencies. Six video data revealed three themes as content orientation (*f*=72), guide orientation (*f*=78), and task analysis (*f*=98).

For *content orientation, SCE*s activate prior knowledge by conceptual relations, daily life examples, and exhibition unit components / physical similarities. In addition to activating prior knowledge, they make students hypothesize by asking questions regarding conceptual relations, daily life examples, and exhibition unit components / physical similarities. It seems that out of 72 utterances, while 47 statements targeted to activate the prior knowledge, 25 remarks focused on making students hypothesize regarding the investigated phenomenon. The numeric distance between APK and H might mean that *SCE*s mostly keen on activating prior knowledge rather than making students hypothesize about the selected scientific concept.

SCE1 uttered the following sentence during the force and pressure week of work and energy case. The sentence is an example of activating prior knowledge (by exhibition unit components / physical similarities), and the contended exhibition unit was "Sand Pendulum":

> *"Is there anybody who knows what pendulum is? What is a pendulum? Do you see it hanging from top to bottom? We have a mass below. One end is tied, and one end is free and swings. Have you noticed?"* [Q45, Appendix I]

Guide orientation is another metacognitive regulatory action under the ***orientating*** category. Under the guide orientation theme, in each transition to exhibition units within the instructional sequence, *SCE*s relocate students by directing them to relocations, providing help on establishing the point of view, and informing on the identification of expectations from students for the use of learning strategy. Similarly, after the transition period, during the conversation, *SCE*s provide turn-taking for students by encouraging other's contribution to the talks. The results showed that out of 78 utterances for guide orientation, *SCE*s used 32 declarations to provide turn-taking and 46 statements to relocate the students.

SCE1 said the following excerpt during the guidance phase of Force and Pressure week for the "Hot Air Balloon" exhibition unit to provide turn-taking (by encouraging other's contribution):

"Is there anyone else who can give me an example?" [Q46, Appendix I]

Task analysis is the final metacognitive regulatory action under the ***orientating*** category. In each transition to exhibition units within the instructional sequence, *SCE*s implicitly refer to task analysis by establishing task demands, informing students about task subjects and constitution, and structuring task instruction. First of all, *SCE*s set task demands for students by stating and restating task instructions. Second, *SCE*s inform students about the task subjects and constitution by saying the general name of the exhibition unit, by stating subcomponents will be used during the talk and by saying daily life examples. Finally, *SCE*s structure task instruction by mentioning critical concepts at the beginning of the conversation, pointing to crucial components, and schematizing the task by hand.

SCE1 said the following utterance during the energy transformation week of the work and energy case to inform students about the task subjects and constitution (by stating the general name of the exhibition unit) for the exhibition unit "Measure Your Power".

"See what we're going to do here. We have a bike here, too. The name of this exhibition unit is Measure Your Power." [Q47, Appendix I]

Table 4.12 shows the number of frequencies assigned to each week and *SCE.* The results showed that SCE2, for both force and pressure, and energy transformation weeks, had higher frequencies for content orientation; whereas, SCE1 had higher frequencies for providing turn-taking among students compared to SCE2. On the other hand, they had similar frequencies for task analysis processes. Moreover, the results showed that mirrors and light absorption revealed higher rates for relocating and establishing task demands compared to force and pressure.

Table 4.12 SCEs' implicit metacognitive regulatory actions during the guidance per lesson unit: Orientating

Week	SCE	Orientating						
		CO		GO		TA		
		APK	H	PTT	RL	ETD	ITSC	STI
FP	SCE1	4	2	7	2	3	11	2
	SCE2	17	12	4	5	1	11	3
ET	SCE1	3	1	12	2	1	7	2
	SCE2	9	5	2	4	1	5	2
MLA	SCE3	11	5	12	28	13	14	3

CO: Content Orientation, GO: Guide Orientation, TA: Task Analysis, APK: Activating Prior Knowledge, H: Hypothesizing, PTT: Providing Turn-Taking, RL: Relocating, ETD: Establishing Task Demands

Although subject-based frequencies told about the differences among orientating themes and *SCE*s, the differences in the number of frequencies based on individual exhibition units might give an insight on the effect of physical characteristics and associated concepts on triggering metacognitive regulatory processes. Table 4.13 shows the number of frequencies of *SCE*s' implicit orientating actions during the guidance per exhibition unit. The results illustrated that both SCE1 and SCE2 had higher frequencies for the Hot Air Balloon exhibition unit.

Table 4.13 SCEs' implicit metacognitive regulatory actions during the guidance per exhibition unit: Orientating

SCE	Exhibition unit	Orientating						
		CO		GO		TA		
		APK	H	PTT	RL	ETD	ITSC	STI
SCE1								
	Sand Pendulum	0	1	0	0	0	2	1
	Air Bubble Race	0	0	0	0	1	3	0
	Hot Air Balloon	3	1	1	0	1	1	0
	Bernoulli's Ball	0	0	0	1	1	2	0
	3d Sand Pool	0	0	1	0	0	1	1
	Press Test	0	0	2	1	0	1	0
SCE2								
	Sand Pendulum	3	0	0	0	0	3	1
	Air Bubble Race	2	3	0	1	0	3	1
	Hot Air Balloon	6	3	1	1	0	1	0
	Bernoulli's Ball	0	3	0	1	0	3	0
	3d Sand Pool	6	1	3	1	0	1	0
	Press Test	0	1	0	1	0	1	1
SCE1								
	3d Sand Pool	0	0	0	0	0	0	0
	Guess Who Wins	3	1	6	2	1	3	0
	Pedal Force	1	0	5	0	0	2	2
	Measure Your Power	0	0	4	0	0	1	0
SCE2								
	3d Sand Pool	1	2	0	2	1	0	0
	Guess Who Wins	4	2	2	0	0	2	2
	Pedal Force	4	0	0	0	1	2	0
	Measure Your Power	0	0	0	2	0	0	0
SCE3								
	Color Shadow	7	1	0	7	1	5	2
	Countless Color	2	0	0	0	1	1	0
	Color Removal	2	1	1	3	4	2	0
	Touch the Spring	0	0	7	11	1	2	0
	Infinite Views	0	1	0	5	2	1	0
	Monochrome Room	0	2	4	2	4	3	1

Figure 4.1 shows the overall results for the *orientating* process. The results showed that activating prior knowledge under content orientation and relocating under guide orientation had higher frequencies during the guidance.

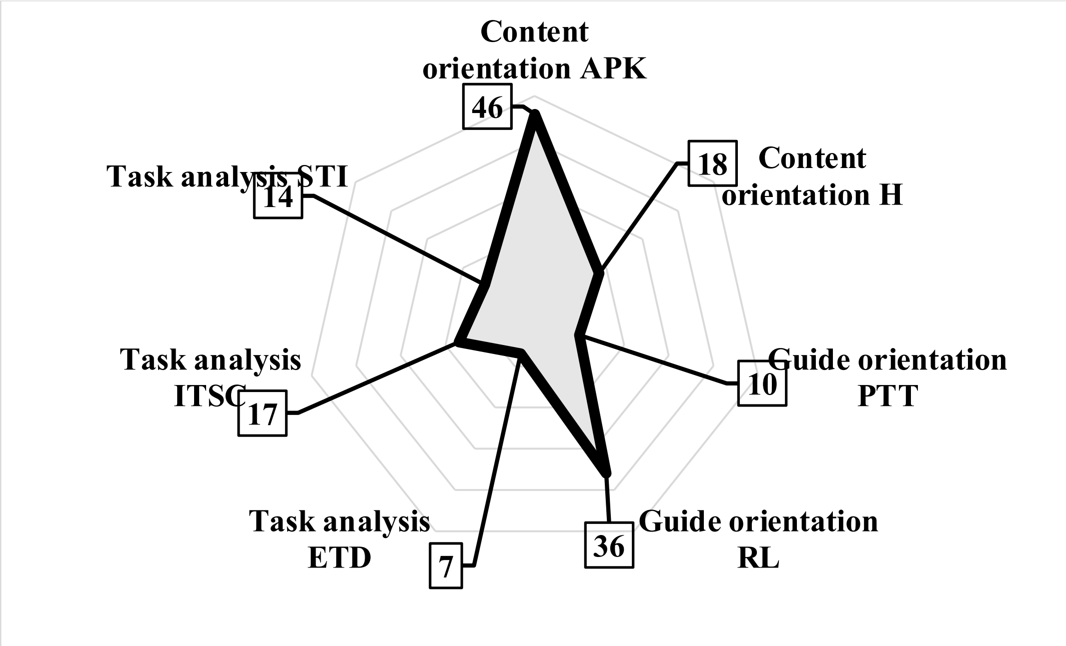


Figure 4.1 Overall results of orientating

APK: Activating prior knowledge, H: Hypothesizing, PTT: Providing turn-taking, RL: Relocating, ETD: Establishing task demands, ITSC: Informing task subjects and constitution, STI: Structuring task instruction

In order to be specific within the orientating process, actions associated with the content orientation, the guide orientation, and task analysis were extracted. Figure 4.2 shows the specific orientating actions of SCEs. The results illustrated that SCEs frequently refer to activate prior knowledge by conceptual relations.

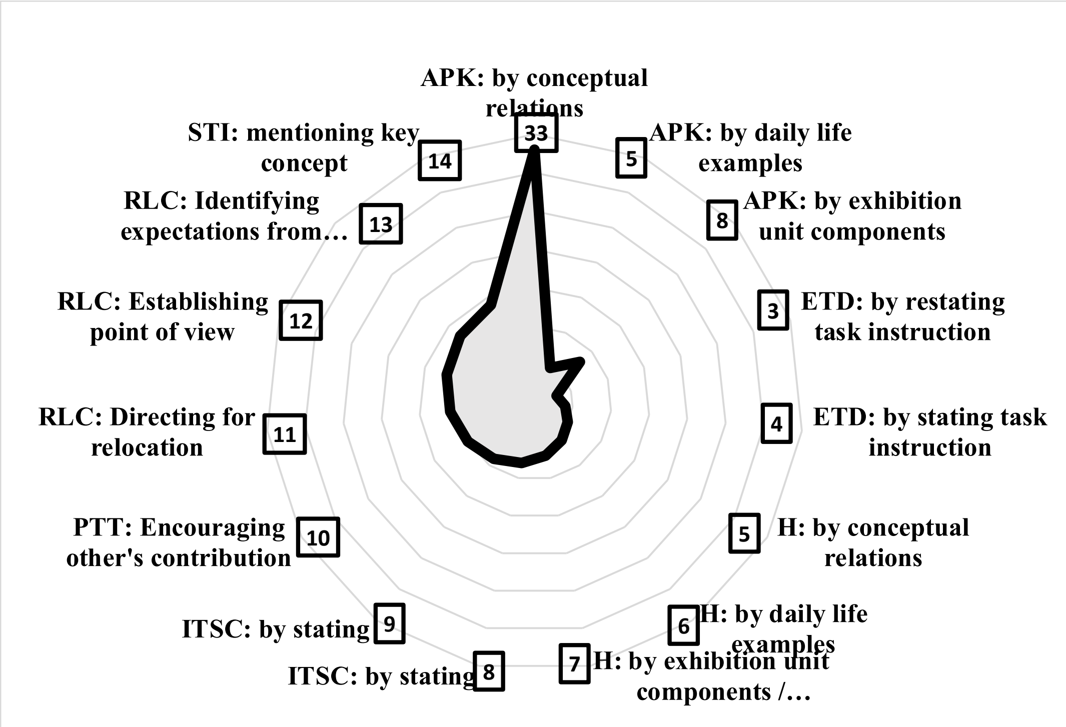


Figure 4.2 SCEs' specific orientating actions

(a) ***Planning:*** This category refers to the metacognitive activities related to the thinking process to achieve the learning objectives via relevant concepts. During the ***planning***, *SCE*s *consider alternatives for conceptual understanding* by changing the strategy by reversing argument and identifying restrictions for conceptual understanding. SCE1 said the following excerpt during the guidance of energy transformation week for the "Guess Who Wins" exhibition unit. It was an example of considering alternatives for conceptual understanding (by changing the strategy by reversing argument).

"Well, let's switch them and start again." [Q48, Appendix I]

Developing an action plan is another theme under the planning category. After relocation, before SCE and students engage in the conceptual understanding, conceptual subgoaling, contextual subgoaling, keeping on observing exhibition unit for clarity later on, looking for key changes during exhibition unit works, organizing thought by questioning, and preparing exhibition unit context are implicit metacognitive regulatory actions hold while developing an action plan. SCE1 said the following excerpt during the guidance of the exhibition unit “Air Bubble Race” in force and pressure week. It was an example of developing an action plan (conceptual subgoaling).

> *“Now there is a pressure applied to our air bubble. Now, what do we do with the air bubble? We're applying a force here, applying an air bubble here, aren't we? How it will move in that dense matter of density. How will it move within a less dense substance? Shall we try? OK.”* [Q49, Appendix I]

Similarly, SCE3 said the following excerpt during the guidance of the exhibition unit “Infinite Views” in mirrors and light absorption week. It was an example of developing an action plan (keeping on observing the exhibition unit for clarity later on).

> *“One on the right and one on the left, if you think this image will appear in both, what will appear in both images this time to be reflected against the mirrors? As the initial images are always reflected in the opposite mirrors, the images of the images will continue to be like this, and the images will continue to reflect each other, creating an infinite image towards infinity, there will be a flow of shrinking images. It requires two simple mirrors. An object must enter between the two mirrors. Here we have two mirrors now. This one. There is a mirror here, the back of it is a mirror, and there is a mirror in front of it. Two mirrors mutually passed. Look now through the holes here and discover this infinite image.”* [Q49, Appendix I]

Figure 4.3. shows the number of frequencies for *SCE*s’ implicit planning activities. The results showed that *SCE*s refer to developing an action plan

more frequently compared to considering alternatives for conceptual understanding during the planning.

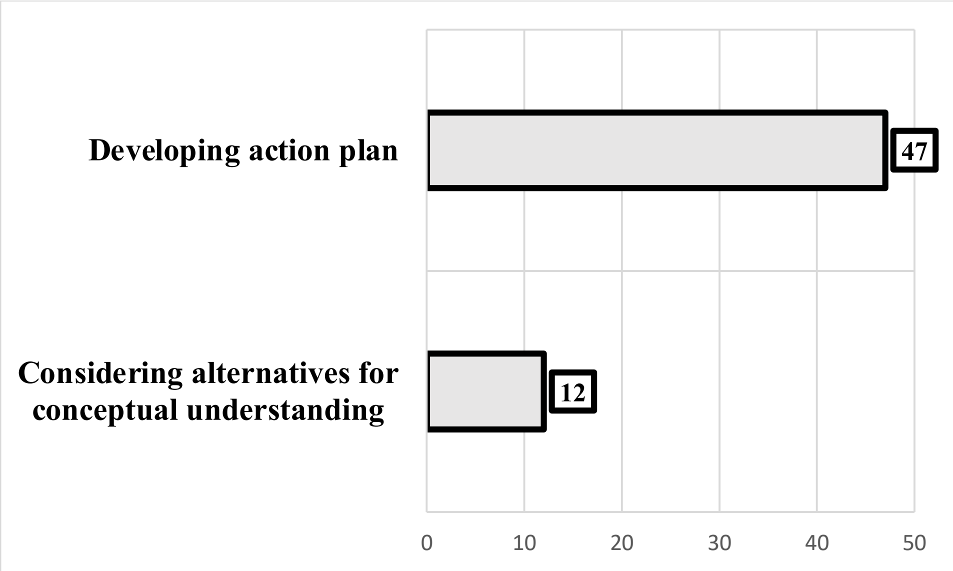


Figure 4.3 *SCE*s' implicit planning activities per the theme

Table 4.14 shows the number of frequencies for *SCE*s' implicit metacognitive planning actions during the guidance per exhibition units. The results showed that *SCE*s rarely refer to planning actions. It shows that while developing an action plan, for Hot Air Balloon, both SCE1 and SCE2 refer to looking for key changes.

Table 4.14 *SCEs*' implicit metacognitive regulatory actions during the guidance per exhibition unit: Planning

SCE	Exhibition unit	Planning								
		CACU				DAP				
		BR	CSR	IRC	CPS	CXS	KO	LKC	OT	PC
SCE1										
	Sand Pendulum	0	0	2	1	0	0	0	1	0
	Air Bubble Race	0	0	0	1	0	0	0	0	0
	Hot Air Balloon	0	1	0	0	0	1	1	0	0
	Bernoulli's Ball	1	0	0	0	0	0	0	0	0
	3d Sand Pool	0	0	0	0	0	0	0	1	1
	Press Test	0	0	2	1	0	1	0	0	0
SCE2										
	Sand Pendulum	0	0	0	1	0	0	0	0	1
	Air Bubble Race	0	0	0	1	0	0	0	0	0
	Hot Air Balloon	0	0	0	1	0	0	2	0	0
	Bernoulli's Ball	0	1	0	1	0	0	0	1	0
	3d Sand Pool	0	0	0	0	0	0	0	3	0
	Press Test	0	0	0	1	0	1	0	1	0
SCE1										
	3d Sand Pool	0	1	0	0	0	0	0	0	0
	Guess Who Wins	0	1	0	0	0	0	0	0	0
	Pedal Force	0	3	0	5	0	0	0	1	0
	Measure Your Power	0	0	0	0	0	0	1	0	0

Table 4.15 (Continue) *SCE*s' implicit metacognitive regulatory actions during the guidance per exhibition unit: Planning

SCE	Exhibition unit	Planning								
		CACU			DAP					
		BR	CSR	IRC	CPS	CXS	KO	LKC	OT	PC
SCE2										
	3d Sand Pool	0	0	0	1	0	0	0	1	0
	Guess Who Wins	0	0	0	0	0	0	0	2	0
	Pedal Force	0	0	0	1	0	0	0	1	0
	Measure Your Power	0	0	0	1	0	0	0	0	0
SCE3										
	Color Shadow	1	1	0	0	0	0	0	0	0
	Countless Color	0	0	0	1	0	0	0	0	0
	Color Removal	0	0	0	0	0	0	0	0	0
	Touch the Spring	0	0	0	2	0	0	0	0	0
	Infinite Views	0	0	0	1	0	1	0	0	0
	Monochrome Room	0	0	0	0	0	0	0	0	0

CACU: Considering alternatives for conceptual understanding, BR: Backward reasoning, CSR: Changing of strategy by reversing argument, IRC: Identifying restrinctions for conceptual understading, DAP: Developing action plan, CPS: Conceptual subgoaling, CXS: Contextual subgoaling, KO: Keeping on observing exhibition units for clarity, LKC: Looking for key changes during observations, OT: Organizing thought by questioning, PC: Preparing exhibition unit context

Figure 4.4 shows *SCE*s' implicit planning activities per sub-themes. It seems that *SCE*s frequently refer to conceptual sub-goaling while developing an action plan.

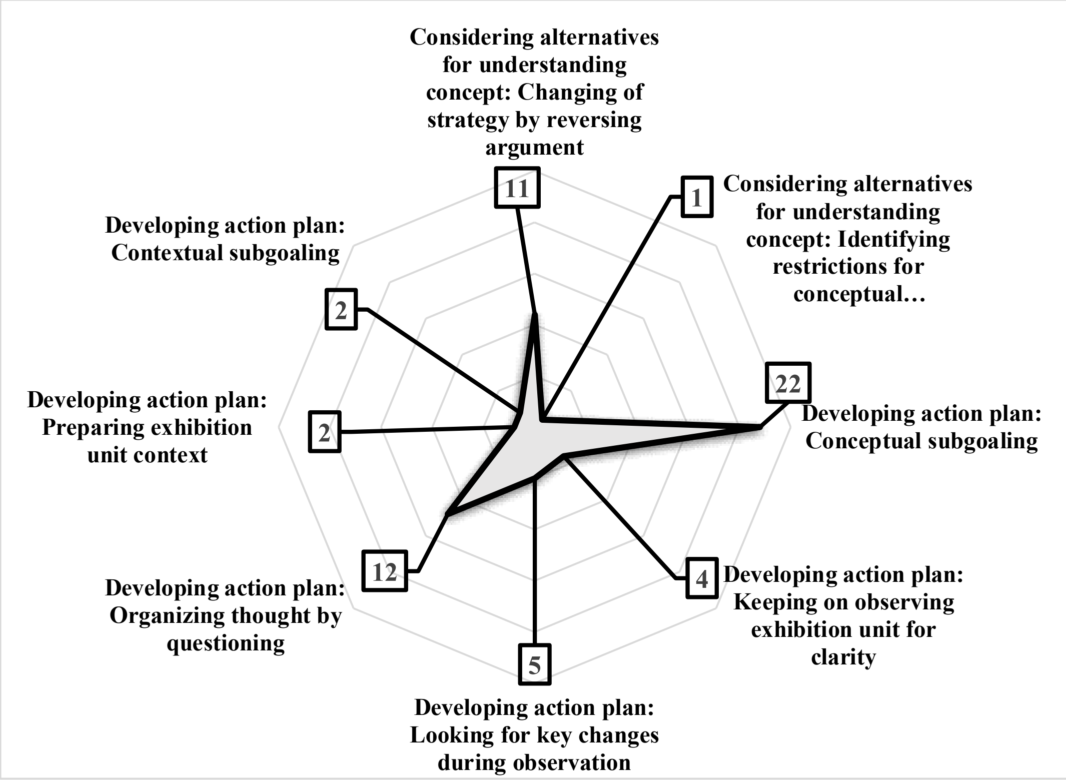


Figure 4.4 *SCE*s' implicit planning actions

(b) ***Monitoring:*** This category refers to the instant and long-term tracking of one's strategy use, progress, and comprehension. *SCE*s' implicit metacognitive activity of monitoring revealed three main themes as monitoring of strategy use, monitoring of progress and comprehension monitoring. First of all, *monitoring of strategy use* includes component structuring, repeating the question, and selective attention for the targeted concepts. Component structuring revealed two codes as emphasizing important information and pointing key components by fingers. On the other hand, repeating questions revealed three codes related to one's comprehension as repeating questions after confusion, in case of comprehension failure and in case no response. Selective attention as the final theme of *monitoring of strategy use* revealed two codes as focusing on specific exhibition unit components and overlooking exhibition unit for conceptual understanding.

SCE1 uttered the following excerpt during the guidance of the exhibition unit "Air Bubble Race" in force and pressure week. It was an example of component structuring (emphasizing important information). After SCE1 and students observe the bubbles within the liquid tubes, she asked students to emphasize the vital information, which was the speed of the air bubble in each liquid so that she found the baseline of the conceptual understanding by highlighting one of the essential components.

SCE1: You see the speed, right? [Q50, Appendix I]

As a second example, SCE3 uttered the following excerpt during the guidance of exhibition unit "Colorful Shadows" in the mirrors and light absorption week. It was an example of repeating questions in case comprehension failure. It seems that SCE3 used monitoring of their strategy use. SCE3 repeatedly asked the question to reach the answer for the constituting components of the yellow light.

SCE3: Main colors, but what colors?

Student: All in white light.

SCE3: All in white light, but where is yellow?

Student: It will be yellow when any light arrives.

SCE3: Will it be yellow when any light comes on? Is there any light coming in I'm going there? The shadow of the aircraft is also yellow. Where is the yellow light? [Q51, Appendix I]

Table 4.16 The number of SCEs' implicit monitoring actions during the guidance

Week	SCE	Monitoring										
		CM				MP				MSU		
		CU	DCE	DCR	NLC	ED	ND	NOC	P	CS	RQ	SA
FP	SCE1	17	1	0	4	1	2	0	0	0	1	1
	SCE2	30	23	4	17	8	2	0	0	6	3	1
ET	SCE1	8	3	0	5	2	0	0	0	0	5	3
	SCE2	16	4	1	12	3	0	1	0	0	5	3
MLA	SCE3	40	18	0	27	7	5	0	0	0	17	10

As a third example, SCE2 uttered the following excerpt during the guidance of the exhibition unit "Sand Pendulum" in force and pressure week. It was an example of selective attention (focusing on the exhibition unit). SCE2 informed students by making them focus on the specific physical shape of the exhibition unit so that she structures the component before the conceptual understanding occurs.

SCE2: It would go between the two points; wouldn't it could come between two locations? But there is no straight rope here. There's a long rope in the V-shape. Look, one of them wants to pull this way. [Q52, Appendix I]

Monitoring of progress is another central theme, including error detection (plus correction), noticing differences, noticing other's correct answers and pausing. SCE3 uttered the following excerpt during the guidance of the exhibition unit "Touch the Spring" in mirrors and light absorption week. It was an example of error detection (plus correction). SCE3 asks a daily life example for concave mirrors and one of the students answers "At the teapot" which is an example for the convex mirror; however, another student detects the incorrect answer and answers as "Spoon, spoon". This was detection of errors among students to correct them. Although it was not accounted for an implicit metacognitive action of science center educator since he facilitated the discussion, it was a critical point to found a shared understanding among the participants.

SCE3: Where?

Student: At the teapot.

(Other) Student: Spoon, spoon. [Q53, Appendix I]

Similarly, the following excerpt is also showing an example of error detection (plus correction). It was an example used for concluding on the talk under claiming understanding. When the student begins to elaborate on SCE2's question by concluding her previous talk, the student begins to answer by using the incorrect answer. However, at the same time, the student pauses and shows confusion, and SCE2 also supports this detected error and corrects the used concept and the student continues elaborating by using that correct concept.

> *Student: When we squeeze, stagnant air, well…*
>
> *ST1: No (click one's tongue). Moving air.*
>
> *SCE2: Moving air going on. When we squeeze because there is still air in the same way going out.* [Q54, Appendix I]

As another example, SCE3 uttered the following excerpt during the guidance of the exhibition unit "Touch the Spring" in mirrors and light absorption week. It was an example of noticing differences under the monitoring of progress. This was also a sign for science center educator regarding students' current reactions. Most of the students who notice the difference acknowledges that by reacting such as:

> *Student: Whoa! It's down there.* [Q55, Appendix I]

Similarly, the following excerpt is one of the examples for noticing other's correct answer. SCE2, during the guidance of the exhibition unit "Pedal Force" in energy transformation week, asks for other types of energy, which can be observed as energy transformation by exhibition unit and one of the students answers it correctly. After SCE2 confirmed the answer, other students showed a noticing expression:

> *SCE2: What additional energy?*
> *Student: Heat.*
> *SCE2: Heat energy.*
>
> *Students (together): Gorblimey! (=Aaaa!) [Q56, Appendix I]*

The following excerpt is one of the examples of pausing. SCE2 asks for the reason of the shapes which pendulum has been drawing, and after an incorrect answer/answer having comprehension failure / not related to conceptual understanding, SCE2 used pausing for monitoring of progress:

> *SCE2: OK. I applied a force to it; I let it move, didn't I? But, did I make it that way? Students: No.*
>
> *SCE2: How does it provide? SCE2: pause. (for 01.4 seconds)*
>
> *SCE2: pointing to the above springs.* [Q57, Appendix I]

Comprehension monitoring is another central theme, including noticing a lack of comprehension, claiming (partial) understanding, demonstrating comprehension by repeating and demonstrating comprehension by elaborating. Noticing a lack of comprehension contends information required not found, noticing comprehension failure and noticing retrieval failure. The following excerpt is one of the examples of noticing a lack of comprehension (information required not found). SCE2 during the guidance of the exhibition unit "Sand Pendulum" asks students whether they are knowledgeable about vector force before she begins to elaborate on the concept and the ST1 answers as extention of students' metacognition to this question:

> *SCE2: You know the vectors, right? Vector force.*
>
> *ST1: No, no. They don't know them.*
>
> *SCE2: Let's say."* [Q58, Appendix I]

Claiming (partial) understanding is another sub-theme of *comprehension monitoring,* including completing *SCE*'s talk, concluding on talk/observation, questioning information in the talk, and synchronous track of *SCE*'s talk. The following excerpt is one of the examples of claiming understanding (concluding on talk/observation) after SCE2, during the guidance of the exhibition unit "Bernoulli's Ball", demonstrates the working principle of Bernoulli's Ball in relation with the moving and stagnant airs. She asks for the old perfume bottles to students and one of the students concluding on the talk as:

> *Student: When we squeeze, stagnant air, well…*
>
> *ST: No (click one's tongue). Moving air.*
>
> *SCE: Moving air going on. When we squeeze because there is still air in the same way going out.* [Q59, Appendix I]

Demonstrating comprehension by elaborating is another sub-theme of comprehension monitoring, including connecting information to previously known and interpreting. Finally, demonstrating comprehension by repeating is the final sub-theme of comprehension monitoring, including quoting and paraphrasing what *SCE* told. The following excerpt is one of the examples for demonstrating comprehension by elaborating (connecting information to previously known) in energy transformation week at the exhibition unit "Guess Who Wins":

> *SCE1: What will the potential energy turn into when I push it down?*
>
> *ST1: To kinetics energy.* [Q60, Appendix I]

Table 4.16 shows SCEs' implicit monitoring activities per exhibition unit for two lesson units, including work and energy and solar system and beyond. The results showed that during the guidance of "Sand Pendulum", both *SCE*s had a chance to observe claiming understanding of the students. Also, *comprehension monitoring* results revealed higher number of frequencies for SCE2 compared to SCE1 for the same exhibition units. Although students' characteristics might cause the difference between the frequencies, the way of SCEs' instruction given to students might be one of the reasons. Besides, SCE3 had higher frequencies for claiming understanding (CU) and noticing a lack of comprehension (NLC) for Monochrome Room and Color Shadows exhibition units.

Table 4.17 SCEs' implicit metacognitive regulatory actions during the guidance per exhibition unit: Monitoring

SCE	Exhibition unit	Monitoring										
		CM				MP				MSU		
		CU	DCE	DCR	NLC	ED	ND	NOC	P	CS	RQ	SA
SCE1												
	Sand Pendulum	5	0	0	0	0	0	0	0	0	1	0
	Air Bubble Race	6	1	0	0	1	2	0	0	0	0	0
	Hot Air Balloon	4	0	0	2	0	0	0	0	0	0	1
	Bernoulli's Ball	1	0	0	0	0	0	0	0	0	0	0
	3d Sand Pool	1	0	0	1	0	0	0	0	0	0	0
	Press Test	0	0	0	0	0	0	0	0	0	0	0
SCE2												
	Sand Pendulum	12	1	1	8	2	0	0	0	2	0	3
	Air Bubble Race	5	6	0	0	2	1	0	0	1	1	0
	Hot Air Balloon	0	2	2	2	0	0	0	0	0	2	0
	Bernoulli's Ball	5	3	0	5	4	1	0	0	0	0	0
	3d Sand Pool	6	9	1	0	0	0	0	0	2	0	0
	Press Test	2	0	0	2	0	0	0	0	0	0	0
SCE1												
	3d Sand Pool	0	0	0	0	0	0	0	0	0	0	0
	Guess Who Wins	9	1	0	4	2	0	0	0	0	5	1
	Pedal Force	0	2	0	1	0	0	0	0	0	0	0
	Measure Your Power	0	0	0	0	0	0	0	0	0	0	0

Table 4.17 (Cont.) SCEs' implicit metacognitive regulatory actions during the guidance per exhibition unit: Monitoring

SCE	Exhibition unit	Monitoring										
		CM				MP			MSU			
		CU	**DCE**	**DCR**	**NLC**	**ED**	**ND**	**NOC**	**P**	**CS**	**RQ**	**SA**
SCE2												
	3d Sand Pool	4	0	0	3	0	0	0	0	0	0	0
	Guess Who Wins	2	3	0	0	3	0	1	0	0	0	3
	Pedal Force	9	3	1	9	0	0	0	0	0	5	0
	Measure Your Power	0	0	0	0	0	0	0	0	0	0	0
SCE3												
	Color Shadow	11	5	0	10	1	0	0	0	0	8	0
	Countless Color	7	0	0	1	0	0	0	0	0	1	0
	Color Removal	3	6	0	0	1	0	0	0	0	0	0
	Touch the Spring	6	5	0	6	2	5	0	0	0	4	9
	Infinite Views	0	1	0	3	2	0	0	0	0	2	1
	Monochrome Room	13	1	0	7	1	0	0	0	0	2	0

CM: Comprehension monitoring, CU: Claiming understanding, DCE: Demonstrating comprehension by elaboratiing, DCR: Demonstrating comprehension by repeating, NLC: Noticing lack of comprehension, MP:Monitoring of progress, ED: Error detection, ND: Noticing differences, NOC: Noticing others' correct answers, MSU: Monitoring of strategy use, P: Pointing with fingers, CS: Component structuring, RQ: Repeating question, SA: Selective attention

Figure 4.5 shows SCEs' implicit metacognitive activities under sub-themes. The results showed that students refer to concluding on SCEs' talk and synchronous track of SCEs' talk to declare their claiming understanding. Also, students refer to connecting information to their previous knowledge to demonstrate by elaborating. And, they frequently notice comprehension failure compared to other ways of noticing lack of comprehension.

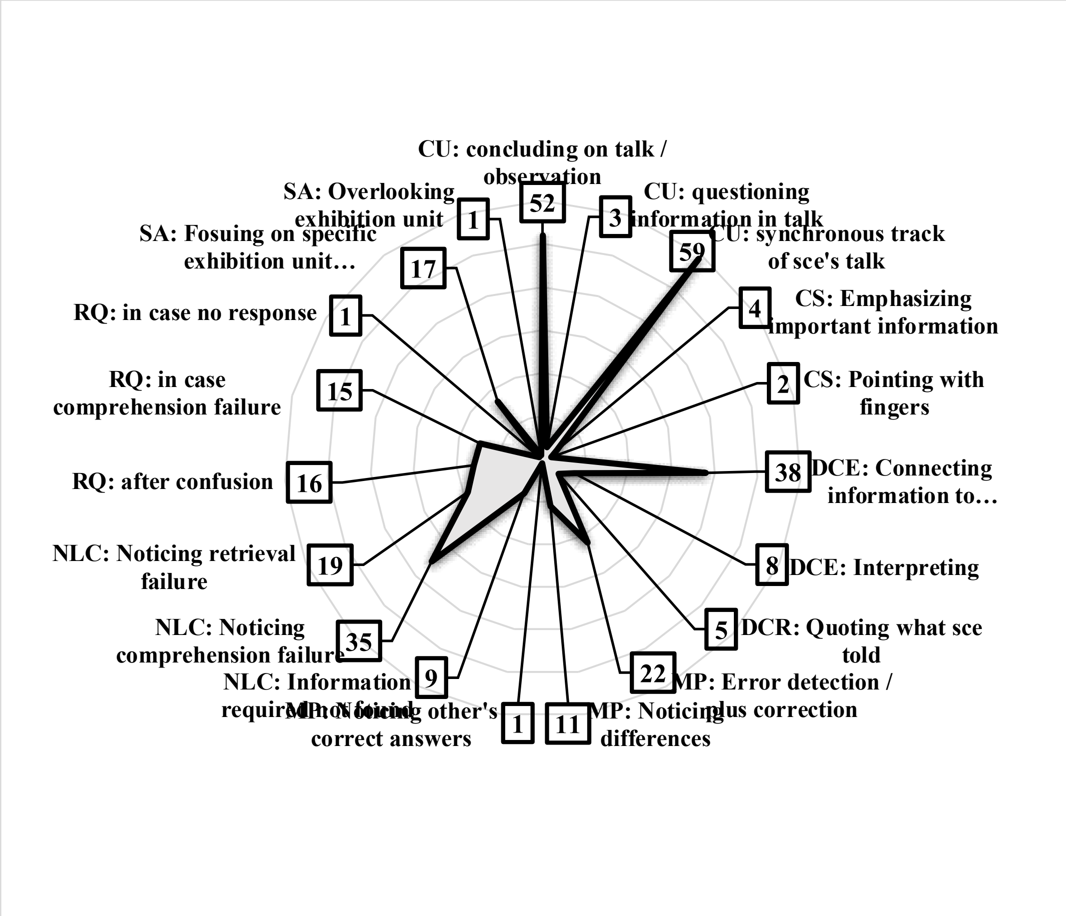


Figure 4.5 SCEs' implicit monitoring activities

On the other hand, Figure 4.6 shows the implicit monitoring activities per the theme. The results show that SCEs had higher opportunities to monitor students' comprehension during guidance. Besides, SCEs use repeating their questions after observing their reactions.

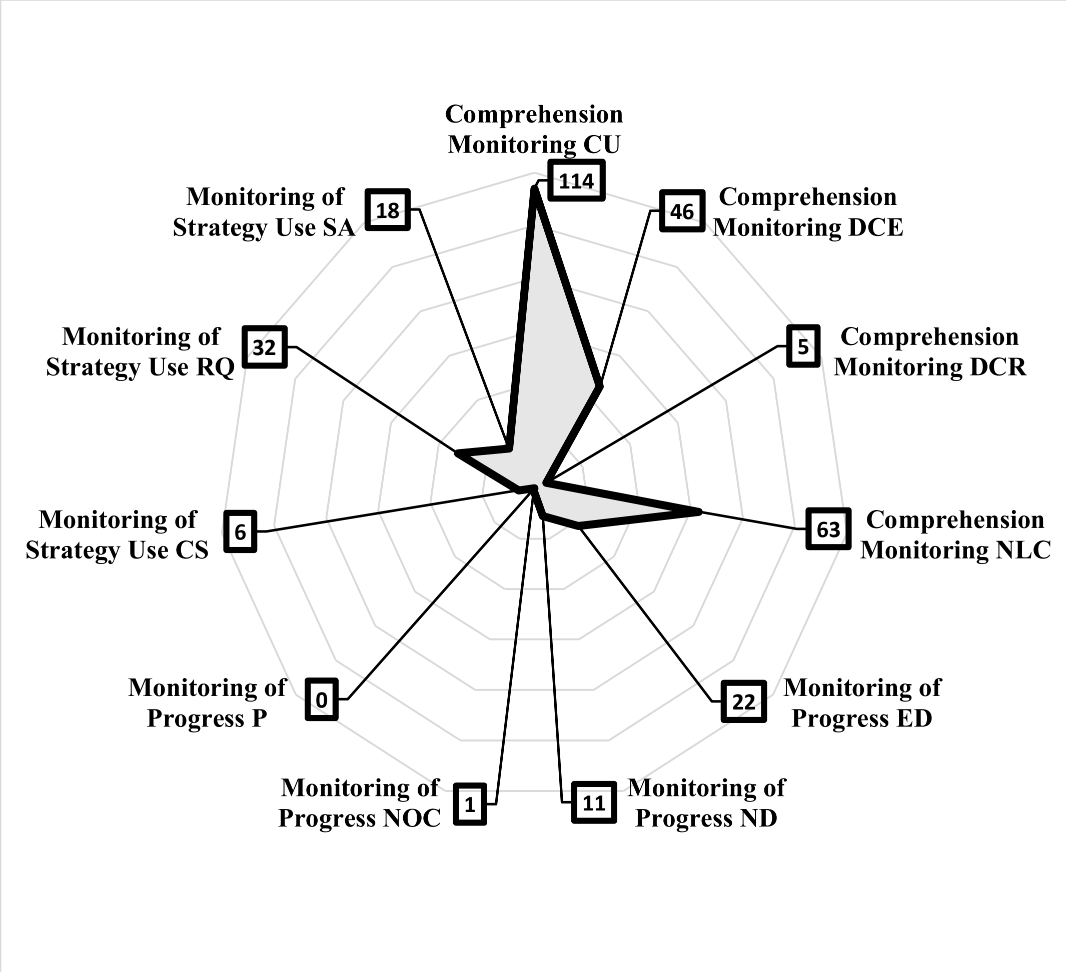


Figure 4.6 SCEs' implicit monitoring activities per the theme

(a) ***Evaluating***: This category refers to the evaluation of the guidance and it revealed two main themes as *checking* and *reflecting*. *Reflecting* contends three sub-themes as reflecting on the learning process/purpose/value, reflecting on previous knowledge and reflecting on talk. The following excerpt is one of the examples for reflecting (on learning process/purpose/value). At the end of the visiting process, SCE3 reflected on it:

> *SCE3: Today, we have toured certain mechanisms here, wandered, as we said later in your free time to come from morning to evening, try to understand what is happening in*

all of them, of course, try to understand the event without disturbing. Try what I do today or what you do, twice, three times, five times. Then, we won't have any limitations. But then, you would not have a narrator. But, as you have already seen for your discovery, there is no book, no narrator, no radio system. There is only information that tells you what is happening with brief information. [Q61, Appendix I]

On the other hand, *checking* contends three sub-themes as the completeness of conceptual definition, correctness of conceptual definition and verification of conceptual definition. Completeness of conceptual definition occurs when *SCE* asks a question to students and their current answer is incomplete for the understanding concept. The following excerpt is one of the examples for the completeness of conceptual definition. After students completed SCE2's talk by a correct expression concerning conceptual understanding during the guidance of the exhibition unit "Air Bubble Race" in force and pressure week:

SCE2: For example, if you drill a hole in the container at three different points from the bottom…

Students: More.

SCE2: More welling, right? Because the pressure applied to it is much more. The pressure applied others decreases with increasing height, making it more difficult to well. [Q62, Appendix I]

Besides, the correctness of conceptual definition occurs when *SCE* asks a question to students and regardless of their completeness if their answer/comment is correct. The above example for completeness of conceptual definition also includes correctness of conceptual definition metacognitive move. Later then, the students completed SCE2's talk as "More.", since the comment was correct, SCE2 commented on it and completed the conceptual definition.

Finally, verification of conceptual definition occurs when *SCE* emphasizes the given examples and verifies them in a different example or way. The following excerpt shows an example of verification of conceptual definition. SCE2, during the guidance of the exhibition unit "Bernoulli's Ball" in force and pressure week, gives an example twice from different fields:

> *SCE: Exactly. Some air is filling in the bottles. What happens when you squeeze when you pump? You're moving, aren't you? Moving air occurs. There was also stagnant air inside. What does that still air freshener do? It pushes towards the side where the pressure is low. Where there is moving air, and thus perfume is released. It is also used in the aircraft wing. If you've noticed, there are propellers, right?*
>
> *Students: Yeah.*
>
> *SCE: On the wing of the plane.*
>
> *Students: Yeah.*
>
> *SCE: There is still air at the bottom and more moving air at the top. What is doing here is less pressure. It pushes its wing from below to the side where the pressure is low. It pushes towards the side where the pressure is low. And so a little plane.*
>
> *Students: It helps.*
>
> *SCE: Help.* [Q63, Appendix I]

Table 4.18 shows the evaluating activities during the guidance per exhibition unit for two lesson units, including work and energy and solar system and beyond. The results revealed that both SCE1 and SCE2 used verification for the conceptual definition for Pedal Force. Besides, SCE3 resulted in a higher number of frequencies for correctness of conceptual understanding for Color Shadows and Monochrome Room.

Table 4.18 SCEs' implicit metacognitive regulatory actions during the guidance per exhibition unit: Evaluating

SCE	Exhibition unit	Evaluating					
		Checking			Reflecting		
		CCD	CCU	VCD	OLP	OPK	OT
SCE1							
	Sand Pendulum	2	3	0	1	0	0
	Air Bubble Race	4	1	0	0	0	0
	Hot Air Balloon	2	2	0	0	1	0
	Bernoulli's Ball	0	0	0	0	0	0
	3d Sand Pool	1	0	0	0	0	0
	Press Test	0	0	1	0	0	0
SCE2							
	Sand Pendulum	6	3	1	0	0	0
	Air Bubble Race	1	8	2	0	1	0
	Hot Air Balloon	1	5	2	0	0	0
	Bernoulli's Ball	1	4	4	0	0	0
	3d Sand Pool	0	6	4	1	1	1
	Press Test	1	0	1	0	0	0
SCE1							
	3d Sand Pool	0	0	0	0	0	0
	Guess Who Wins	4	2	3	0	0	0
	Pedal Force	3	2	5	0	0	0
	Measure Your Power	0	0	0	0	0	0
SCE2							
	3d Sand Pool	4	2	2	1	0	0
	Guess Who Wins	5	3	1	1	0	0
	Pedal Force	8	5	7	0	1	0
	Measure Your Power	0	0	0	1	0	0

Table 4.18 (Cont.) SCEs' implicit metacognitive regulatory actions during the guidance per exhibition unit: Evaluating

SCE	Exhibition unit	Evaluating					
		Checking			Reflecting		
		CCD	CCU	VCD	OLP	OPK	OT
SCE3							
	Color Shadow	10	12	1	3	3	1
	Countless Color	0	2	1	6	0	1
	Color Removal	10	6	0	1	0	0
	Touch the Spring	2	4	0	1	0	0
	Infinite Views	1	3	1	0	0	0
	Monochrome Room	5	17	3	0	1	1

CCD: Checking completeness of conceptual definition, CCU: Checking correctness of conceptual understanding, VCD: Verification of conceptual definition, OLP: Reflecting on learning process, OPK: Reflecting on previous knowledge, OT: Reflecting on talk

Figure 4.7 shows SCEs' implicit evaluating activities. It shows that SCEs frequently checked the correctness of conceptual understanding compared to the completeness of conceptual definition and verification of the conceptual definition. Besides, they reflected on the learning process/purpose/calue at a higher rate compared to reflection on talk and previous knowledge.

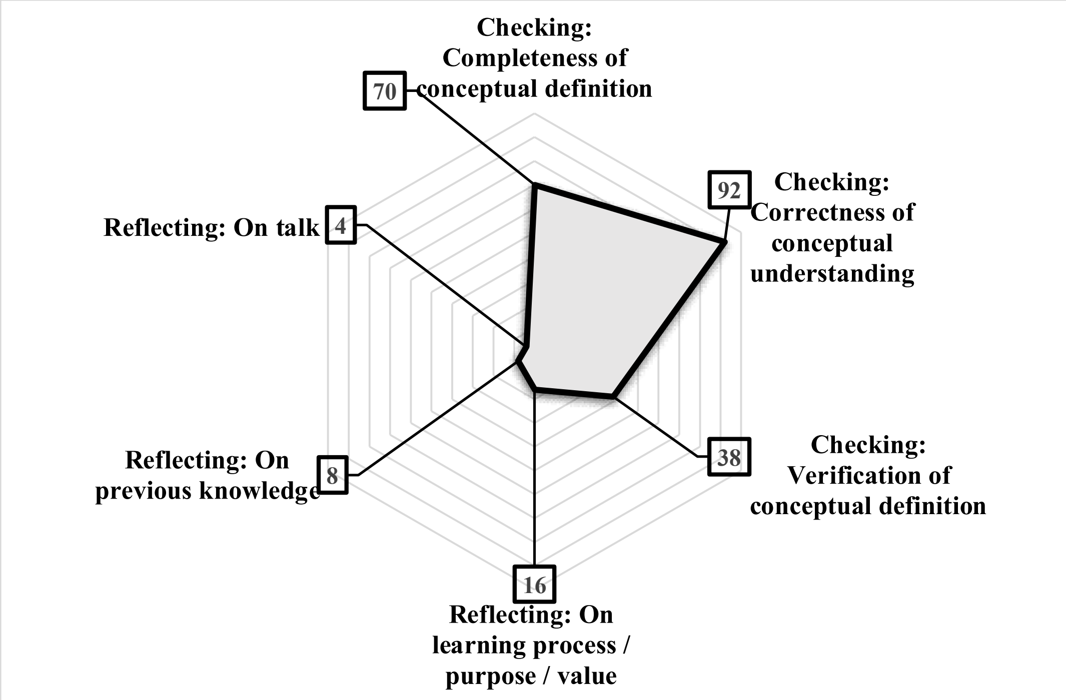


Figure 4.7 SCEs' implicit evaluating activities

Besides, Figure 4.8 shows SCEs' implicit evaluating activities per the theme. The results showed that SCEs frequently refer to checking compared to reflecting.

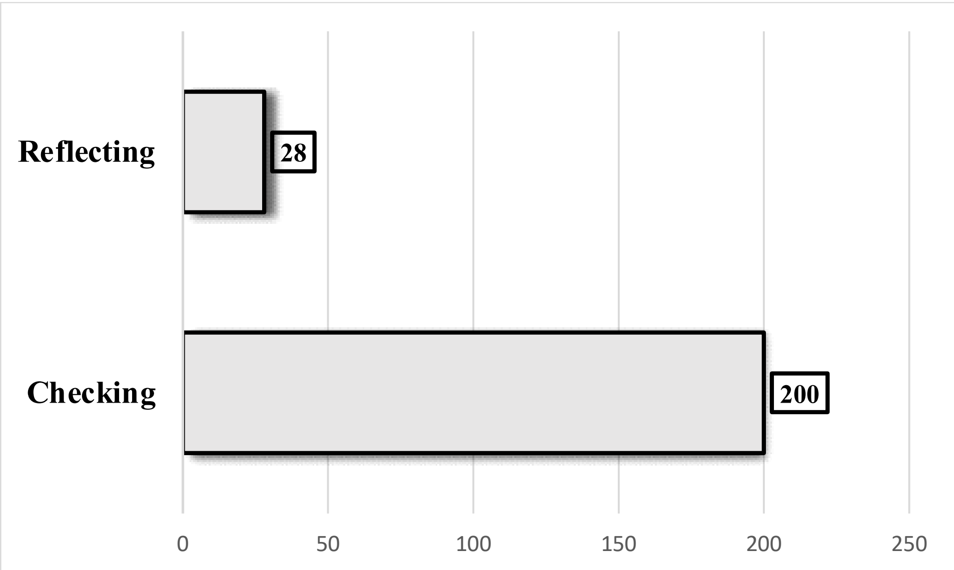


Figure 4.8 SCEs' implicit evaluating activities per the theme

Students' experience of the science center visit during their science lesson hours (RQ2a.i: Baseline Research Question)

This research question aimed at founding a baseline to understand students' science center visit experience after the visit before detecting their levels of conceptual understanding from the conceptual diagnostic papers. Findings from ***guidance science diary*** included the results for this question.

Reminder: Guidance science diary included four weeks of science center visit and 90 students out of 119 delivered their guidance science diaries. 31 of them was for the exhibition units related to the learning objectives of force and pressure, 25 of them was related to energy transformation, 10 of them was related to mirrors and light absorption and 24 of them was related to solar system and beyond in different three cases. Since the work and energy lesson unit covers six weeks of lecture hours, the learning objectives of that unit were divided into two weeks as force and pressure and energy transformation.

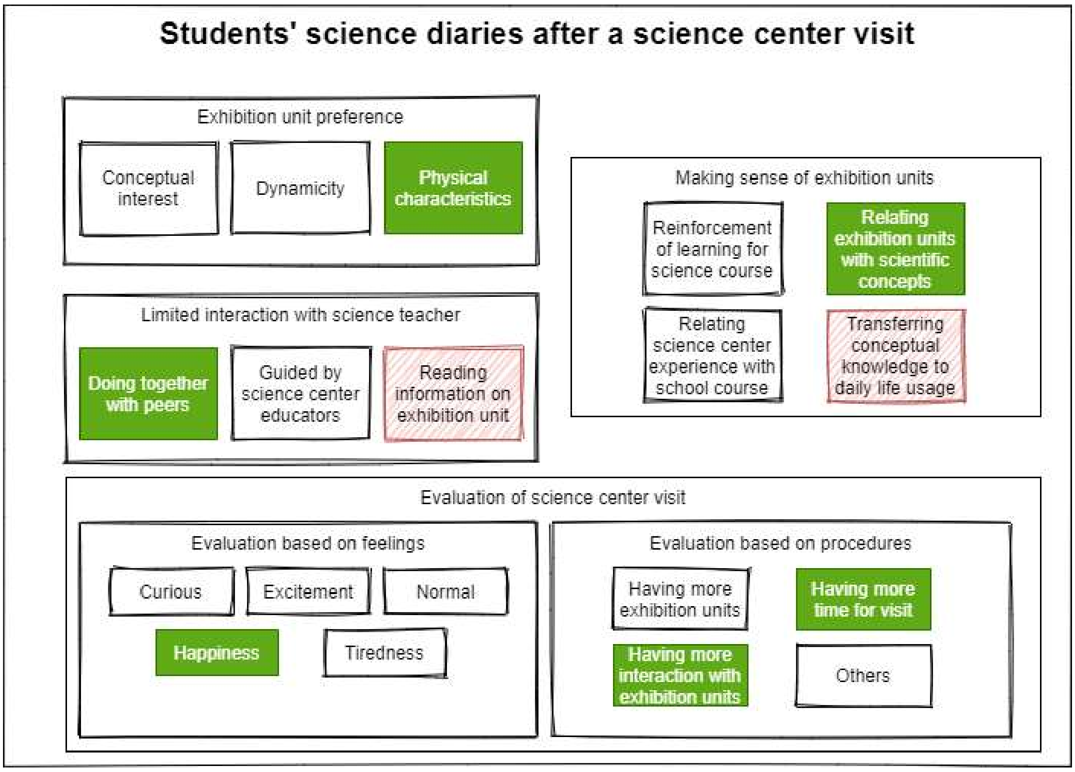


Figure 4.9 Diagram for students' science diaries after science center visit

Table 4.19 shows the conceptualization of students' guidance science diaries after each science center visit. Students' guidance science diaries emerged four main themes as (a) *exhibition unit preference,* (b) *limited interaction with science teacher,* (c) *making sense of exhibition units,* and (d) *evaluation of science center visit.*

(a) ***Exhibition unit preference:*** First of all, 40 students mentioned that they preferred to interact with exhibition units based on their *conceptual interest*, *dynamicity,* and *physical characteristics* of the exhibition units. Overall results showed that although it does not infer a significant difference in students' utterances regarding the physical characteristics of the exhibition units were higher compared to their conceptual interest and dynamicity. This might imply that students mostly preferred to visit exhibition units regarding their physical characteristics.

(b) ***Limited interaction with science teacher:*** Secondly, 67 students out of 90 guidance science diaries mentioned the reasons of their limited or no interaction with science teachers as visiting the exhibition units with peers (*N*=59), guided by science center educators (*N*=32) and listened to them and reading information on exhibition units (*N*=7). Stu.07 mentioned about reading information on exhibition units to learn how to use it at the following reflective writing. However, students did not frequently mention about this compared to doing science center activities with their peers and taking guidance by science center educators.

> *"I did not ask the question to the teacher. Since the names of experiment, purpose, and how to use it were written on the machine with black font."* [Q64, Appendix I]

Table 4.19 Conceptualization of students' science diaries after a science center visit (*N*=90)

Themes and Sub-Themes	Number of students (n)	Frequency of being told (f)
Exhibition unit preference	***40***	***44***
Conceptual interest	*12*	*12*
Dynamicity	*11*	*12*
Physical characteristics	*19*	*20*
Limited interaction with science teacher	***67***	***107***
Doing together with peers	*59*	*67*
Guided by science center educators	*32*	*33*
Reading the information on exhibition unit	*7*	*7*
Making sense of exhibition units	***51***	***145***
Reinforcement of learning for a science course	*25*	*28*
Relating exhibition units with scientific concepts	*35*	*63*
Relating science center experience with school course	*26*	*33*
Transferring conceptual knowledge to daily life usage	*18*	*21*
Evaluation of science center visit	***80***	***120***
Evaluation based on feelings	*72*	*88*
Curious	7	7
Excitement	19	20
Happiness	54	56
Normal	4	4
Tiredness	1	1
Evaluation based on procedures	*25*	*32*
Having more exhibition units	4	4
Having more interaction with exhibition units	16	17
Having more time to visit	9	10
Others	1	1

(a) ***Making sense of exhibition units:*** Students stated ***making sense of exhibition units*** provided them *relating exhibition units with scientific concepts* (*N*=35), *relating science center experience with school course* (*N*=26), *transferring conceptual knowledge daily life usage* (*N*=18), and *reinforcing their science learning* (*N*=25). First of all, results showed that a majority of the students indicated they *relate exhibition units to relevant scientific concepts*. The following excerpt illustrated an example of that Stu.02 used force concept during the making sense of exhibition unit.

> *"For the first experiment, we put the sand into the box tied to the rope and applied force. We applied the first for the first time, but then other ropes pull in their directions and applied force. And the sand was poured down below the box and constituted different shapes."* [Q65, Appendix I]

Similarly, Stu.03 used concepts of pressure and surface area during the making sense of the exhibition unit.

> *"I do not know the name of the experiment, but it was with sand. I confused where pressure increases and decreases at our science classes. But, I know now. For instance, for snowshoes having wide surface area, pressure decreases; but, for heeled shoes having narrow surface area, pressure increases. I do not confuse them anymore."* [Q66, Appendix I]

On the other hand, although some of the students *related the working principle of the exhibition unit with scientific concepts*, they rarely gave detailed answers for this relation. Among the ones having accurate answers for conceptual understanding, there existed no understanding or misconceptions. In the following excerpts, Stu.04 mentioned no understanding and misconception regarding the force and gas pressure concepts respectively.

> *"We saw a pendulum. This pendulum constituted skewed lines. I could not make sense of this experiment."* [Q67, Appendix I]

"If there does not exist hot air in these balloons, they are shrinking. When hot air is filled into it, they are inflating the balloon and raising." [Q68, Appendix I]

Besides, Stu.04 mentioned about her science center visit experience by referring to reinforcement.

"We are visiting every two weeks. It is good to go through the lesson topic for the first week and visit the science center for the second week. This reinforces our learning." [Q69, Appendix I]

Although Stu.04 promoted continuous science center visit experience as supporting reinforcement of learning, the student's first guidance science diary showed that there exists no understanding or misconceptions regarding the force and pressure lesson unit. This was one of the signals that students' guidance science diaries might not be enough to detect their levels of conceptual understanding regarding the associated learning objectives.

In addition to relating exhibition units with concepts, students *transferred their experience to a usable format in daily life*. In the following excerpt, Stu.05 and Stu.06 transferred the science center experience to the daily life usage by *emphatisizing*.

"If radio and light work after pedaling, we have been applying for 75-watt energy. Generating electricity was difficult here. I understood we would not waste electricity in this experiment." [Q70, Appendix I]

"I like very much that exhibition unit having bicycles including light and radio. If we used that one in the parks, it interests people. They listen to music and do sport." [Q71, Appendix I]

Finally, 80 out of 90 students ***evaluated their science center visits*** *based on their feelings* and *procedures* carried out by the science center. 71 students out of 72 who evaluated their experience *based on their feelings* mentioned positive feelings; whereas, one of them mentioned being tired during the visit. Students also mentioned having "more"s regarding science center visit as having more exhibition units (*N*=4), having more time to visit (*N*=9), and having more interaction with exhibition units (*N*=16). Students' written accounts showed that they wanted to have more interaction with exhibition units within the science center visit. The time restriction and group size might be the reason for students' interaction desire. However, the guidance science diary should be investigated regarding separated guidance weeks.

Therefore, when received guidance science diaries divided into four weeks based on their associated learning objectives, the frequencies that sub-themes told by students were shown in Table 4.4. Since force and pressure (FP) and energy transformation (ET) weeks have the same students who visited Feza Gürsey Science Center, the frequencies by weeks may point out probable changes among weeks. Although energy transformation week received fewer science diaries from students (*N*=25) compared to force and pressure week (*N*=31), the frequency for limited interaction with teachers showed increase and students mostly mentioned interaction with their peers during the visit. Stu.01 wrote the following excerpt for *doing interaction with peers*:

> *"Questions I asked my friends were related to names of the exhibition units and the purpose of the experiment. Yet, they were not questions. They were conversations between us. There were exhibition units I showed as well."* [Q72, Appendix I]

In addition to *peer interaction*, less frequency regarding relevant exhibition units with scientific concepts was revealed; whereas, students indicated more examples of *transferring conceptual knowledge to daily life usage* compared to force and pressure week. Although the reason for this might seems like two different weeks, it might be caused by the exhibition unit characteristics in which energy transformation week, there were exhibition nits as models of exemplary requiring empirical inductive reasoning.

Table 4.20 Frequencies being told by students' science diaries after a science center visit for each learning objectives

Themes and Sub-Themes	FP	ET	MLA	SSAB
Exhibition unit preference	***16***	***3***	***6***	***18***
Conceptual interest	9	1	2	7
Dynamicity	2	2	0	1
Physical characteristics	5	0	4	11
Limited interaction with science teacher	***28***	***33***	***9***	***36***
Doing together with peers	16	22	7	22
Guided by science center educators	11	10	2	10
Reading information on exhibition unit	1	2	0	4
Making sense of exhibition units	***71***	***61***	***1***	***0***
Reinforcement of learning for science course	16	12	0	0
Relating exhibition units with scientific concepts	43	20	0	0
Relating science center experience with school course	16	16	1	0
Transferring conceptual knowledge to daily life usage	4	17	0	0
Evaluation of science center visit	***38***	***39***	***10***	***22***
Evaluation based on feelings	20	26	10	22
Curious	2	1	1	3
Excitement	4	5	2	9
Happiness	15	19	7	15
Normal	0	2	1	1
Tiredness	0	0	0	1
Evaluation based on procedures	18	13	0	0
Having more exhibition units	2	2	0	0
Having more interaction with exhibition units	8	9	0	0
Having more time for visit	9	1	0	0
Others	0	1	0	0

Beside force and pressure and energy transformation weeks, students returned back their guidance science diaries for mirrors and light absorption (MLA), and solar system and beyond (SSAB) lesson units did not mention their science center visit experience regarding *making sense of exhibition units.* Therefore, the levels of students' conceptual understanding during their visit needs to be investigated in a different way. To fill this gap, a sheet including students' experience photos taken from the guidance stage was prepared and delivered to them to relate the concepts and the exhibition units.

Changes in scientific conceptual understanding levels for selected concepts of students regarding SCEs' implicit metacognitive actions (RQ2a)

This research question tried to pinpoint the relation between *SCE*s' implicit metacognitive regulatory actions and the level of students' conceptual understanding. Before answering this question, the missing part of the *current practices study,* including students' thoughts related to their science center visit experience, was investigated. Since after students took the guidance, they had a science diary for their science center visit and ***conceptual diagnostic paper*** related to their levels of conceptual understanding for the selected scientific concepts.

Reminder: Conceptual diagnostic paper included four weeks of science center visit, and 101 students out of 119 delivered their conceptual diagnostic papers. Thirty-four of them were for the exhibition units related to the learning objectives of force and pressure, 33 of them were related to energy transformation, 12 of them were related to mirrors and light absorption, and 22 of them was related to the solar system and beyond in different three cases. Since the work and energy lesson unit covers six weeks of lecture hours, the learning objectives of that unit were divided into two weeks as force and pressure and energy transformation.

Correct and Incorrect Use of Concepts

Table 4.21 illustrates the frequencies of correct and incorrect use of the concepts being written at students' conceptual diagnostic papers after the science center visit for the selected exhibition units. The correct and incorrect use of concepts were counted per week: (a) *force and pressure,* (b) *energy transformation,* (c) *mirrors and light absorption,* and (d) *solar system and beyond.*

(a) ***Force and Pressure:*** This week included five exhibition units within the conceptual diagnostic paper. These exhibition units were 3d Sand Pool, Air Bubble Race, Bernoulli's Ball, Hot Air Balloon, and Sand Pendulum. *Force and Pressure* revealed 23 correct use for describing the working principle by using concepts related to 3d Sand Pool ($N_{height} = 1$, $N_{pressure} = 16$, and $N_{surface\ area} = 6$), 46 correct use for Air Bubble Race ($N_{density} = 22$, $N_{liquid\ pressure} = 20$, $N_{height} = 2$, and $N_{force} = 2$), 52 correct use for Bernoulli's Ball ($N_{air} = 29$, $N_{pressure} = 22$, and $N_{force} = 1$), 66 correct use for Hot Air Balloon ($N_{density} = 12$, $N_{pressure} = 19$, $N_{gas} = 12$, $N_{gravity\ force} = 1$, $N_{expansion} = 3$, and $N_{hot\ air} = 19$), and 39 correct use for Sand Pendulum ($N_{force} = 16$, $N_{friction\ force} = 3$, $N_{resultant\ force} = 18$, and $N_{gravity\ force} = 2$) out of 34 students. On the other hand, *Force and Pressure* revealed five incorrect use for describing working principle by using concepts in 3d Sand Pool ($N_{layer} = 20$, $N_{physical\ map} = 2$, and $N_{weight} = 2$), one incorrect use for Air Bubble Race ($N_{wind} = 1$), one incorrect use for Bernoulli's Ball ($N_{layer} = 1$), one incorrect use for Hot Air Baloon ($N_{force} = 1$), and eight incorrect use for Sand Pendulum ($N_{pressure} = 6$ and $N_{weight} = 2$).

(b) ***Energy Transformation:*** This week included four exhibition units within the conceptual diagnostic paper. They were 3d Sand Pool, Guess Who Wins, Measure Your Power, and Pedal Force. *Energy Transformation* revealed 18 correct use for describing the working principles by using concepts in 3d Sand Pool ($N_{energy} = 10$, $N_{mass} = 5$, and $N_{weight} = 3$), 38 correct use of concepts in Measure Your Power ($N_{gravitational\ potential\ energy} = 3$, $N_{kinetic\ energy} = 16$, $N_{force} = 10$, $N_{energy} = 5$, $N_{pressure} = 3$, $N_{work} = 2$, and $N_{air\ energy} = 1$), 40 correct use of concepts in Guess Who Wins ($N_{potential\ energy} = 9$, $N_{kinetic\ energy} = 10$, $N_{force} = 2$, $N_{mass} = 6$, and $N_{weight} = 10$) and 78 correct use of concepts in Pedal Force ($N_{kinetic\ energy} = 15$, $N_{force} = 7$, $N_{energy} = 35$, $N_{electrical\ energy} = 9$, $N_{work} = 3$, and $N_{energy\ transformation} = 9$) out of 33 students. On the other hands, *Energy Transformation* revealed three incorrect use for describing working principles by using concepts in 3d Sand Pool ($N_{force} = 1$, $N_{height} = 1$, and $N_{pressure} = 1$), six incorrect use of concepts in Guess Who Wins ($N_{force} = 1$, $N_{weight} = 2$, and $N_{pressure} = 3$), 40 correct use of concepts in Measure Your Power ($N_{electrical\ energy} = 1$, $N_{friction} = 1$, and $N_{pressure} = 1$) and three incorrect use of concepts in Pedal Force ($N_{friction} = 2$, and $N_{savings} = 1$).

(c) ***Mirrors and Light Absorption:*** This week included three exhibition units within the conceptual diagnostic paper. They were Countless Color, Monochrome Room, and Touch the Spring. *Mirrors and Light Absorption* revealed 14 correct use for describing working principles by using concepts in Countless Color ($N_{color} = 10$, $N_{light} = 3$, and $N_{light\ reflection} = 1$), 16 correct use of concepts in Monochrome Room ($N_{absorption} = 2$, $N_{color} = 8$, $N_{frequency} = 1$, $N_{light\ reflection} = 3$, $N_{light\ refraction} = 1$, and $N_{white\ light} = 1$), and 17 correct use of concepts in Touch the Spring ($N_{concave\ mirror} = 1$, $N_{mirror} = 8$, and $N_{reflection} = 8$) out of 12 students. On the other hand, *Mirrors and Light Absorption* did not reveal any incorrect use of concepts.

(d) ***Solar System and Beyond:*** This week included four exhibition units within the conceptual diagnostic paper. They were Constellation Viewer, Gravity Well, Solar System Model, and Summer Sun / Winter Sun. *Solar System and Beyond* revealed 38 correct use for describing working principles by using concepts in Constellation Viewer ($N_{constellation} = 21$, and $N_{star} = 17$), 48 correct use of concepts in Gravity Well ($N_{distance\ to\ sun} = 2$, $N_{black\ hole} = 16$, $N_{gravitational\ force} = 17$, $N_{planets} = 6$, and $N_{solar\ system} = 1$), 49 correct use of concepts in Solar System Model ($N_{distance\ to\ sun} = 12$, $N_{planets} = 22$, and $N_{solar\ system} = 15$), and 41 Summer Sun Winter Sun ($N_{axial\ tilt} = 17$, $N_{distance\ to\ sun} = 16$, $N_{heatness} = 3$, and $N_{seasons} = 5$) out of 22 students. On the other hand, *Solar System and Beyond* revealed one incorrect use for describing working principles by using concepts in Summer Sun Winter Sun ($N_{galaxy} = 1$).

Table 4.21 Frequencies of correct and incorrect use of concepts being told by students' conceptual diagnostic paper after a science center visit for selected exhibition units

Themes and Sub-Themes	Correct Use of Concepts	Incorrect Use of Concepts
Force and Pressure	***(n=34) 226***	***(n=14) 16***
3d Sand Pool	23	5
Air Bubble Race	46	1
Bernoulli's Ball	52	1
Hot Air Balloon	66	1
Sand Pendulum	39	8
Energy Transformation	***(n=33) 174***	***(n=11) 15***
3d Sand Pool	18	3
Guess Who Wins	38	6
Measure Your Power	40	3
Pedal Force	78	3
Mirrors and Light Absorption	***(n=11) 47***	***(n=0) 0***
Countless Color	14	0
Monochrome Room	16	0
Touch the Spring	17	0
Solar System and Beyond	***(n=22) 176***	***(n=1) 1***
Constellation Viewer	38	0
Gravity Well	48	0
Solar System Model	49	0
Summer Sun Winter Sun	41	1

Revealed results showed that students frequently used concepts related to the exhibition units about their science center visit experience. For example, for 3d Sand Pool, students used *pressure* and *surface area* concepts frequently. Similarly, for Air Bubble Race, students used *density* and *liquid pressure* frequently when the height of liquids within tubes is the same. Also, students did not refer to *force* repeatedly, which could be used as a baseline term to push the pomp to make exhibition unit work. Moreover, for Bernoulli's Ball, students used *air* and *pressure* concepts which were frequently used by the science center educator during the guidance period; however, similar to used concepts for Air Bubble Race, used concepts seem to be embedded in the exhibition unit obviously as *air* and uttered by science center educator in an explicit way as *pressure*. Similar to previous concepts used during elaborating on the working principles of exhibition units, concepts used for Hot Air Balloon and Sand Pendulum were frequently uttered concepts during the guidance phase. For instance, *friction force* which could be used as a concept for Sand Pendulum to describe why the pendulum gets slower throughout the time, was not mentioned by students frequently. To sum up, the correct and incorrect use of concepts showed that the exhibition unit characteristics might foster students' conceptual understanding and make it easier to connect the working principle with the concepts which they are currently engaged in. On the other hand, keywords used during the guidance period by science center educator and students' immediate answers for elaboration during the guidance period might also be another important factor in shaping students' conceptual understanding.

The Levels of Students' Conceptual Understanding

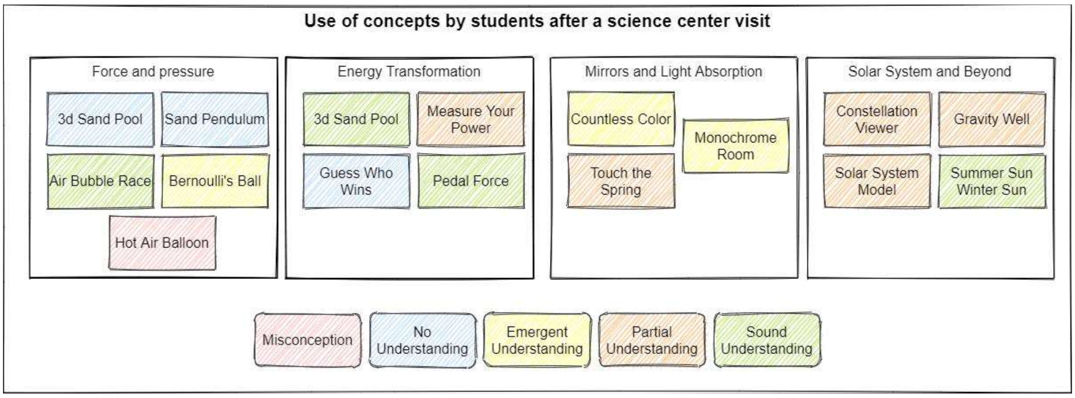


Figure 4.10 Diagram for use of concepts by students after a science center visit showing the associated exhibition units to the levels of students' conceptual understanding

The levels of students' conceptual understanding refer to what extent students used scientific concepts. Table 4.22 shows the number of students who demonstrated various levels of conceptual understanding for each lesson subject.

Table 4.22 Frequencies of the number of students' conceptual understanding written within students' conceptual diagnostic paper after the science center visit for the selected exhibition units

Exhibition Units	Conceptual Understanding				
	Misconception	No Understand	Emergent Understand	Partial Understand	Sound Understand
Force and Pressure					
3d Sand Pool	3	19	0	5	8
Air Bubble Race	1	12	3	8	10
Bernoulli's Ball	2	7	11	3	8
Hot Air Balloon	9	4	3	13	6
Sand Pendulum	2	17	0	12	3
Energy Transformation					
3d Sand Pool	2	0	1	4	5
Guess Who Wins	3	11	0	14	2
Measure Your Power	2	5	8	15	5
Pedal Force	2	3	2	11	12
Mirrors and Light					
Absorption					
Countless Color	1	3	8	0	0
Monochrome Room	1	5	5	1	0
Touch the Spring	0	1	2	8	1
Solar System and Beyond					
Constellation Viewer	0	0	1	16	5
Gravity Well	1	2	5	11	5
Solar System Model	1	0	0	13	9
Summer Sun Winter Sun	5	2	2	0	13

(a) ***Force and Pressure:*** This week included five exhibition units as 3d Sand Pool, Air Bubble Race, Bernoulli's Ball, Hot Air Balloon, and Sand Pendulum. Results showed that students' misconceptions under *Force and Pressure* revealed three references for 3d Sand Pool, one reference for Air Bubble Race, two references for Bernoulli's Ball, nine references for Hot Air Balloon and two references for Sand Pendulum. Moreover, students' level of conceptual understanding considering no understanding had 19 references for 3d Sand Pool, 12 references for Air Bubble Race, seven references for

Bernoulli's Ball, four references for Hot Air Balloon and 17 references for Sand Pendulum. On the other hand, the emergent understanding was revealed for zero times for 3d Sand Pool, three times for Air Bubble Race, 11 times for Bernoulli's Ball, three times for Hot Air Balloon and zero times for Sand Pendulum. And, the partial understanding was revealed three times for 3d Sand Pool, eight times for Air Bubble Race, five times for Bernoulli's Ball, 13 times for Hot Air Balloon and 12 times for Sand Pendulum. Finally, students showed sound understanding for eight times in 3d Sand Pool, for ten times in Air Bubble Race, for eight times in Bernoulli's Ball, for six times in Hot Air Balloon and for three times in Sand Pendulum. Table 4.23 shows example excerpts for each exhibition unit of Force and Pressure guidance week about the levels of students' conceptual understanding.

Table 4.23 Example excerpts to fit the levels of conceptual understanding being written by students' conceptual diagnostic paper after the science center visit for Force and Pressure week

Exhibition Units	**Conceptual Understanding**				
	Misconception	**No Understanding**	**Emergent Understanding**	**Partial Understanding**	**Sound Understanding**
3d Sand Pool	The weight increases from the equator to the poles because when we add more blue sand over the sand, the weight increases.	High places are light brown, mediums are white, and sea-level is seen in blue color.	-	We collected the sand in one place and applied pressure according to the surface area.	When pressing with one finger, the pressure is high as the surface area is small. The pressure decreases because the surface area is large when pressed with the palm.
Air Bubble Race	Whichever gets denser, it goes up faster.	The first one has only water. The second is water and glycerin. The third is glycerin. The biggest bubble appeared in glycerin.	They apply force to the pipes consisting of water, glycerin with water, and glycerin and create bubbles.	We tried how the bubbles came out with the pressure we applied. We saw the fluid pressure.	The first chamber contains water. The second chamber contains glycerin, the third chamber contains water and glycerin. Glycerin moves more slowly because it has a higher density. The density of the glycerin with water is moderate and slower to medium. Because the density of water is less, it is faster.
Bernoulli's Ball	With the pressure of the air, the ball went even higher, so the higher the air, the higher the pressure.	It's showing the gas pressure.	The air from below kept the ball up and pulled to itself.	The stagnant air keeps him out.	Since the air blown from the pipe is moving, the inert air pushes the ball towards the moving air. Therefore, the ball remains in control of the air in the pipe.
Hot Air Balloon	A balloon with a decreasing density descends. However, the balloon with an increasing density goes up.	The balloon inflates as the air is released, just like in Cappadocia.	Rise of the balloon with fire from below.	The density of the heated air decreases. As the density decreases, the balloon goes up.	As the gas heats up, the density expands, and the balloon flies up.
Sand Pendulum	When we leave it at a certain point, it's distributing because of the weight.	When the sand is placed in the pendulum connected by the ropes, the pendulum is pushed, and the sand flowing through the hole moves in certain directions and draws certain shapes.	-	With the result of the resultant force, the sand moved flat.	The rope draws a shape in the direction of the force applied and stops by the friction of the air.

(a) ***Energy Transformation:*** This week included four exhibition units as 3d Sand Pool, Guess Who Wins, Measure Your Power, and Pedal Force. Results showed that misconception under *Energy Transformation* revealed two references for 3d Sand Pool, three references for Guess Who Wins, two references for Measure Your Power, and two references for Pedal Force. On the other hand, no understanding level revealed zero references for 3d Sand Pool, 11 references for Guess Who Wins, five references for Measure Your Power, and three references for Pedal Force; whereas, emergent understanding level revealed on reference for 3d Sand Pool, zero references for Guess Who Wins, eight references for Measure Your Power, and two references for Pedal Force; partial understanding level revealed four references for 3d Sand Pool, 14 references for Guess Who Wins, 15 references for Measure Your Power, and 12 references for Pedal Force. Table 4.24 shows the example excerpts for each exhibition unit of Energy Transformation guidance week about levels of students' conceptual understanding.

Table 4.24 Example excerpts to fit the levels of conceptual understanding being written by students' conceptual diagnostic paper after the science center visit for Energy Transformation week

Exhibition Units	**Conceptual Understanding**				
	Misconception	**No Understanding**	**Emergent Understanding**	**Partial Understanding**	**Sound Understanding**
3d Sand Pool	-	High places, low places, and sea levels have been shown. Besides, the distance has a different color, but when we press the sand for example, we sink into our hands and make pressure.	We throw the balls and understand, which is heavy and light.	Types of energy and what the energy depends on. We threw the ball at the same height and observed three different masses. In one, we compared the same mass balls with different heights.	We saw that the balls with the same mass of the balls having the same heights opened a deeper pit in the sand. When the balls with higher gravitational potential energy (height) and more mass were thrown from the same height, the ball with more mass opened a deeper pit in the sand.
Pedal Force	When the pedals are turned, the frictional force is converted into light in the lamp and sound energy on the radio.	We've saved money by turning low-cost and slow lights and sounds. Saving.	The radio is running at 75 volts. Volts increase as you pedal.	With the energy generated by pedaling, we lit the bulb and turned on the radio as we turn the pedal, the mechanism inside turns and generates electricity.	Turning the pedals turned on the sound and the lights of the bulb, which is about working with energy. By applying force to the pedals, it makes the bulb and sound come in.
Guess Who Wins	Here we saw the effect of the distribution of weights on rounds of the same weights. The weight of the given round went faster because the pressure on the ground was less.	One was heavy, one was light, and the two went faster, leaving the lighter. Which is fast or which is slow. We learned it.	-	We left the circles of the same weight from the same height, which of them first went down. The weight of the ball that has been revealed has come down faster than the car tire.	Velocities of masses according to their distribution. Circles left in the same place were converted from gravitational potential energy to kinetic energy.
Measure Your Power	This machine features up to horsepower. Separation of air molecules into the air.	Make the ball go up to electrical equipment. Observe the operation of the electric device by turning the ball there	We turned the propeller and rotated the pedals to vent the ball. We turn the pedal, the vent is spinning, and the ball flies.	Motion energy is transferred to the air energy to move the ball up. The pedal turns the ball up	The force of the ball by turning the pedals into the air. Motion energy is converted into gas particles and gravitational potential energy by venting.

(a) ***Mirrors and Light Absorption:*** This week included three exhibition units as Countless Color, Monochrome Room, and Touch the Spring. Results showed that misconception revealed one reference for Countless Color, one reference for Monochrome Room, and zero references for Touch Spring; whereas, no understanding level revealed three references for Countless Color, five references for Monochrome Room, and one reference for Touch the Spring. Also, the emergent understanding level revealed eight references for Countless Color, five references for Monochrome Room, and one reference for Touch the Spring. And, partial understanding level revealed zero references for Countless Color, one reference for Monochrome Room, and eight references for Touch the Spring. Finally, sound understanding level revealed zero references for Countless Color, zero references for Monochrome Room, and one reference for Touch the Spring. Table 4.25 shows the example excerpts for each exhibition unit of Mirrors and Light Absorption guidance week about levels of students' conceptual understanding.

Table 4.25 Example excerpts to fit the levels of conceptual understanding being written by students' conceptual diagnostic paper after the science center visit for Mirrors and Light Absorption week

Exhibition Units	Conceptual Understanding				
	Misconception	No Understanding	Emergent Understanding	Partial Understanding	Sound Understanding
Countless Color	I understood the reflection of the light better. Colorful clothes appear in colorful light. White clothes appear in white light.	When something comes in front of the beam, the colors are scattering, and I see blue, green and red.	There were color mixes. We have made the colors we want.	-	-
Monochrome Room	I have observed that the objects reflect their own light.	There we all had purple lips. And our clothes changed in color.	The room would be monochrome when the lights were off because the clothes that were on the filter inside did not give their color and would appear monochrome. It was nice. There were other toys inside. Even when they were colorful, it looked just one color. It was beautiful. I observed the colors.	The red outfit appeared in its color. The frequency was appropriate.	-
Touch the Spring	-	It was very nice, but I couldn't touch it.	Touch the spring exhibition unit was nice, we tried to touch the spring, but we couldn't touch it because there was no spring. It was like, but when we looked through the glass, we saw that the spring was under the board, and when I touched for the second time, I held the spring.	Touch the spring exhibition unit was very nice. I touched the spring, and it had a fool. The spring was reflected with the help of the mirror.	Thanks to the concave mirror, I saw the spring large and reverse.

(a) ***Solar System and Beyond:*** This week included four exhibition units as Constellation Viewer, Gravity Well, Solar System Model, and Summer Sun / Winter Sun. First of all, misconception revealed zero references for Constellation Viewer, one reference for Gravity Well, one reference for Solar System Model, and five references for Summer Sun Winter Sun; whereas, no understanding level revealed zero reference for Constellation Viewer, two references for Gravity Well, zero references for Solar System Model, and two references for Summer Sun Winter Sun. Also, emergent understanding level revealed one reference for Constellation Viewer, five references for Gravity Well, zero references for Solar System Model, and two references for Summer Sun Winter Sun; whereas, partial understanding level revealed 16 references for Constellation Viewer, 11 references for Gravity Well, 13 references for Solar System Model, and zero references for Summer Sun / Winter Sun. Finally, sound understanding level revealed five references for Constellation Viewer, five references for Gravity Well, nine references for Solar System Model, and 13 references for Summer Sun Winter Sun. Table 4.26 shows the example excerpts for each exhibition unit of Solar System and Beyond guidance week about levels of students' conceptual understanding.

Table 4.26 Example excerpts to fit the levels of conceptual understanding being written by students' conceptual diagnostic paper after the science center visit for Solar System and Beyond week

Exhibition Units	Conceptual Understanding				
	Misconception	No Understanding	Emergent Understanding	Partial Understanding	Sound Understanding
Gravity Well	Planets in the solar system revolve around the black hole.	Acceleration of the ball as it moves down.	There was a well in the ground plane, and the ball rolled there, and after a while, we saw it fall into the well. A ball was left in the gravity well, and the gravity moved on the ball, causing it to fall into the well.	The proximity of the planets in the solar system to the sun, is directly proportional to the rotation speed. The planets in the solar system have a greater gravitational force than the other planets.	With the force of gravity, I saw the objects being drawn into the well. I observed that a ball in the gravity well spins over the object for a long time and then falls into the well after a while.
Constellation Viewer	-	-	First, I wondered what it worked for, and then I tried. It's about the merger of stars.	We saw the stars unite and form a shape. The stars merged with each other to form the big bear constellation.	I saw the stars coming side by side to form constellations. I have made it clear that we cannot understand the distances of stars in constellations according to their dimmer or luminosity.
Solar System Model	Mercury is the largest planet in the solar system, and Jupiter is the smallest planet.	-	-	I observed the distance of the planets to the sun. We observed the properties of the planets in the solar system.	The planets in the solar system have seen their distance from the sun, eight planets. We have seen the planets in the solar system, their distance from the sun, their size, and which planets have rings.
Summer Sun Winter Sun	In our world, because the axis is inclined, we saw that the summer is closer to the sun, and the winter is farther away from the sun and warmer. It shows that the inclination of the axis is closer to the sun in summer and farther away in winter.	Clock by summer Clock by winter	In summer and winter, I saw what percentage of the sun we use. I saw the distance and proximity of sunlight in summer and winter.	-	Since the earth inclines the axis, we have seen that in winter, it is closer to the sun, and in summer, it is farther and warmer. We saw the inclination of the axis to be farther in winter and warmer in summer.

4.3.2 Collaboration Phase

Reminder: The collaboration phase is the second phase of the multiple case study. It refers to the collaborative work of seventh-grade students while they are answering the questions on the worksheets given to them during their mutual work. Students were paired based on their gender and proximity within the class. And, the pairs were brought to the science center by a school bus within their available hours by getting the permission from the school management, the teacher, and their parents. Students were transferred in pairs not to make them wait for other students. They were informed about the collaborative work before they began. And, they wore eye tracking glasses and their eyes were calibrated. Then, they worked collaboratively for approximately one hour. After their collaborative session ended, the pairs were interviewed regarding their collaborative work. Then, students were brought to the school back.

A total of 30 pairs (since 4 pairs and two individuals of them were excluded during the results) participated in the collaboration phase for three cases. The cases divided into three lesson units as "Work and Energy", "Mirrors and Light Absorption", and "Solar System and Beyond". Firstly, "***work and energy***" lesson unit divided into two weeks due to its demanding lesson objectives in align with the guidance phase. A total of seven matched-pairs and two individuals (one girl, one boy) participated in the collaborative work for "***work and energy***" for two weeks after the guidance period. Thus, one pair of this lesson unit participated for two times. Second, for "***mirrors and light absorption***" lesson unit, a total of 16 pairs (four pairs were excluded from the results) from two difference schools participated in the collaborative work. Finally, for "***solar system and beyond***" lesson unit, a total of 12 matched-pairs from one class participated in the collaborative work. Therefore, analysis for the collaboration phase includes a total of 30 pairs with 60 individual students. The data were gathered through written worksheets during the collaborative work, first-eye video recording by eye glasses, second-eye video camera recording, and voice recordings of retrospective interviews.

Students' Individual and Inter-individual Metacognitive Processes (RQ3-RQ4)

Although the data analysis was performed by taking one peer as a unit of analysis (Figure 4.11), since each peer has interaction with other peer and the environment, their individual and inter-individual metacognitive actions were determined based on the single unit.

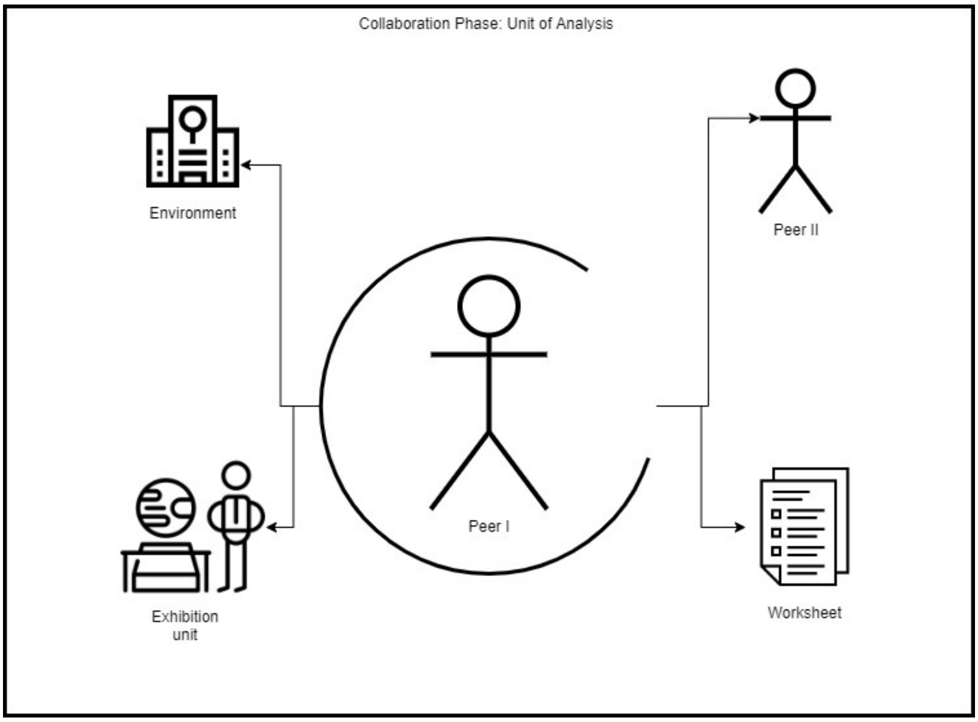


Figure 4.11 Schema of the unit of analysis for the collaboration phase

To give an overall look considering each lesson unit for the associated metacognitive processes, Table 4.27 illustrates the frequencies for each lesson unit. When it is examined regarding each unit, actions related to monitoring process had the highest frequencies during the collaborative activity, while planning and evaluating had the lowest frequencies. The results shows that although six student pairs were available for the *work and energy* lesson unit, the observed frequencies were higher for this lesson unit associated with the metacognitive categories.

Table 4.27 The number of frequencies being observed based on lesson units

Categories	Units	Number of Pairs	Frequency of being observed
Orientating		**30**	**4396**
	Work and Energy	6	992
	Solar System and Beyond	12	1525
	Mirrors and Light Absorption	12	1879
Planning		**30**	**980**
	Work and Energy	6	352
	Solar System and Beyond	12	303
	Mirrors and Light Absorption	12	325
Monitoring		**30**	**4712**
	Work and Energy	6	1502
	Solar System and Beyond	12	1314
	Mirrors and Light Absorption	12	1896
Evaluating		**30**	**1078**
	Work and Energy	6	275
	Solar System and Beyond	12	372
	Mirrors and Light Absorption	12	431

Table 4.27 illustrates that the lesson units may also result in differences for the frequencies of the associated metacognitive processes. Figure 4.12 summarizes the frequencies for the students' actions related to metacognitive processes during collaborative activity based on the lesson units. It shows that while work and energy lesson unit had the highest frequencies for each metacognitive category, solar system and beyond had the lowest frequencies.

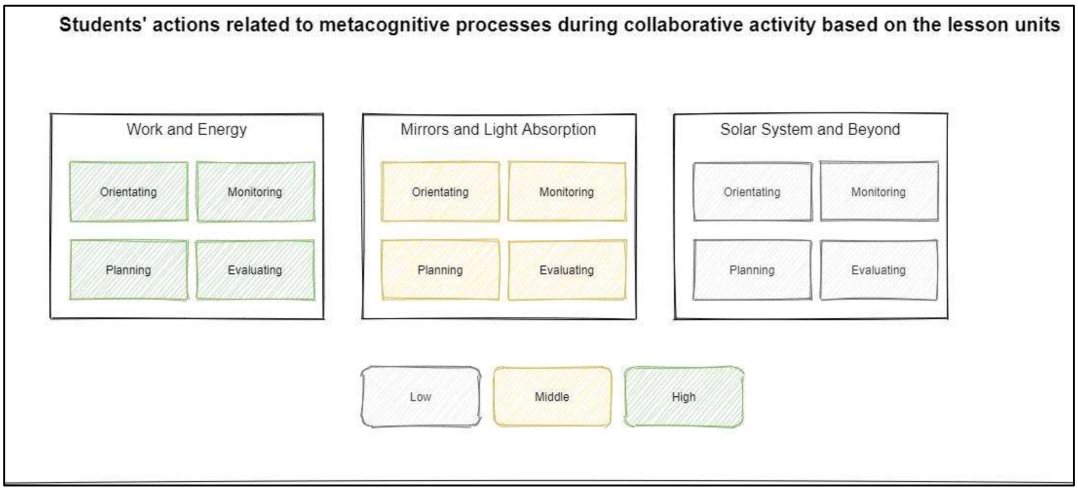


Figure 4.12 Diagram for the students' actions related to metacognitive processes during collaborative activity based on the lesson units

Before giving the details for students' metacognitive actions during the collaborative work, a compete diagram of students' metacognitive actions will illustrate the most prominent findings by providing a holistic overlook. Figure 4.13 shows that *distributing role of duties* under ***planning in advance*** and ***interim planning*** had high frequencies during students' planning actions. This might refer to students prefer to distribute the role of duties before take an action by defining each of the roles as acting (who is engaging with the exhibition unit), following (who is following the other pair's actions and verbal accounts), leading (who leads for that instant during the collaborative activity), writing (who takes the pen and takes note on the worksheet), and switching role (which needs a direct interaction and common agreement between two pairs). Also, switching role under *distributing role of duties* had higher frequencies which may refer to students need to switch the roles by adapting the current environmental changes (including person-related factors (tiredness of writing, need to give spot to other friend), task-related factors (non-accessable material characteristic), environment-related factors (need to find the direction related to the answer)).

On the other hand, students showed higher frequencies for *claiming understanding* by *concluding on exhibition unit* frequently during the ***comprehension monitoring***.

This may refer to students conclude on exhibition unit rather than questioning on the exhibition unit if it provides a clear understanding and match with the related scientific concepts. Moreoever, students mostly showed *demonstrating comprehension by questioning* during they were not looking at the exhibition units. Moreoever, during the collaborative pairs ***monitor of their strategy use***, *adapting pace* and *repeating after confusion* had higher frequencies for adapting strategy use. The higher frequency for *adapting pace* may refer to need for calibrating the movements between the students. Also, collaborative pairs frequently referred to *repeating after confusion* for the *adapting strategy use.* This may mean that students repeated the actions, read information, read question, or given answer by other peer to adapt their strategy use during they were trying to understand the issue conceptually. Also, students used *looking for key components* and *highlighting important information* actions during their structuring the component and the text frequently. This may refer that collaborative pairs mostly focus on detecting the related information or component during answering the questions. Similarly to this, collaborative pairs referred *focusing on specific exhibition unit component.* As a final highlighted metacognitive action, students *reflected on progress* for their *collaborative activity.* This may refer that students made their steps in align with the collaborative pair during the activity. And, it seems from the field notes that, student pairs who had higher level of collaboration reflected on the progress for their collaborative activity.

In the collaboration phase, although ***evaluating*** is an important leg of the students' metacognitive actions during their collaborative activity, students demonstrated low frequencies in evaluating actions. However, the most observable result had the lower frequency included the *checking correctness of conceptual understanding.* Indeed, students used *checking completeness of the conceptual understanding/definition* in higher frequencies compared to the correctness of conceptual understanding. This may refer that students passed to the other question without verifying it.

As a final summary of the diagram in Figure 4.10, *self-*, *other-*, *shared-*, and *non-access* metacognition emerged in a time-based manner throughout the collaborative activity. From the field notes, and notes taken during the video analysis, although each student group was paired based on their gender and proximity within the class, at the beginning of the collaborative activity they refer to metacognitive actions which are based on the self-point of views. In a timely manner, especially students who were collaborative pairs from low performer students in science courses, showed metacognitive actions related to other-perspective. However, the students who were believed as low performers (regarding their grades and teacher's statement) showed no signal regarding the metacognitive actions. Although these students were exposed to the guidance tour for the prior knowledge and showed conceptual understanding on the diagnostic paper test after the science center visit, they had difficulties to verbally define their prior self-experiences and understand other's verbal accounts. This might refer to a non-access (suspended) metacognition in which students do not have any awareness for the definition of either self or other's metacognitive actions. However, they frequently used pointing behaviors and repeating after confusion actions, although they could not verbalize their metacognitive experiences and connect them with their previous experience. Finally, shared metacognitive actions occur when collaborative pairs shared a common ground when the higher level of conceptual understanding occurred among the pairs.

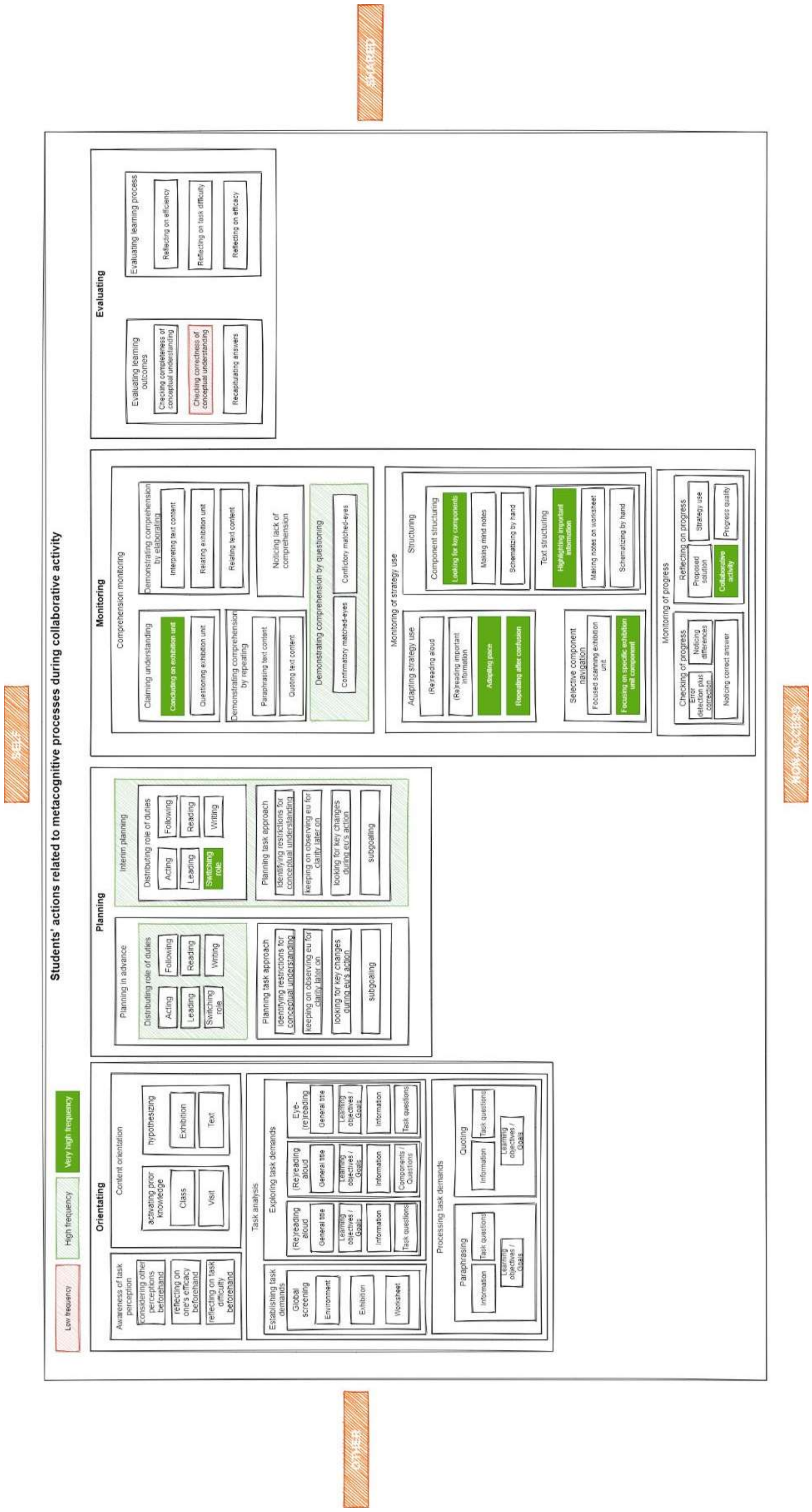


Figure 4.13 Complete diagram of students' actions related to metacognitive processes during collaborative activity

(a) Orientating: This category refers to students' channeling for the collaborative work. It revealed three main themes as (i) *content orientation,* (ii) *task analysis*, and (iii) *awareness of task perception.* These three main themes also divided into sub-themes and had characteristics occurred regarding individual and inter-individual metacognitive regulatory processes. Table 4.28 shows the overall frequencies for ***orientating*** action.

Table 4.28 The number of frequencies being observed for orientating action during all units

Sub-Themes	Number of the pairs (n)	Frequency of being observed (f)
Orientating	***30***	***4396***
Content Orientation (CO)	*30*	*728*
Activating prior knowledge (APK)	30	644
Hypothesizing (H)	30	84
Task Analysis (TA)	*30*	*3556*
Processing task demands (PTD)	30	84
Establishing task demands (ETD)	30	1988
Exploring task demands (ETD)	30	1484
Awareness of task perception (ATP)	*30*	*112*
Considering other perceptions beforehand	30	56
Reflecting on one's efficacy beforehand	30	28
Reflecting on task difficulty beforehand	30	28

In orienting category, while the most observed theme was task analysis (f=3556), the least observed theme was awareness of task perception (f=84). Table 4.28 presents the details regarding main and subthemes of orientating.

a. *Content Orientation:* This theme refers to students' orientation to the content before planning the collaborative activity. It revealed two sub-themes which are activating prior knowledge, and hypothesizing. First, activating prior knowledge was triggered by in-class knowledge, and by prior experience from the guidance session. Also, both activating prior knowledge, and hypothesizing sub-themes resulted in different frequencies for three characteristics which are by conceptual relations, by daily life examples, and by exhibition unit components / physical characteristics.

b. *Task Analysis: Task analysis* refers to students' analysis processes before the planning session considering the task demands and the subject matter area. This theme revealed three sub-themes which are *establishing task demands*, *exploring task demands*, and *processing task demands*. First, establishing task demands refers to the students' detection of the task demands before they begin to plan the collaborative activity. It revealed following metacognitive actions: reading learning objectives, reading task questions, rereading learning objectives, rereading task questions, quoting task questions and paraphrasing task questions. The following excerpt was an example of exploring task demands including reading learning objectives. This scene began by that Stu1 looked at the eyes of Stu2 in the time that Stu2 was looking at the learning objectives area on the worksheet. Then, Stu1 looked at the 3d Sand Pool and turned one's wyes to the learning objectives area of the worksheet. At the same time, Stu2 mentioned the inconsistency between the learning objective and the selected exhibition unit.

[1] Stu1: (Stu1 is looking at Stu2's eyes.).
[2] Stu2: Okay. (Stu2 is looking at the first part of the worksheet. (learning objectives area))
[3] Stu1: (Stu1 is turning one's eyes to the direction in align with the 3d Sand Pool.)
[4] Stu1: (Stu1 is looking at the first part on the worksheet (learning objectives area))
[5] Stu2: But, I will say something, the thing here and the sand are not the same thing.

Also, exploring task demands refers to the students' exploration regarding the components of the given task and the subject matter area. It also revealed following metacognitive actions: reading general title from the worksheet, looking for the number of questions from the worksheet, global worksheet screening, global exhibition unit screening, reading general title from the exhibition unit, and looking for the components of the exhibition units. The following excerpt was an example for global worksheet screening. In this scene, Stu1 and Stu2 were looking at the worksheet, synchronously. Then, Stu1 turned the page and looked the image of 3d Sand Pool exhibition unit before they began to answer the questions. Synchronously, Stu2 looked at the image of 3d Sand Pool.

[1] Stu2: (Stu2 is looking at the worksheet)
[2] Stu1: (Stu1 is looking at the worksheet)
[3] Stu2: Yes.
[4] Stu1: (Stu1 is turning the page.)
[5] Stu1: (Stu1 is looking at the image of 3d Sand Pool)
[6] Stu2: (Stu2 is looking at the image of 3d Sand Pool)

Similarly, the following excerpt represents an example for reading general title from the exhibition unit. Table 4.29 demonstrates the movement sequence of collaborative partners during their orientating action for establishing the task demands. In this scene, Stu1 and Stu2 were approaching to the Bernoulli's Ball exhibition unit [1, 2]. Then, synchronously, Stu1 and Stu2 were looking at the title of the Bernoulli's Ball [3, 4]. Stu1 got closer to the exhibition unit compared to Stu2 and pointed to the title on the exhibition unit with her finger [5]. Then, Stu1 and Stu2 synchronously read the title [6]. And, Stu1 gave a signal by saying "Yes" before they began to conduct the experiment. Finally, Stu1 and Stu2 looked at the ball component [8, 9].

Table 4.29 Eye movement sequence of collaborative pairs during their establishment of the task demands

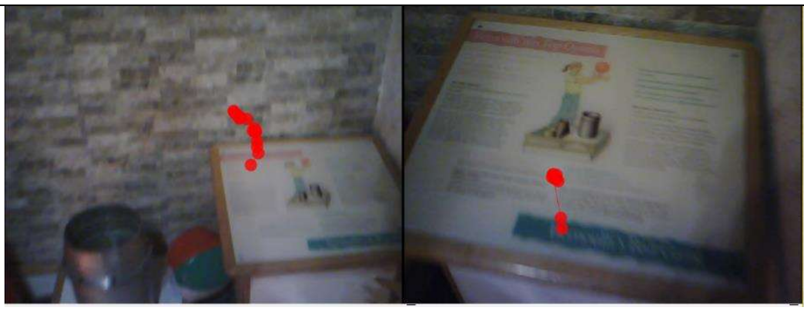
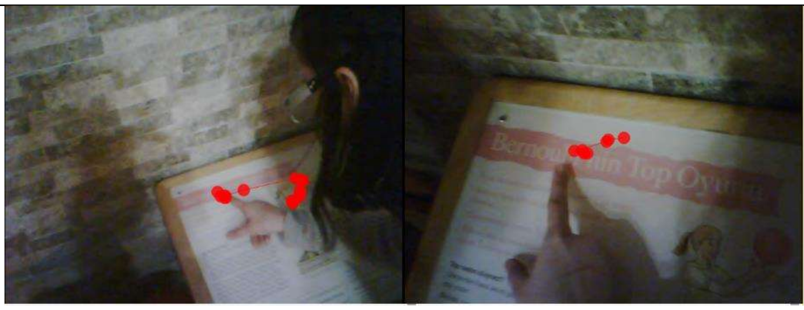
Focus type	**Movement Sequence**
General focus	 [1] Stu1: (Stu is looking at the Bernoulli's Ball) Let's look at this name. [2] Stu2: (Stu2 is looking at the Bernoulli's Ball)
Specific focus	 [3] Stu1: (Stu1 is looking at the title of the Bernoulli's Ball, English version) [4] Stu2: (Stu2 is looking at the title of the Bernoulli's Ball, Turkish version)
Specific focus by emphasizing	 [5] Stu1: (Stu1 is pointing to the title on the exhibition unit with her finger) [6] Stu2: (Synchronously read) Bernoulli's Ball.

Table 4.29 (Cont.) Eye movement sequence of collaborative pairs during their establishment of the task demands

Focus type	Movement Sequence
Specific focus to the related exhibition unit components	 [7] Stu1: Yes. [8] Stu2: (Stu2 is looking at one of the core components, ball) [9] Stu1: (Stu1 is looking at the core components, ball and blower, in a faster way)

c. *Awareness of task perception:* Becoming aware of task perception refers to the students' awareness regarding the person, and task variables which could be observed by the metacognitive actions including reflecting on question-difficulty, reflecting on one's self efficacy, and considering other task perceptions. The following excerpt gathered during the study was an example to considering other task perceptions sub-theme. In this scene, Stu1 and Stu2 were searching for an exhibition unit to fulfill their aims to complete the scientific concepts within the related lesson unit. Stu1 and Stu2 began to look at each other at a synchronous time. Then, Stu2 made a visual search on the science center environment while Stu1 looked at the worksheet. This scenario illustrates Stu1 and Stu2 considered other task perceptions throughout their journey to reach the activity purpose.

[1] Stu2: (Stu2 is looking at Stu1's eyes.).
[2] Stu1: (Synchronously, Stu1 is looking at Stu2's eyes.) In fact, gas…
[3] Stu2: Gas pressure.
[4] Stu1: With pressure.
[5] Stu2: Would want.
[6] Stu1. Related. Yes.
[7] Stu2: But. (Stu2 is looking at the environment for visual search.)
[8] Stu1: (Stu1 is looking at the worksheet)
[9] Stu2: Not here.

(b) ***Planning***: This category refers to students' planning activities before and during the collaborative work. Therefore, it revealed two main themes as (i) *planning in advance*, and (ii) *interim planning*. While *planning in advance* refers to the planning action before students' collaborative work, *interim planning* refers to the in-situ and in-time planning action during students' collaborative work. Both *planning in advance* and *interim planning* revealed two sub-themes as planning solving task approach and distributing role of the duties. And, planning solving task approach sub-theme revealed three planning action for both main theme as developing reading plan, developing action plan, and considering various alternatives for solving the task. Besides, distributing role of duties refers to the distribution of roles among the students which had been emerging during their collaborative work.

Table 4.30 The frequencies being observed for planning action

Sub-Themes	Number of the pairs (n)	Frequency of being observed (f)
Planning	**28**	**980**
Planning in Advance (PA)	*28*	*532*
Planning solving task approach	28	420
Developing reading plan	28	28
Developing action plan	28	280
Considering various alternatives for solving task	28	112
Distributing role of duties	28	112
Interim Planning (IP)	*28*	*448*
Planning solving task approach	28	224
Developing reading plan	28	56
Developing action plan	28	112
Considering various alternatives for solving task	28	56
Distributing role of duties	28	224

a. *Planning in Advance*: Developing action plan sub-theme in the scope of *planning in advance* main theme refers to students' planning action before they begin the hands-on practice on how they will answer the questions. The following excerpt (Table 4.31) was an example for developing action plan within planning in advance. This movement sequence demonstrates the interaction between Stu1 and Stu2. They both began to make sense of the exhibition unit by aligning their gazes to each other. Then, while Stu2 explained regarding the working procedure of the exhibition unit, Stu2 was following Stu1's eyes. Since Stu2 was in the explainer role, Stu2 was focusing on the specific area which was the related exhibition unit component. Stu2 was planning how the exhibition unit components should be placed. And, Stu1 confirmed this plan.

Table 4.31 Movement sequence of collaborative pairs during developinc action plan for planning in advance

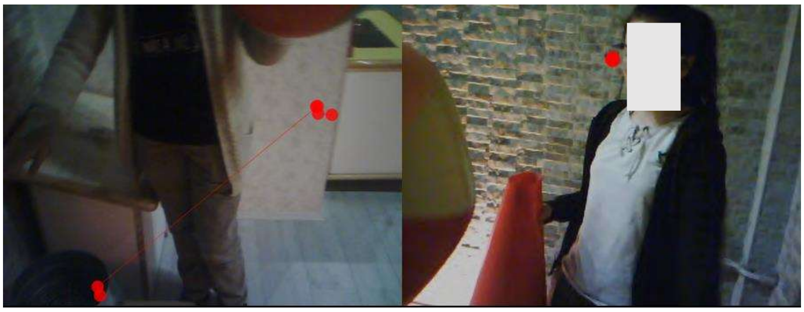
Focus Type	**Movement Sequence**
Eye focus	 [1] Stu2: (Stu2 is holding the cone. Stu2 is looking at Stu1's eyes.) [2] Stu1: (Stu1 is holding the ball. Stu1 is looking at Stu2's eyes, synchronously)
Specific focus to the related exhibition unit component Eye focus	 [3] Stu2: (Stu2 is looking at the blower) Now, when we cut off the air, the ball stopped. It was coming down. [4] Stu1: (Stu1 is looking at Stu2's eyes. And, synchronously said:) It was coming down.
Specific focus to the related exhibition unit component Eye focus	 [5] Stu2: (Stu2 is looking at the ball) [6] Stu1: (Stu1 is looking at Stu2's eyes)

Table 4.31 (Cont.) Movement sequence of collaborative pairs during developinc action plan for planning in advance

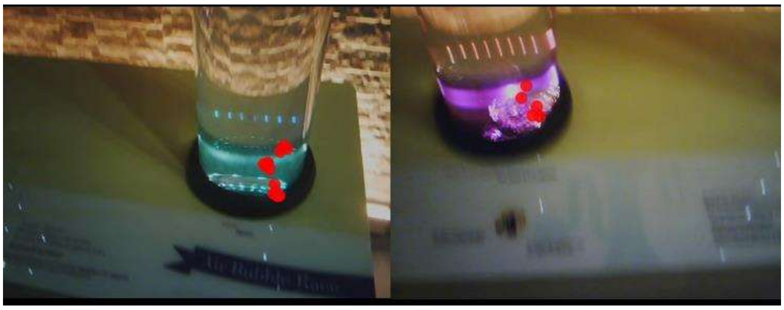
Focus Type	Movement Sequence
Specific focus to the related exhibition unit components	
Eye focus	[7] Stu2: (Stu2 is looking at the cone.) [8] Stu2: Now, we will put this tool here. [9] Stu1: (Stu1 is looking at the Stu2's arm during Stu2 was putting the cone on the blower.)

(b) *Interim Planning*: Developing action plan sub-theme in the scope of *interim planning* main theme refers to students' planning action during they are doing the hands-on practice. The following excerpt (Table 4.32) was an example for developing action plan within *interim planning*. This movement sequence represents the interaction between Stu1 and Stu2 during they were doing the Air Bubble Race exhibition unit. After they had already planned what they would do during they were doing the exhibition unit, they planned their actions in the need of an alignment for a stepwise demonstration. Stu1 and Stu2 began by looking at the information card. After, Stu1 leaded the movement sequence by saying "Let's show one first", Stu1 directed Stu2 as "Lift it" so that Stu2 was prepared to lift the pomp. In a synchronous way, while Stu1 was looking at the tube and the pomp managed by Stu2, Stu2 was looking at the tube and the pomp managed by Stu1. Then, they aligned themselves by counting before pushing the pomp and observe the differences for the air bubbles.

Table 4.32 Movement sequence of collaborative pairs during developinc action plan for interim planning

Focus Type	Movement Sequence
Specific focus on the text	
	[1] Stu1: Let's show one first. (Stu1 is looking at the information card on the exhibition unit) [2] Stu2: (Stu2 is looking at the information card on the exhibition unit)
Specific focus to the related exhibition unit component	
Cross eyes	[3] Stu1: Lift it. (Stu2 is looking at the glycerin with water tube and the pomp related to it.) [4] Stu2: (Stu1 is looking at the water tube and the pomp related to it.)
Specific focus to the related exhibition unit component	
Cross eyes	[5] Stu2: (Stu2 is looking at the pomp belonged by glycerin with water tube.) [6] Stu1: (Stu1's eyes transitioning between water tube and the pomp belonged by it.) At the same time.

Table 4.32 (Cont.) Movement sequence of collaborative pairs during developinc action plan for interim planning

Focus Type	**Movement Sequence**
Specific focus to the related exhibition unit components	
Cross eyes	[7] Stu1: One, two, tree. (Stu1 is pushing the pomp for water tube. Stu1 is looking at the bubble rising below for glycerin with water tube.) [8] Stu2: One, two, tree. (Synchronously with Stu1. Stu2 is pushing the pomp for glycerin with water tube. Stu2 is looking at the bubble rising below for the water tube.)

(c) ***Monitoring***: This category refers to students' instant observation regarding own, other's, and shared strategy use, progress, and comprehension. It revealed three main themes as (i) *monitoring of strategy use*, (ii) *monitoring of progress,* and (iii) *comprehension monitoring* (see Table 4.33).

a. *Monitoring of strategy use*: This theme revealed five sub-themes which are text structuring, component structuring, selective component navigation, and adapting strategy use. First, text structuring refers to students' monitoring action during they are making sense of the given text from the worksheet. This strategy use included highlighting important information, making notes on the worksheet, and schematizing by text/pen. Second, component structuring refers to students' monitoring action during they are making sense of the exhibition units associated to the related scientific concepts. This strategy use included looking for key components, making mind notes, and schematizing by hand. Third, selective component navigation refers to focused observation of the exhibition unit related to its components and potential relation to the scientific concepts. It included two monitoring actions as focusing on specific exhibition components, and scanning exhibition unit. Finally, adapting strategy use was the final monitoring action under the *monitoring of strategy use.* It refers to adaptation of the strategies during their instant observation for enhancing the one's and other's capacities for the conceptual understanding. It included four monitoring actions as re(reading) aloud, re(reading) important information, re(reading) after confusion, adapting reading pace. And, re(reading) refers to monitoring of one's and other's strategy use regarding the repetitive reading to make sense of the given texts or exhibition units.

Component structuring under the structuring related to *monitoring of strategy use* refers to students' adaptation to the task instructions by drawing their main outline. By pointing to (underlining) core concepts means that students either point out the specific exhibition unit component related to the core concept or they underline the core concepts from the given text. Second, schematizing task instructions refers to students' drawing (real or imaginary) of the task instruction to visualize it. The following interaction between Stu1 and Stu2 illustrates an example for pointing to core concepts within Sand Pendulum exhibition unit. In this exhibition unit, there is a rope and a handle. Also, one's hand plays an important role to underline the core concepts. By the hand, the student applied a force and before applying the force, students structure the task instruction. For this excerpt, Stu1 is in the directing role and synchronously Stu2 orient oneself to follow other student's direction.

[1] Stu1: Because to here. (Stu1 is looking at the hand by pointing)
[2] Stu2: (Synchronously, Stu2 is looking at the handle)
[3] Stu1: When you did something with your hand. Do it.
[4] Stu2: (Synchronously, Stu2's hand is approaching to handle on exhibition unit during Stu1 tells about the functioning related to the exhibition unit)

Similarly, the following excerpt illustrates an example for schematizing. Stu1 used one's hand to schematize the instruction.

[1] Stu1: Here. (Stu1 is looking at the box)
[2] Stu1: Iıı.. when we pour the sand. (Synchronously, Stu2 is following Stu1's instruction)
[3] Stu1: (Stu1 moved one's hand as making "hand pouring" behavior. The hand is at the bottom). In the direction of the force we push this, this is going, coming.
[4] Stu2: Yes.
[5] Stu1: At that time, the sand is pouring and drawing shape. (Stu1 is looking to the worksheet from the sand box.)

b. *Monitoring of progress*: This main theme revealed two sub-themes which are reflecting on progress, and checking of progress. While *reflecting on progress* included reflecting on the proposed solution, reflecting on the quality of the progress made, reflecting on the strategy use and reflecting on the collaborative activity, *checking of progress* included error detection/plus correction, noticing differences, and noticing correct answer. First, reflection on the strategy use refers to the progress monitor during students' strategy use such as reading, scanning, adapting, or structuring. Second, reflecting on the proposed solution refers to the progress monitor during and after solving the problems / answering to the questions. Third, reflection on the quality of the progress made refers to students' monitor of the progress throughout the collaborative work. Finally, reflecting on the collaborative activity refers to students' own and other's contribution to collaborative work and it closely interrelated with the potential change for the distribution of the roles.

c. *Comprehension monitoring*: This main theme revealed five sub-themes which are *noticing lack of comprehension*, *claiming understanding, demonstrating comprehension by repeating*, and *demonstrating comprehension by elaborating,* and *demonstrating comprehension by questioning*. First, *noticing lack of comprehension* refers to students' remark of own and other's comprehension failure during the collaborative work. Second, *claiming understanding* revealed two sub-themes as concluding on the exhibition unit, and questioning the activity occurred by the exhibition unit. While concluding on the exhibition unit refers to students' conclusion or causal relationship regarding the working principles of the exhibition unit, questioning exhibition unit action refers to students' effort for understanding the working principles of the exhibition unit. Third, *demonstrating comprehension by repeating* revealed two sub-themes as quoting text content, and paraphrasing text content. While quoting text content refers to students' reference to the text content during the comprehension, paraphrasing text content refers to students' own statements for the text content during the comprehension. Finally, *demonstrating comprehension by elaborating* included three monitoring actions as interpreting text contents, relating text content, and relating exhibition unit. Interpreting text contents refers to students' own understanding from the given texts. Also, relating text content refers to students' monitoring action by setting relationships between the given text and the scientific concept. On the other hand, relating exhibition unit refers to students' effort for setting the relationship between the working principle of the exhibition unit and the scientific concept.

Table 4.33 The frequencies being observed for monitoring action

Sub-Themes	n	f
Monitoring	**30**	**4712**
Monitoring of strategy use (MoSU)	*30*	*2914*
Structuring	30	705
Component structuring	30	567
Looking for key components	30	392
Making mind notes	25	50
Schematizing by hand	25	125
Text structuring	28	138
Highlighting important information	6	28
Making notes on worksheet	28	456
Schematizing by text	2	10
Selective component navigation	30	230
Focusing on specific exhibition components	28	146
Focused scanning exhibition unit	28	84
Adapting strategy use	30	1979
Rereading aloud	30	1036
Rereading important information	30	56
Rereading after confusion	30	112
Adapting reading/acting pace	25	775
Monitoring of progress (MoP)	*25*	*549*
Reflecting on progress	25	316
Reflecting on the proposed solution	25	50
Reflecting on the quality of the progress made	21	175
Reflecting on the collaborative activity	22	25
Reflecting on the strategy use	23	66
Checking of progress	25	233
Error detection plus correction	24	82
Noticing differences	25	87
Noticing correct answer	23	64

Table 4.33 (Cont.) The frequencies being observed for monitoring action

Sub-Themes	n	f
Monitoring	**30**	**4712**
Comprehension Monitoring (CM)	*28*	*893*
Noticing lack of comprehension	23	144
Claiming understanding	28	186
Concluding on exhibition unit	28	140
Questioning exhibition unit action	22	46
Demonstrating comprehension by repeating	24	70
Quoting text content	24	48
Paraphrasing text content	22	22
Demonstrating comprehension by elaborating	22	344
Interpreting text content	18	160
Relating text content	22	144
Relating exhibition unit	22	44
Demonstrating comprehension by questioning	23	149
Confirmatory matched-eyes	23	121
Conflictory matched-eyes	19	28

(d) ***Evaluating***: This category refers to student's evaluation of own and other's current learning situation during and/or after collaborative work. It revealed two main themes as *evaluating learning outcomes*, and *evaluating learning process*.

a. *Evaluating learning outcomes*: This main theme revealed four sub-themes which are checking correctness of the conceptual understanding, checking completeness of the conceptual understanding, checking effectiveness of the conceptual understanding, and recapitulating answers. First, checking correctness of the conceptual understanding refers to checking correctness of student's own and other's conceptual definition. Second, checking completeness of the conceptual understanding refers to student's evaluation on the completeness of the conceptual definition. Third, checking effectiveness of the conceptual understanding refers to student's evaluation regarding the conceptual understanding whether it could be effective in defining the concepts or not. Finally, recapitulating answers refers to students' summarization of the answers which were given during the collaborative work.

b. *Evaluating learning process*: This main theme revealed three sub-themes which are reflecting on personal efficiency, reflecting on task difficulty, and reflecting on self-efficacy. First, reflecting on personal efficiency refers to student's own and other's personal evaluation regarding their efficiency as an individual and collaborative pairs during they were answering the questions. Second, reflecting on the task difficulty refers to students' evaluation on task demands including the worksheet questions, scientific concepts, exhibition units, and the learning path they had followed. Finally, reflecting on self-efficacy refers to students' evaluation of own, other's, and shared efficacy during and after the collaborative work.

Table 4.34 The frequencies being observed for evaluating action

Sub-Themes	n	f
Evaluating	***28***	***958***
Evaluating learning outcomes (ELO)	*26*	*740*
Checking correctness of the conceptual understanding	24	72
Checking completeness of the conceptual understanding	22	448
Recapitulating answers	22	220
Evaluating learning process (ELP)	*24*	*218*
Reflecting on efficiency	22	44
Reflecting on task difficulty	23	46
Reflecting on self-efficacy	16	128

Looking Patterns (RQ3a-RQ4a)

Looking patterns revealed related metacognitive processes under four area of interest as (a) *environment*, (b) *exhibition-unit*, (c) *peer*, and (d) *worksheet* (Figure 4.14, see Appendix K). First of all, looking patterns for the *environment* included eye movement behaviors as *focusing on exhibition unit at a distance, looking to a blank during silence, visual search for a complementary exhibition unit, visual search for a knowledadgable person, visual search for an information card, visual search for familiarization,* and *visual search for related-exhibition unit.* Second, looking patterns for *exhibition unit* included *acting without being directed, explanation on information card, focusing on components, global screening, noticing differences after acting, title on information card, tracking other's direction during acting, tracking other's explanation during visiting/looking,* and *tracking self-direction during acting.* Third, looking patterns for *peer* included looking at *face/eye with no eye-contact, matched-eyes, traking of looking direction without any eye contact, tracking of other's hand movement, and tracking of other's pointing.* Finally, looking patterns for *worksheet* included *re/visiting worksheet components, answer area, global screening, global screening across the pages, image, number, purpose statement, question, tracking of other's reading, tracking of other's writing,* and looking at *the written answers.*

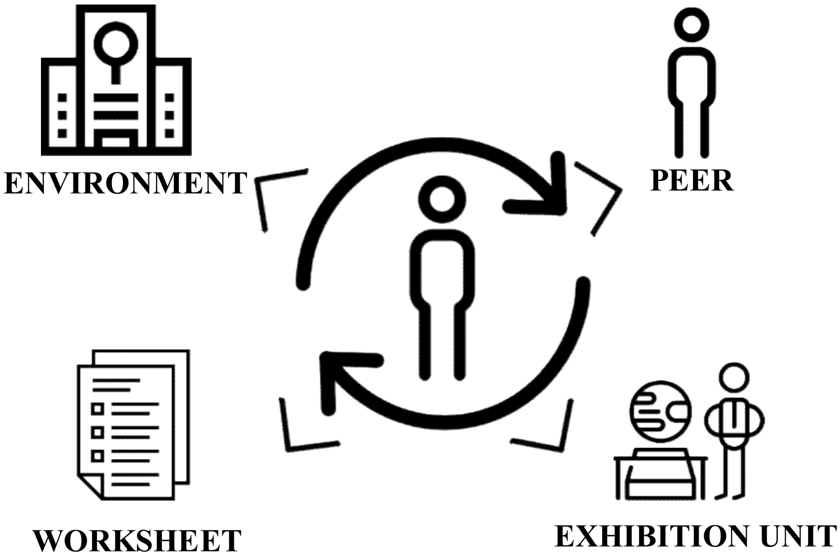


Figure 4.14 Analysis of looking patterns considering four environmental structures

To summarize the looking patterns and associate them with the metacognitive processes, Figure 4.15 shows each environmental structure. Looking patterns showed that when one of the collaborative pairs looked at the other one, this looking behavior can be related to monitoring related actions.

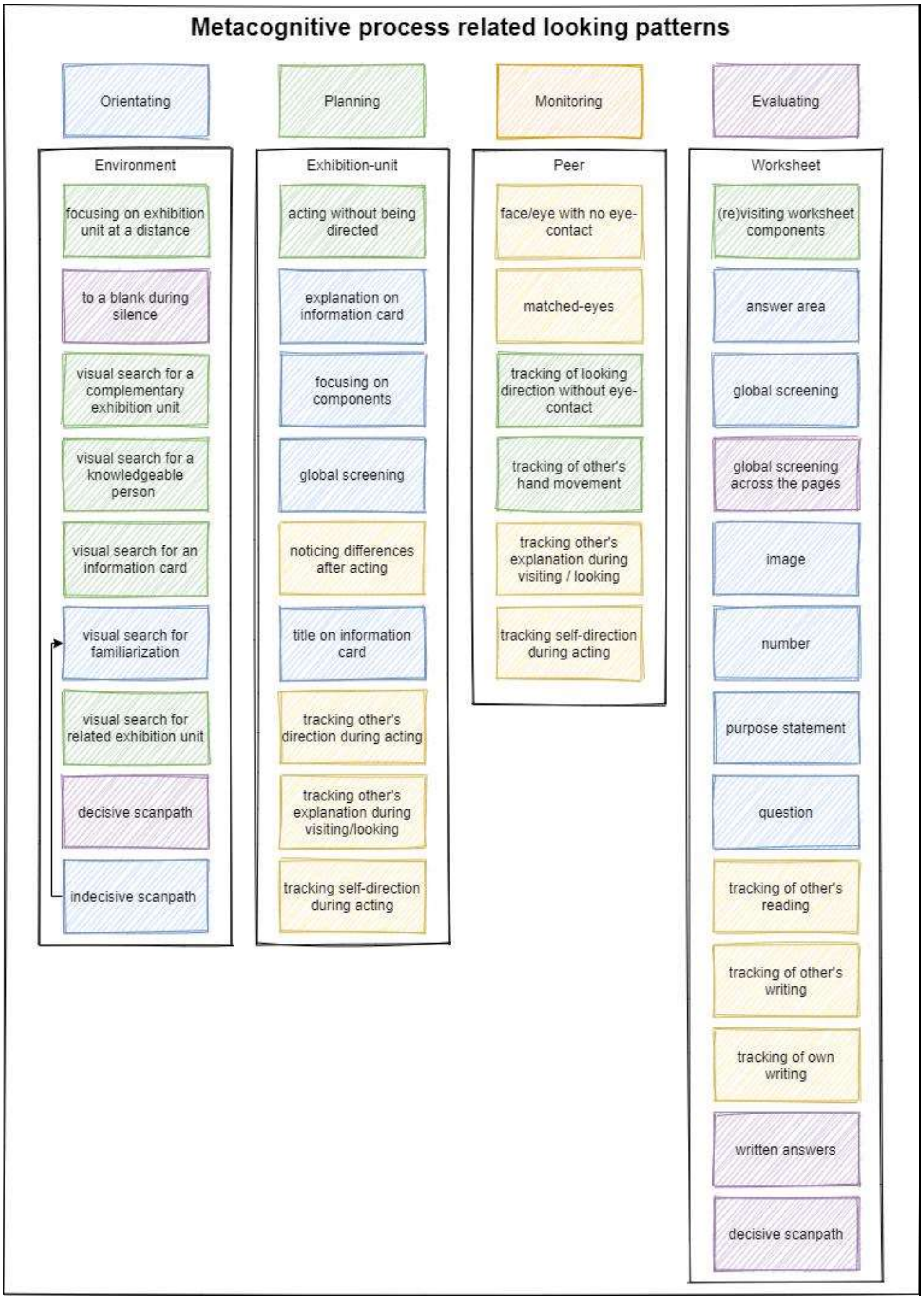


Figure 4.15 Diagram for students' looking pattern associated metacognitive processes

Students Macro-Level Results for the Collborative Activity

Written Results of Collaborative Activity

Correct and Incorrect Use of Concepts

The frequencies of correct and incorrect use of the concepts being written at students' worksheets during their collaboration activity for the selected exhibition units. The correct and incorrect use of concepts were counted per week: (a) *force and pressure,* (b) *energy transformation,* (c) *mirrors and light absorption,* and (d) *solar system and beyond.*

(a) Force and Pressure: This week included five exhibition units within the worksheet. While the total number of correct use of the concepts for the force and pressure week was 132, the total number of incorrect use of the concepts was only two. The selected exhibition units were 3d Sand Pool, Air Bubble Race, Bernoulli's Ball, Hot Air Balloon, and Sand Pendulum. Table 4.46 illustrates how many correct and incorrect use of the concepts occurred for the concepts related to force and pressure.

Table 4. 35 The number of correct and incorrect use of the concepts occurred for the concepts related to force and pressure

Themes and Sub-Themes	Correct Use of Concepts	Incorrect Use of Concepts
Force and Pressure		
Air flow	1	0
Air pressure	11	0
Density	5	0
Depth	5	0
Energy	1	0
Force	23	0
Friction	1	0
Gravitation	1	0
Gravitational force	3	0
Gravitational potential energy	1	0
Heat	4	0
Height	6	0
Liquid pressure	3	0
Moving air	6	0
Pressure	19	0
Resultant force	2	0
Solid pressure	5	1
Stagnant air	4	1
Surface area	12	0
Velocity	2	0
Warmed air	7	0
Weight	10	0

(b) ***Energy Transformation:*** This week included four exhibition units within the conceptual diagnostic paper. They were 3d Sand Pool, Guess Who Wins, Measure Your Power, and Pedal Force. *Energy Transformation* revealed 18 correct use for describing the working principles by using concepts in 3d Sand Pool ($N_{energy} = 10$, $N_{mass} = 5$, and $N_{weight} = 3$), 38 correct use of concepts in Measure Your Power ($N_{gravitational\ potential\ energy} = 3$, $N_{kinetic\ energy} = 16$, $N_{force} =$

10, N_{energy} = 5, $N_{pressure}$ = 3, N_{work} = 2, and $N_{air\ energy}$ = 1), 40 correct use of concepts in Guess Who Wins ($N_{potential\ energy}$ = 9, $N_{kinetic\ energy}$ = 10, N_{force} = 2, N_{mass} = 6, and N_{weight} = 10) and 78 correct use of concepts in Pedal Force ($N_{kinetic\ energy}$ = 15, N_{force} = 7, N_{energy} = 35, $N_{electrical\ energy}$ = 9, N_{work} = 3, and $N_{energy\ transformation}$ = 9) out of 33 students. On the other hands, *Energy Transformation* revealed three incorrect use for describing working principles by using concepts in 3d Sand Pool (N_{force} = 1, N_{height}= 1, and $N_{pressure}$ = 1), six incorrect use of concepts in Guess Who Wins (N_{force} = 1, N_{weight}= 2, and $N_{pressure}$ = 3), 40 correct use of concepts in Measure Your Power ($N_{electrical\ energy}$ = 1, $N_{friction}$= 1, and $N_{pressure}$ = 1) and three incorrect use of concepts in Pedal Force ($N_{friction}$ = 2, and $N_{savings}$=1).

Table 4.36 The number of correct and incorrect use of the concepts occurred for the concepts related to force and pressure

Themes and Sub-Themes	Correct Use of Concepts	Incorrect Use of Concepts
Energy Transformation		
Air	5	0
Depth	4	0
Electric	2	0
Electrical energy	2	0
Energy	28	0
Energy transformation	3	0
Force	20	0
Friction	1	1
Friction force	0	3
Gravitational potential energy	9	0
Heat energy	2	0
Height	14	0
Kinetic energy	14	0
Light	8	0
Potential energy	2	0
Solid pressure	1	0
Sound	6	0
Surface area	1	0
Velocity	14	2
Volume	5	0
Weight	15	5
Weight distribution	1	2
Work	7	0

(c) ***Mirrors and Light Absorption:*** This week included three exhibition units within the conceptual diagnostic paper. They were Countless Color, Monochrome Room, and Touch the Spring. *Mirrors and Light Absorption* revealed 14 correct use for describing working principles by using concepts in Countless Color (N_{color} = 10, N_{light}= 3, and $N_{light\ reflection}$ = 1), 16 correct use of concepts in Monochrome Room ($N_{absorption}$= 2, N_{color}= 8, $N_{frequency}$ = 1, N_{light}

$_{reflection} = 3$, $N_{light\ refraction} = 1$, and $N_{white\ light} = 1$), and 17 correct use of concepts in Touch the Spring ($N_{concave\ mirror} = 1$, $N_{mirror} = 8$, and $N_{reflection} = 8$) out of 12 students. On the other hand, *Mirrors and Light Absorption* did not reveal any incorrect use of concepts.

Table 4.37 The number of correct and incorrect use of the concepts occurred for the concepts related to force and pressure

Themes and Sub-Themes	Correct Use of Concepts	Incorrect Use of Concepts
Mirrors and Light Absorption		
Absorption	15	0
Color	255	0
Concave mirror	17	4
Convex mirror	8	15
Flat mirror	21	2
Light	66	0
Mirror	75	0
Optical illusion	1	0
Prism	5	0
Reflection	29	0
White light	58	1

(d) ***Solar System and Beyond:*** This week included four exhibition units within the conceptual diagnostic paper. They were Constellation Viewer, Gravity Well, Solar System Model, and Summer Sun / Winter Sun. *Solar System and Beyond* revealed 38 correct use for describing working principles by using concepts in Constellation Viewer ($N_{constellation} = 21$, and $N_{star} = 17$), 48 correct use of concepts in Gravity Well ($N_{distance\ to\ sun} = 2$, $N_{black\ hole} = 16$, $N_{gravitational\ force} = 17$, $N_{planets} = 6$, and $N_{solar\ system} = 1$), 49 correct use of concepts in Solar System Model ($N_{distance\ to\ sun} = 12$, $N_{planets} = 22$, and $N_{solar\ system} = 15$), and 41 Summer Sun Winter Sun ($N_{axial\ tilt} = 17$, $N_{distance\ to\ sun} = 16$, $N_{heatness} = 3$, and $N_{seasons} = 5$) out of 22 students. On the other hand, *Solar System and Beyond* revealed one incorrect use for describing working principles by using concepts in Summer Sun Winter Sun ($N_{galaxy} = 1$).

Table 4.38 The number of correct and incorrect use of the concepts occurred for the concepts related to force and pressure

Themes and Sub-Themes	Correct Use of Concepts	Incorrect Use of Concepts
Solar System and Beyond		
Axial tilt	4	0
Celestial body	19	0
Constellation	6	0
Distance to sun	3	0
Earth	52	0
Jupiter	1	0
Light year	10	0
Mars	21	0
Mercury	1	0
Moon	8	0
Neptune	6	0
Orbit	14	0
Planet	81	0
Saturn	1	0
Season	14	0
Solar system	16	0
Space	20	0
Star	89	0
Sun	64	0
Telescope	2	0
Uranus	1	0
Venus	2	0

Students' Reasoning and Evaluation Outputs on the Worksheet

Table 4.50 shows students' coding for their writings on the worksheets during their collaborative activity. The results revealed five main themes under two categories which are written texts inferring to reasoning and inferring to evaluation. The reasoning category includes three main themes as ***causal reasoning***, ***faulty reasoning***, and ***comparative reasoning***; whereas, the evaluation category includes two main themes as ***evaluation of the exhibition unit (context variable)***, and ***evaluation of the self (person variable)***.

Table 4.39 Themes for students' writings on the worksheets during their collaborative activity

Themes and Sub-Themes	FP	ET	MLA	SSAB
Causal reasoning				
Conceptual Relations				
Conceptual	5	15	73	31
Spatial	17	10	15	30
Physical	17	16	28	24
Physical Relations				
Spatial	7	7	7	27
Visual	5	4	56	13
Faulty reasoning	***8***	***23***	***43***	***6***
Comparative Reasoning				
Conceptual Relations				
Conceptual	4	11	0	12
Spatial	0	6	4	7
Physical	4	4	6	4
Physical Relations				
Spatial	0	1	1	7
Visual	3	1	5	15
Evaluation of the exhibition unit (context)				
Conceptual match	9	3	14	29
Phenomenal match	10	3	8	16
Physical match	0	3	7	27
Evaluation of the self (person)				
Goal setting	29	23	67	63
Goal monitoring	4	16	85	48
Goal assessment	36	76	99	66

The students demonstrated two main ways for ***causal and comparative reasoning*** based on *conceptual relations* and *physical relations*. While *conceptual relations* included reciprocal relations during causal reasoning with conceptual, spatial and physical utterances, *physical relations* included reciprocal relations during causal reasoning in align with the spatial and visual utterances. Also, students' circular reasoning or reasoning outputs demonstrating misinterpretation or misunderstanding of the phenomenon were counted as ***faulty reasoning***. In addition to written texts inferring to reasoning, students demonstrated three main ways for both the ***evaluation of the exhibition unit (context variable)***, and the ***evaluation of the self (person variable)***. While students evaluated the exhibition units during the selection of them based on their *conceptual match*, *phenomenal match*, and *physical match*, they evaluated themselves based on the *goal setting, monitoring,* and *assessment* procedures. The frequencies obtained for all main and the sub-themes were categorized per week: (a) *force and pressure,* (b) *energy transformation,* (c) *mirrors and light absorption,* and (d) *solar system and beyond.*

(a) Force and Pressure**:** This week included five exhibition units within the worksheet. While the *conceptual relations* revealed five, 17, and 17 statements regarding the conceptual-conceptual, conceptual-spatial, and conceptual-physical relations, the physical relations revealed seven, and five statements regarding the physical-spatial, and physical-visual relations. Also, ***faulty reasoning*** revealed eight statements for this week. In addition to causal and faulty reasoning, students uttered a total of eight statements referring to comparative reasoning based on the conceptual relations, and three statements referring to comparative reasoning based on the physical relations. The following excerpt illustrated an example for faulty reasoning. The students had a faulty reasoning based on the physical attributes. The students saw the air bubble and they relate the air bubble with sending the water rather than applying a force to the pomp and having an air bubble with different dimensions due to the density of the liquids:

> *"The water inside the hole goes up when we send the other water to the air."* [Quotation 64, Appendix I]

Second, students matched the exhibition units with the current subject conceptually by nine times, and phenomenally by ten times. However, there was not physical attribution to the exhibition unit. Besides, students evaluated themselves during their collaborative activity. 29 of students' statements were related to goal setting process; whereas four of the statements were related to goal monitoring, and 36 of the statements were related to the goal assessment.

***(b) Energy Transformation*:** This week included four exhibition units within the worksheet. They were 3d Sand Pool, Guess Who Wins, Measure Your Power, and Pedal Force. *Energy Transformation* revealed 23 utterances for goal setting, 16 utterances for goal monitoring and 76 utterances for goal assessment. Also, students rarely matched the exhibition unit by conceptually, phenomenally, and physically for the evaluation of the exhibition unit regarding the current lesson unit. Besides, the results revealed 23 utterances for the example of faulty reasoning.

***(c) Mirrors and Light Absorption*:** This week included four exhibition units within the worksheet. They were Countless Color, Monochrome Room, Infinite Views, and Touch the Spring. The results revealed 73 utterances for conceptual to conceptual relations during students' causal reasoning. Also, 43 utterances of faulty reasoning occurred. The most of the frequencies occurred for faulty reasoning were related to the abstract terminologies which were observable physical phenomena such as light absorption (seeing the red color during the yellow light is open) or mirror reflection (image view via convex or flat mirrors). Besides, students evaluated themselves more frequently related to their goal assessment. This might be the reason to have encouragement or need for the confirmation related to the concepts for mirrors and light absorption.

***(d) Solar System and Beyond*:** This week included four exhibition units within the worksheet. They were Constellation Viewer, Gravity Well, Solar System Model, and Summer Sun / Winter Sun. The results revealed six faulty reasoning by students during the collaborative activity. Besides, students matched the exhibition units with the current lesson unit more frequently. Also, students evaluated themselves during their collaborative activity more frequently related to goal setting, and goal assessment.

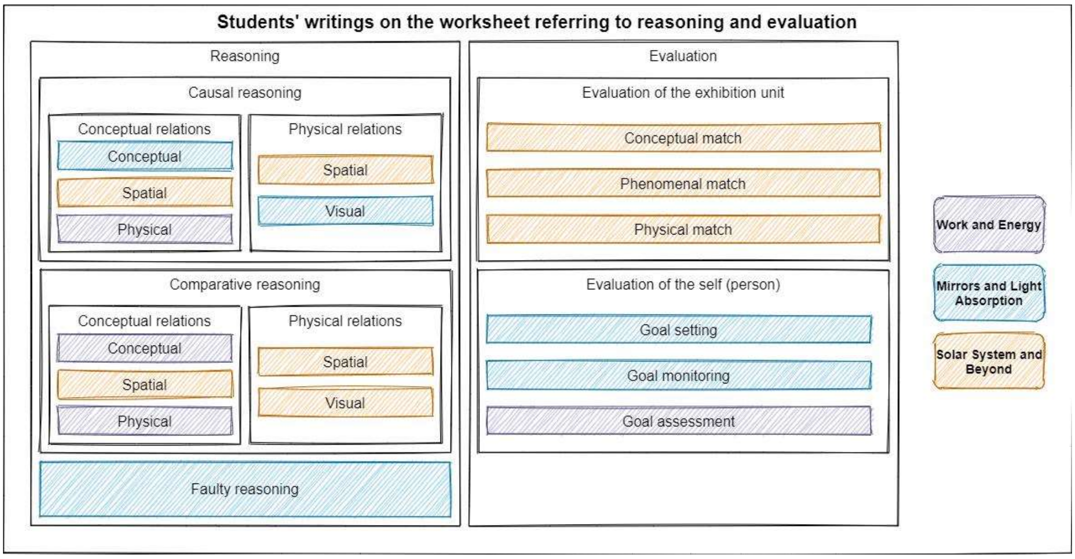


Figure 4.16 Diagram for students' writings on the worksheet referring to reasoning and evaluation

CHAPTER 5

DISCUSSON, CONCLUSION AND SUGGESTIONS

This chapter includes discussion, conclusion and suggestions sections of the study. The chapter began with the discussion of the findings for the current practices with the subtitles educational and organizational current practices respectively. After all, the findings of the multiple case study contended guidance and collaboration phases in the light of other studies related to metacognitive processes. Finally, suggestions for practitioners and policy makers and suggestions for further researches proposed alternative ways to implicate the findings or conduct the research regarding the future considerations.

5.1 Discussion

This thesis study investigated 7th grade students' metacognitive processes during and after collaborative learning activities within science center contexts as a multimethod study. Due to the complex nature of the science center contexts, it needs to investigate the current practices of them. Thus, at the first hand, this study investigated the current practices of science centers in Turkey to provide a comprehensive guide for both educational and organizational processes from the perspective of instructional design. And, at the second hand, a further research-driven instructional design examined students' metacognitive processes during collaborative activities within science center environments. The findings suggest that instructional design is a holistic process and taking both science center educators' and students' metacognitive processes into consideration might increase the effectiveness of instructional design.

5.1.1 Current Educational and Organizational Practices in Science Centers

Current practices in science centers divided into two main categories as *current educational practices* and *current organizational practices* that are closely related to instructional design and educational effectiveness in science centers. While *current educational practices* emerges sub-categories as designing instruction and enhancing collaboration, *current organizational practices* emerges sub-categories as barriers, expectations, needs, and solution attempts. Science center educators' and science teachers' experiences regarding the educational and organizational practices were stated in the light of the related literatures in the following sections.

The current practices study investigated the educational practices of science centers under the lens of science center educators' and science teachers' experiences. Science center educators' experiences and verbal accounts were the primary qualitative data for the study. Designing instruction and enhancing collaboration themes under the current educational practices evaluated the metacognitive-oriented interventions implemented for the science center activities. Before discussing the current educational practices and current organizational practices, a summary is needed by illustrating their overall diagrams. While Figure 5.1 shows the overall finding of the current educational practices; whereas, Figure 5.2 shows the overall finding of the current organizational practices, and Figure 5.3 shows science teachers' experiences of science center visits.

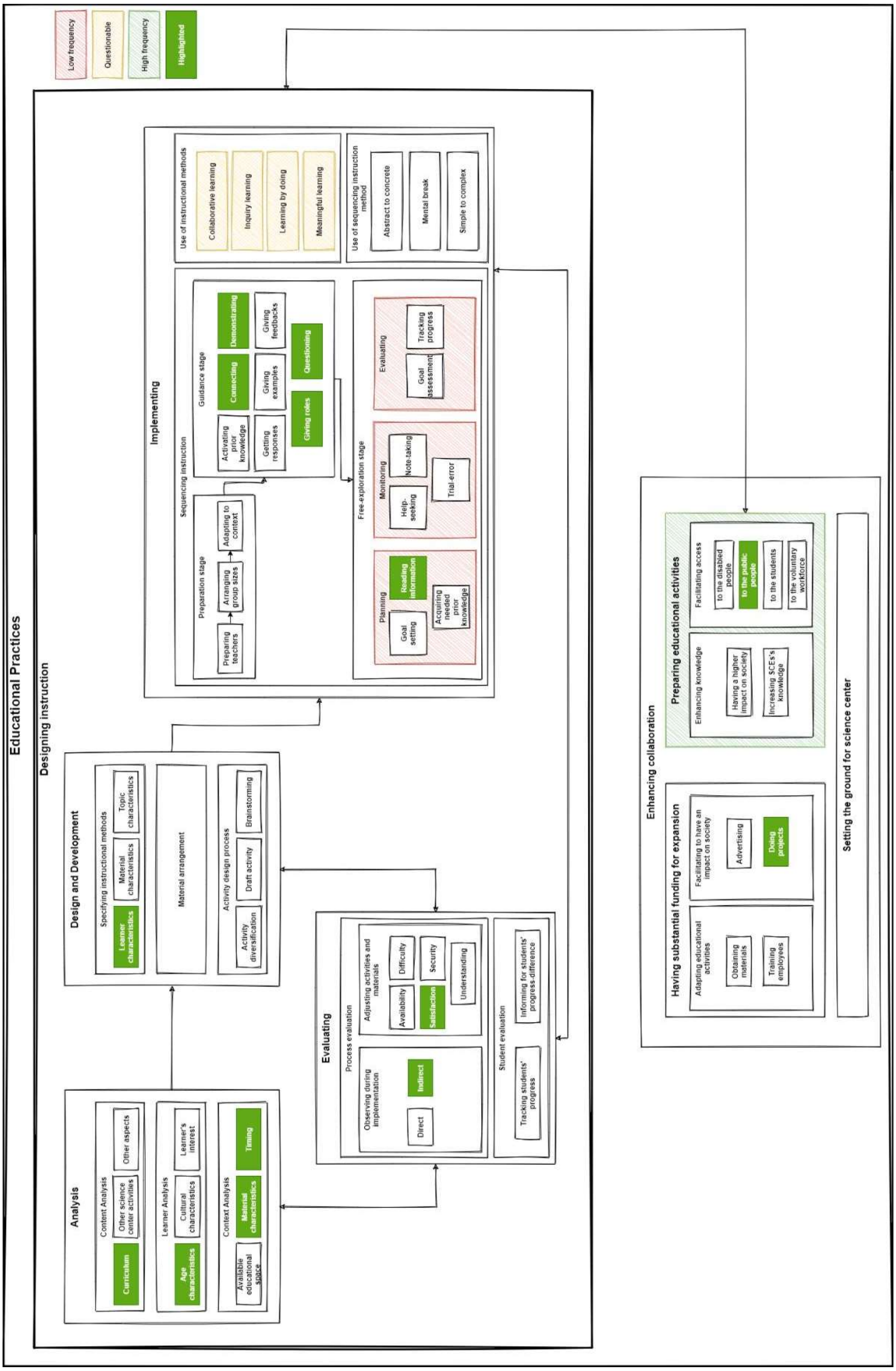


Figure 5.1 Findings of the current educational practices

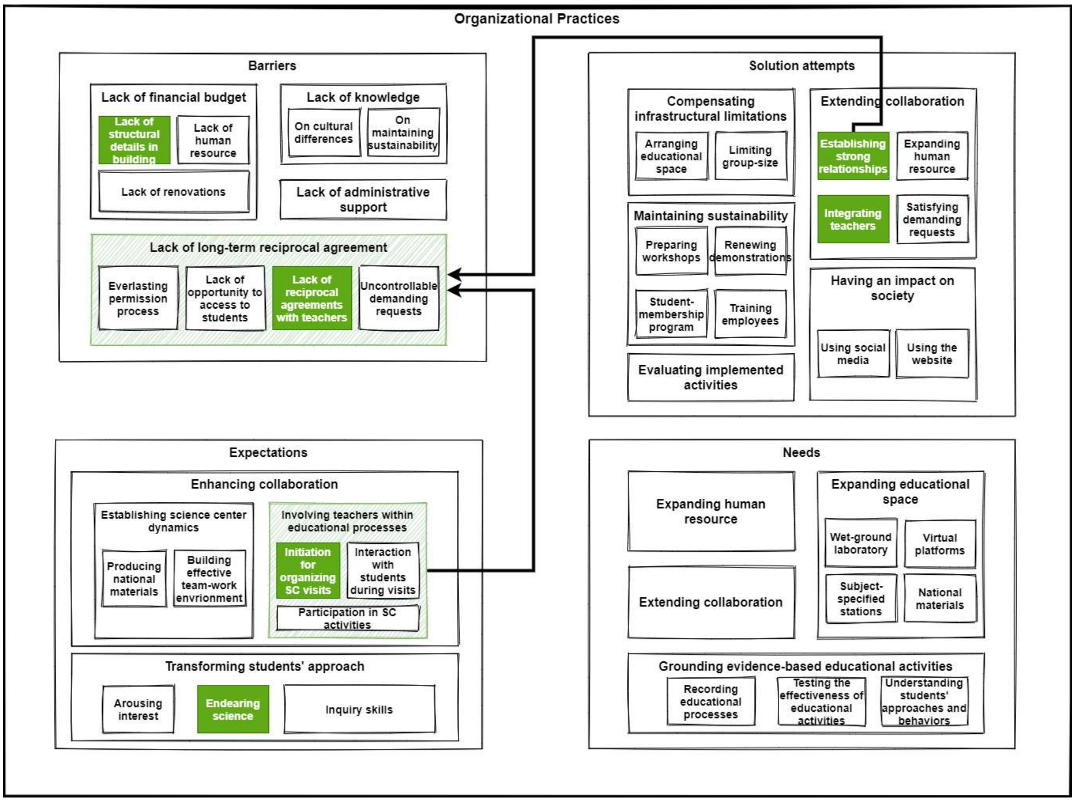


Figure 5.2 Findings of the current organizational practices

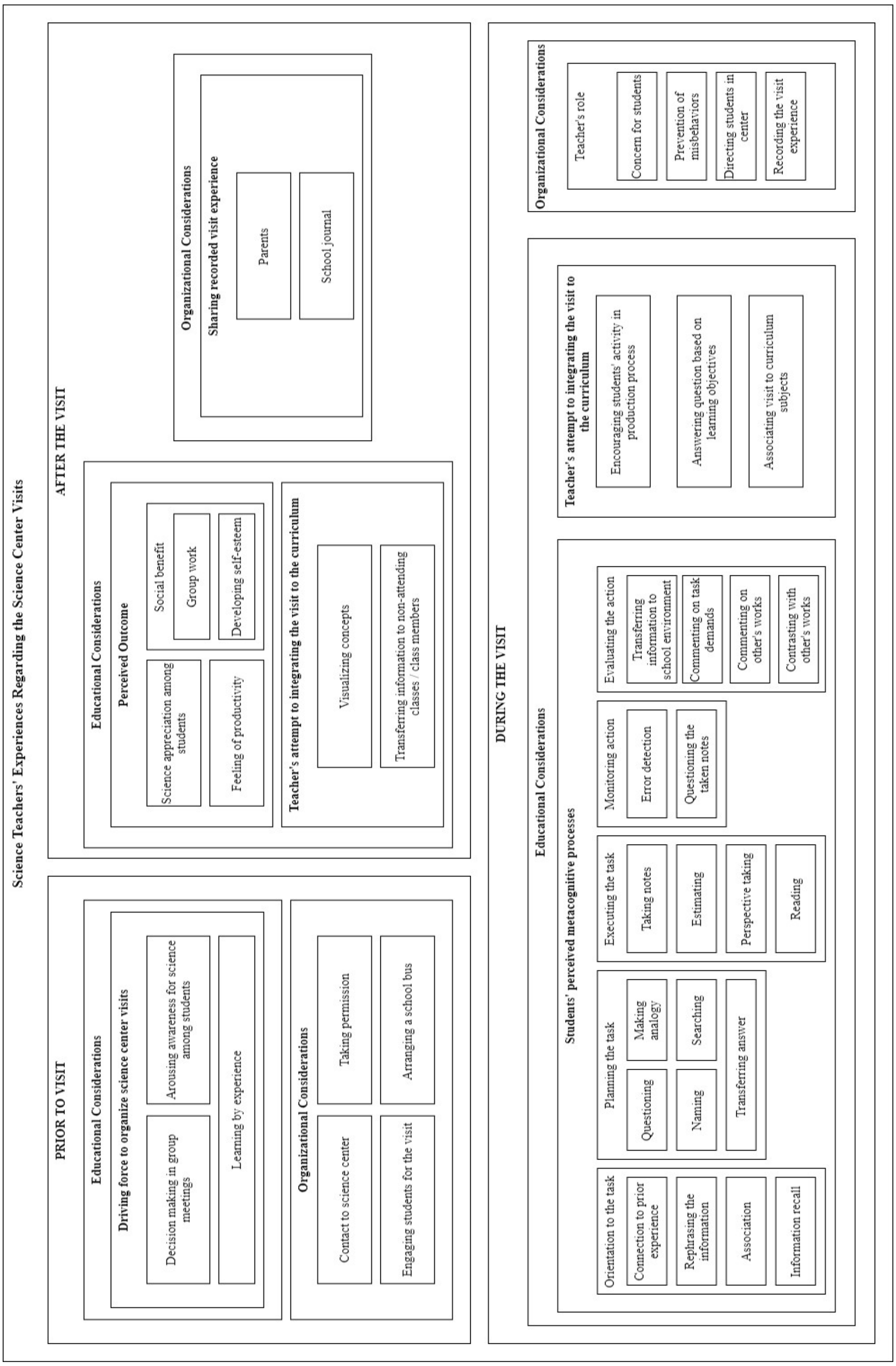


Figure 5.3 Findings of science teachers' experiences of science center visits

The research question of "What are the current educational practices in science centers?" revealed a cyclical stepwise instructional design process based on the science centers' current educational practices and enhancing collaboration theme as to guide and increase the effectiveness of the instructional design process.

First of all, emerged stepwise instructional design process includes *analyzing, designing-developing, implementing,* and *evaluating* phases. Although it is a cyclic stepwise process, the design and development phases intersected. And, the evaluating phase had a reciprocal relationship with each design phase. Figure 5.4 illustrates in which direction each phase interacts with each other. During the analysis, design and development emerged within the same theme as a phase due to the reciprocal relationship between them. *Brainstorming with colleagues* moderates the relationship between design and development due to the dynamic nature of the science center environments. Although there is no evidence or finding in the literature to combine design and development phases within the same theme, these phases might show intersection in wild. So, dynamic nature of the science center might offer three-way characteristics to promote brainstorming among colleagues: *back-end interior design issues, continual change in target population*, and *adaptivity for instructional materials*. First of all, *back-end interior design issues* might provide a lens for combination of the design and development phases considering the placement of interactive materials, and creation of the conversational open areas for learning within the science center contexts. Creating renewable instructional spaces embedded in interior design might link arms of design and development phases so that colleagues might promote brainstorming.

Second, there is a *continuous change in population* regarding ages, personal traits, and school levels so that science center educators need iterative design and development processes serving together to provide effective instructional activities for each population group. Lastly, *adaptivity for instructional materials* is also an account for combining the design and development phases due to the existence of a variety of lesson subjects and concepts to deliver as an instruction. Since there is not any designed materials, such as "a toolkit for developing instruction for science centers”, design and development phases may continue together for adapting the instructional materials. Iterative design processes also ensure the connectedness of complex domains for the expert knowledge. Recently, Fries, Son, Givvin, and Stigler (2020) offered a *practices connections* framework where there needs a connectedness by practicing among core concepts, key representations and contexts and practices of the world. Thus, over time, students might create coherent understanding regarding the concepts. This also requires a holistic approach to instructional design to take core concepts, key representations, contexts, and the practices of the world into account. Iterative design for the instruction for making sense of the scientific concepts within the science center environments might necessitates a bridge between design and development phases through the agency of brainstorming among colleagues.

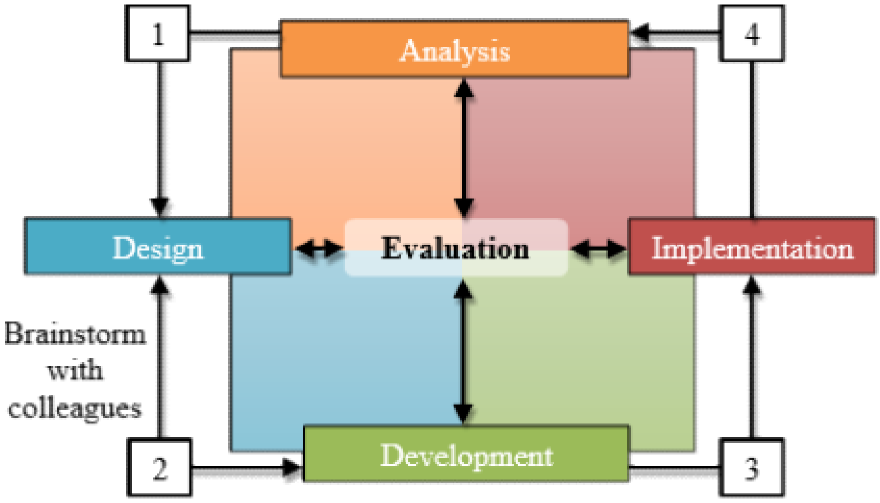


Figure 5.4 An overview of designing instruction theme

After discussing why design and development phases might intersect, it needs to mention each sub-theme as a phase. Also, each phase has sub-phases. First of all, the *analysis* phase has content analysis, learner analysis, and context analysis. *SCE*s mostly prefer to use ***school curriculum*** as a baseline for the content analysis rather than referring to other science centers’ activities and in-situ experiences. Although *SCE*s highlighted the importance of school curriculum as being the most prominent source, Bamberger and Tal (2007) reported neither science center staff nor school teachers connect the knowledge with their school curriculum. On the contrary to this finding, *SCE*s among Turkey stated that they closely relate the concepts in the school curriculum to the exhibition units by the help of examining the contemporary learning objectives in the curriculum. It is an essential issue to connect the conceptual knowledge and the practical implications for science subjects based on the lesson objectives in the school curriculum. However, it is not sufficient to foster students' meaning-making processes for a better conceptual understanding.

Another study of Bamberger and Tal (2008) investigated the long-term effect of visiting a science center on students' knowledge connection, knowledge communication and life-long learning desire and found a positive long-term effect among the variables. The importance of knowledge communication and knowledge connection for the life-long learning desire necessitates learner and context analyses as well due to need for building a bridge between scientific concepts and the contextual variables including learner, time and space. And, the emerged analysis phase also reveals learner and context analyses. *SCE*s mostly referred to age and material characteristics for the learner and context analyses. These references might be a complementary issue accompanying school curriculum to deliver an effective instruction during the workshops and guided-tours.

Although *SCE*s' verbal accounts ensured in the analysis phase, they take school curriculum, age and material characteristics for a better instructional design, these parameters are not sufficient for a better conceptual understanding. The relationship between students' cognitive levels and conceptual understanding might need a variety of parameters to take into account beside the age and the material characteristics. Marek, Boram, Laubach and Gerber (2002) investigated the relationships between conceptual understanding and different interactive exhibits among students who have been clustered regarding their cognitive development levels. Findings assured that students at each cognitive development level has greater conceptual understanding from interactive science exhibits requiring empirical-inductive (EI) reasoning compare to interactive science exhibits requiring hypothetical-inductive (HI) reasoning. In the study, interactive science exhibits were classified as requiring EI reasoning and HD reasoning. Marek et al. (2002) proposed to museum design experts for developing and including interactive exhibition units which pinpoint to all cognitive developmental levels since it was resulted that exhibition units requiring HD reasoning leads to misconceptions or no understanding of the scientific concepts for even upper elementary school students. Although the conclusion derived by Marek's (2002) study, in the time which does not require free-exploration for students and provided assistance, these interactive exhibits may also provide scientific background for the students regarding the science concepts compatible with their science curriculums. An adaptive way for students' cognitive levels embedded in the material characteristics may need further investigation for the short-term and long-term effects.

There have been few studies on the effects of the science center visit on the long-run on students' cognitive and non-cognitive outcomes (Falk & Dierking, 1997; Krange, Silseth & Pierroux, 2020). The results from the current practices study showed that during the implementing phase for the instructional desing, *SCE*s rarely referred to metacognitively-oriented methods and procedures. Although they mentioned collaborative learning, inquiry learning, learning by doing and meaningful learning methods, students' observed metacognitive actions does not reveal a high frequency for planning, monitoring, and evaluating. It is critical to observe students' metacognitive processes to make the necessary renovations on instructional programs. It is questionable that in science center environments, why these observed behavioral patterns aligned with the sub-dimensions of metacognitive regulation occur and what they provide for students regarding skill and knowledge acquisition in science-related subjects. Although *SCE*s reported students' behaviors, which may be directly or indirectly related to their metacognitive processes, it seems that there is not much effort to manifest their metacognitive knowledge and regulation within science center environments during self-learning activities. However, students' monitoring of their own progress via help seeking, note taking and trial and error had higher frequencies compared to planning and evaluating actions. The reason for this might be directly associated with students' need for auxiliary materials to make sense of the scientific concepts. Hands-on worksheets, and directive instruction to faciliate managing students' metacognitive actions might be a way to enhance their self-directed activities during their free-exploration time.

Researches on worksheet-design might give an insight on how students' metacognitive actions can be promoted during the guided visits. Nyamupangedengu & Lelliott (2012) conducted a collective case study with three groups of students on how selected students use worksheets throughout their field-trips to support their learning. Although they did not state any measurement method for learning, instant observation of a group of student behaviors and conversations within the group showed that the worksheets were used as a guide, a prompt to ask relevant questions regarding the subject matter area, an instrument for maintaining focus on the subject and a way to promote collaboration among the individual learners. Taking worksheet-design, prompted questions and targeted exhibits into account may propose a way to connect the exhibits with a focus on targeted subject matters for effective gain conceptual understanding in short time duration.

As a step-forward study, Hauan & Dewitt (2017) compared four worksheet designs to understand which may better encourage for deep engagement of students for supporting their progress towards conceptual understanding. They compared open exploration (a sheet to demonstrate exhibition units), traditional worksheet (with exhibition units and questions), paper-guided learning worksheet (with exhibition units, illustrations and guided texts on paper), and digital-guided learning worksheet (with exhibition units, illustrations and guided texts on the tablet). They found that four groups of students engaged in the study demonstrated differences in their learning-related behaviors and students who used guided learning worksheets were stated as actively patriated in learning activity among their groups. Thus, either guided worksheets for free-exploration time, or guided tours via a *SCE* may require detailed methodological and instructional steps considering the instructional design processes. So, with a holistic approach considering ecologically friendly materials, and the person variables during the science center visit, the implementation phase may also provide an instruction which is not loaded on students' cognitive operations. For the implementation phase, *SCE*s rarely referred to content organization strategies such as simple to complex chains and use of mental break to provide decreasing students' cognitive loads. Altough it seems that science centers do not consciously take students' cognitive loads into account, revealing such processes is also essential to offer practical instructions.

Besides, since the exhibition unit design is a significant factor in specifying an appropriate instructional method and having potential in increasing conceptual learning curves by triggering learners' metacognitive acts, in-depth observation of the interaction between exhibition units and learners may be a necessary procedure. In the literature, it seems that various methods have been applied for the interaction design of the exhibition units. One of the most recent methods brings eye-tracking technology into the stage. Jung, Zimmerman, and Perez-Edgar (2018) conducted a case study by using mobile eye-tracking to observe the interaction between a learner and learning resources in a science museum environment for offering a methodology in instructional design and technology researches. Jung et al. (2018) claimed that interaction engaged by a learner within an educational source in an out-of-school environment provides a sequence of the area of interest, which may be beneficial in designing instructions in these dynamic environments. The absence part of the practical suggestions for current educational practices might be overcome by conducting such kind of researches in these dynamic and complex environments.

Studies offering an exploratory environment for the students aligned with the purpose of the visit. Since science centers are complex environments that may cause an increase in extraneous cognitive load, allocation of the students' attention may be distributed, and it may result in not focusing on the desired concepts rather than promoting the surface-level understanding regarding the existing exhibition units. In order to go beyond the surface-level, a facilitator for concentrating on the scientific concepts may be provided, such as worksheets. However, worksheets are not adequate for making students focus on the related conceptual issues without any instructional strategy which is applied to the worksheets. Worksheets fitted to specified instructional methods concerning the outcomes of the formative evaluation might provide a free-exploration opportunity to students while they are trying to understand the concepts. Especially for novice learners, there may be a need for guidance through worksheets or exhibition units. However, due to the lack of financial budget, it is difficult to renovate exhibition units. Thus, offered worksheets embedding a variety of instructional strategies may be cost-effective. However, it needs evidence-based educational researches to determine under what conditions which instructional strategy might be useful for which target group. So, the collaboration between *SCE*s and schools occupies a vital place during the activity-preparation stage. This issue was also discussed under the current organizational practices.

Another featured finding was about the differences among perceived metacognitive processes of the students. Although both the teachers and the science centers listed their perceived metacognitive actions of the students during the interviews, teachers had more elaborative list for the metacognitive actions.

Conclusion for Current Educational Practices

To sum up, investigating *current educational practices* among science centers located in Turkey on behalf of the descriptive issues brings two main issues to the forefront. These issues turn around designing instruction and enhancing collaboration. Enhancing collaboration is one of the significant issues to enhance educational effectiveness within science centers. Each agent of the educational system including teachers, science center educators, students, and private and state institutions, has a substantial role in enhancing educational effectiveness. Especially during the foundation of the science centers, collaborating with other stakeholders provides the ways to reach out to a financial budget. Thus, this financial budget facilitates having an impact on society and adapting educational activities or materials for educational processes. Collaborating with other science center educators and teachers from different institutions also facilitates enhancing knowledge among science center educators. Similarly, collaborating with diverse stakeholders provides deciding on the theme of the science centers with the help of educators (academicians, other science center educators or current science center educators). It seems that for setting the ground of educational practices, collaboration during the foundation of the science center has a significant role and one step behind this reveals to design the instruction to enhance educational effectiveness.

Based on the educational practices held by science centers, these descriptive instructional design processes speculate on the sub-phases that emerged phases have. In that sense, the analysis phase has content analysis, learner analysis, and context analysis, respectively. *SCE*s mentioned that they use the school curriculum and other science centers' educational activities to become familiar with the content from a variety of sources. Besides, the school curriculum accounted for the most prominent source for the content analysis since *SCE*s prefer to arrange educational space considering students' lesson objectives to match the related concepts of them with exhibition units or workshops.

In addition to content analysis, learner analysis is also an important issue to determine how and under what conditions the content will be reflected to visiting school groups. *SCE*s stated that they consider learners' ages, cultural characteristics, and interests before designing an educational activity. Learner analysis before the design of educational activity within the science center facilitated the examination of the activities and materials displayed to students and set ground to determine the teaching sequence and appropriate teaching methods for the target group. Although the selected exhibition units targeting a concept have similar characteristics, the learners define the extent of how and in what conditions *SCE*s deliver the concepts to students. One possible reason to understand learner analysis is to provide the content under learners' characteristics, including ages, cognitive, and metacognitive levels. However, there are not many research processes within science centers to understand how students act within this environment while they are engaging in different scientific concepts. Also, learner analysis might not just be restricted with ages and cognitive levels of students. Since during the guidance phase, *SCE*s consider average or expected levels of students, it does not fit all students. Detecting students' cognitive and metacognitive levels might provide finding ways to encourage students in accomplishing to acquire the target concept.

Context analysis, on the other hand, considers the material characteristics, the available educational space, and the possible time duration for a school group. Specifying available educational space and time is essential for creating a school visit plan, which also clarifies the issues on how long *SCE*s and visiting school groups will have time for science center experience and what kind of lesson objectives will be delivered to students. One possible reason to have context analysis is to constrain the environmental factors. Stated environmental factors by *SCE*s are also closely related to specifying instructional strategies. Material characteristics such as paper-based activities, an exhibition unit that is allowing students working in collaborative pairs, or doing the work as an individual determines the shape of the educational activity. For now, this process is under the heal of *SCE*s. However, a systematization for the context analysis might decrease *SCE*s' workload and compensate for the lack of human resources. This systematization might depend on the modeling of each phase under what conditions students can benefit the most for the target scientific concepts.

After the analysis phase, an intertwined phase, which is the designing-developing phase occurs. The reason why each phase interacts with each other is that *SCE*s need to brainstorm throughout the development of educational activities. This process is also closely related with the evaluating phase under formative evaluation. During formative evaluations, after *SCE*s prepared the draft educational activities, they brainstorm on the activities with other colleagues. This brainstorm session plays a mediator role between designing and developing phases while contributing to formative evaluation. This session includes others' revisions and feedback on the functionality of the activities, the reflectivity of conceptual elements, and the diversity for addressing different subjects. Since these brainstorming sessions set a bridge between design and developing phases, the designing-developing phase might be systematized by defining the sub-issues to evaluate each prepared activity. A rubric fitted to science centers' purpose, available materials, and available human resources might simplify the phase.

*SCE*s who stated that they have been taking school teachers' feedbacks, subject matter experts' feedbacks working in universities, and addressing to school curriculum on their draft activities either prepared for workshops or demonstrations as a part of school visits. Formative evaluation brings positive aspects for the design-development phase. For simplifying formative evaluation, a rubric may be prepared for the educational activities so that more subject matter experts may evaluate short time duration. These rubrics may support draft activities assessment objectively. In the scope of the designing-developing phase, *SCE*s stated that they also consider educational space for arranging materials, including workshops and exhibition units, to provide a smooth transition between different conceptual elements.

The implementing phase, on the other hand, revealed three themes as sequencing instruction, the use of instructional methods, and the use of sequencing instruction methods. First, sequencing instruction is an essential theme divided into three stages as preparation, guidance, and free-exploration. In the preparation stage, science centers prepare teachers before the visit and specify the school visit group size. Science center's handbooks, teachers' visits to science centers before the school group visit, and pre-trainings by *SCE*s were the preparation ways of the science center visit for the teachers. Among 13 participated science centers, 8 of them declared to conduct the preparation stage. Although it satisfies the majority of the science centers, the inoperative function of this stage is discussed at the current organizational practices. All aside, the preparation of teachers for the science center environment before school group visits is essential to enhance educational effectiveness. Thus, teachers get knowledgeable on how they can orient the students during the visit, how they can relate the exhibition units with the associated lesson objectives, and how they can develop an effective collaboration during the school group visits with science centers.

Although few science centers reported, they involve teachers for the decision-making processes regarding the relevance of lesson objectives with prepared instruction or handbooks, which are including quick information regarding exhibition units and duties that will be held on science center environments. Unfortunately, few teachers can get involved in educational processes throughout the school group visits. Although the preparation stage was determined to be implemented for an effective school group visit both to include teachers into the processes and make students gain targeted information and skills besides providing enjoyment, efficient ways to involve teachers during the preparation stage preserves its difficultness due to barriers in regard with collaboration. However, the effective implementation of this preparation phase may also facilitate the effective integration of teachers in guidance and free-exploration phases. In addition to the preparation of teachers, specifying school group sizes by considering the available educational space is another practice in the preparation phase. Large school groups are being accepted for a visit by considering factors such as available educational space, available *SCE*s, and teachers. The motivation behind this implication is that the probability of having communication with *SCE*s and teachers, allocating adequate time duration for exhibition units, and not having a similar experience of students on science center visit decreases. Keeping school groups in absolute numbers may increase the probability of having equivalent learning experience during school group visits to the science center.

Second, the guidance stage during instruction revealed eight sub-stages as the activation of pre-knowledge, demonstration, asking questions, taking responses, giving feedback, giving roles to students, giving examples, and connecting the subject matter with daily life or other exhibition units. Although the order of sub-stages may vary depending on the science center environment and differences in *SCE*s' characteristics, sub-stages begin with activating pre-knowledge by story-telling on the subject matter and end with relating the information to another exhibition unit or daily life. In particular, during the transition to each exhibition unit, to provide meaningful learning opportunities for the students, the exhibition units are associated with each other or with daily life examples.

Finally, the free-exploration stage of the instructional sequence allows students to decide to select the exhibition units they will engage freely. The level of social interaction between students, science center educators, and teachers is a vital factor in fostering students' learning activities. This stage also allows observing students' metacognitive processes under planning, monitoring, and evaluating sub-processes. First, based on *SCE*s' verbal accounts, three science centers observe the students during their planning of the exhibition unit by setting a learning objective, reading the information and obtaining the necessary pre-knowledge. This finding suggests that few of the science center educators are aware of the students' planning activity during their self-learning.

Similarly, for monitoring, few *SCE*s mentioned students try to achieve the purpose of the exhibition unit by trial and error method, inspects whether she acquires new information, and shows help-seeking behaviors when she realizes she cannot achieve success for her identified objective. Also, for the evaluating, one *SCE* reported students might follow their progressive improvements and check the whole process they have engaged in the exhibition unit in a summative manner. within science center environments during self-learning activities.

The use of instructional methods is an essential issue during the implementing phase declared by all science centers. This theme collected under four stated learning theories as collaborative learning, inquiry learning, learning by doing, and meaningful learning. The selection of the appropriate instructional method during implementing depends on the content and learner characteristics. Besides, during *SCE*s define the instructional sequence for the school visit groups, a content organization such as abstract to concrete and simple to complex chains. Also, *SCE*s use a time-duration (mental break) to allow students to decrease their cognitive load. However, it seems that science centers do not consciously take students' cognitive loads into account. Revealing such processes is also essential to offer practical instructions.

Finally, evaluating is a pivotal phase interconnected to each phase. Interconnection with analyzing, designing-developing, and implementing occurs as formative evaluation; whereas, the end of the process results in the summative evaluation. Summative evaluation of educational practices within the science center divided into two evaluative processes as process evaluation and student evaluation. First of all, process evaluation refers to summative evaluation and renewal of educational activities regarding the level of security, intelligibility, satisfaction, and difficulty. One reason for the importance of the process evaluation is to take the materials and educational processes into account at the same time. Also, it tries to understand what kind of effects constructed materials have on each agent of the science center visit. Second, student evaluation refers to the tracking of students to evaluate their performance promptly. It is also critical for the science center visits both to inform science centers on their educational effectiveness and to tighten the collaboration among schools and science centers.

As another critical issue designing instruction reveals a stepwise circular process in which has the stages as analyzing, designing-developing, implementing, and evaluating. It seems that the evaluating stage has a bidirectional interrelationship with others. Also, designing and developing are interoperating at the same stage. The findings showed that while the majority of science centers use process evaluation through observing during implementation and adjusting activities and materials after implementation, a minority of science centers use student evaluation. One reason for this is that science centers have an inadequate number of science center educators to conduct assessment and evaluation activities. Tracking students' behaviors and learning trajectories based on the delivered instruction is a crucial issue to predict future instructional design issues. One possible way for this is to enhance collaboration between teachers, schools, and science centers so that students' progress regarding conceptual learning can be recorded.

Current Organizational Practices

The research question of "What are the current organizatiol practices in science centers?" revealed four issues to assure a foundation of a prescriptive instructional design model based on the science centers' current organizational practices. These were collected under four sub-categories as barriers, expectations, needs, and solution attempts. Each sub-category has common themes and sub-themes to draw the portrait of an instructional design process of science centers.

*SCE*s' perceptions revealed four essential issues related to *educational space, teachers' effective participation, human resources,* and *maintaining sustainability.* And, these four facets are closely related to each other and the instructional design process of the science centers. From a holistic perspective approach, the *lack of personnel* is an important factor to offer diversed educational activities making sense for the students' conceptual understanding, maintaining sustabinability and arranging education space to satisfy the students' learning needs. To overcome this barrier, school-science center partnership may offer a long-run positive effect on reducing the results of *restricted human resources.* Houseal et al. (2014) concluded teachers take a mediator role within a student-teacher-scientist partnership programs. Similarly, Tal and Steiner (2006) reported that teachers who involved in the planning the science center activities within a teacher-science center partnership program, the educational activities had higher qualities. Besides, recent studies from Turkey reported a gap between teachers' expected and actual science center activities (Karademir et al., 2020). Thus, the high level of collaboration between school-teacher and science centers may both compansate the *human resources* barrier, and provide a systematic approach to material and method selection for better conceptual understanding.

Besides, *educational space* is another essential issue for organizational practices. In this respect, the congruency between learning objectives and exhibition units is important which may facilitate the design and implementation of a teaching sequence (Roberts and Lyons, 2017). To provide these information for the congruency, interaction design for exhibition units may be one of the essential issues for defining the *educational space*. Recent research by Roberts and Lyons (2017) argued the reason why interaction between visitors and interactive exhibits did not produce more learning talk might be the fluency of actions. Such kind of research may be useful to specify the needs of exhibit design based on a sociocultural theory perspective that wants to make visitors engage in exhibits in a meaningful way (gaining learning outcome compatible with learning objective). Considering the essential factor in exhibit design, the compatibility of learning objectives with the exhibition units is a critical issue. In other words, compatibility refers to establishing linkage between the design of the exhibit and classroom teaching unit, which may facilitate the design and implementation of a teaching sequence adopted to the science museum visit. In addition to the compatibility of learning objectives, clarity of the learning objectives of the exhibits is vital for specifying the teaching sequence. As the content and learning objectives of the exhibits are easier to make sense, for the design of a guided visit to the science museum may consider setting a bridge between goals of exhibition units and lesson unit objectives by teachers. Chen, Xin and Chen (2017) proposed that context-aware technology developed as a guide-tour may have long-term benefits by making visitors concentrate on each task rather than skipping them after a quick engagement. Thus, being aware of the context during the guided tour may result in higher level of students' conceptual understanding.

Different types of exhibits were stated as having the possibility to foster students' conceptual understanding differently (Afonso and Gilber, 2007). Afonso and Gilber (2007) reported that analogy-based exhibits needed for showing relationships rather than only entities to trigger causal explanations among visitors compared to the exhibits as examplars of phenomena. This might show that prior knowledge is an essential factor for making sense of the exhibition unit. However, if a learner has no prior knowledge, the educative value of the exhibition unit may be questionable regarding the conceptual understanding.

Indeed, although Stocklmayer and Gilbert (2002) assured that engaging in exhibits can provide experiences to set memories regarding the subject matter which may also be useful in making sense of the subsequent exhibit, Afonso and Gilbert (2006) found that even the similar exhibits under the same subject are connected in a pedagogical chain, visitors were not showing connections related to subjects in a short-time period. Afonso and Gilbert (2006) proposed that the previous knowledge of the visitors can be triggered to reveal the educative value of exhibits as exemplars of phenomena. Although this implication proposal seems to target at designing the exhibits by considering learners' spontaneous behaviors and evaluations regarding their immediate experiences, a holistic design not only targeting at a single exhibit but also targeting at design sequence for similar exhibits connected in a pedagogical chain. For setting these relations in physical and conceptual levels, worksheets on a specific subject matter area rather than only relying on the texts on exhibits may be prepared for the guidance as an educational and organizational practice as well.

Conclusion for Current Organizational Practices

Based on barriers, needs, expectations, and solution attempts based on *SCE*s' perceptions, four issues related to *educational space*, *teachers' effective participation*, *human resources*, and *maintaining sustainability* come to the forefront. Considering *human resources* issues to provide more effective educational activities in science center settings, the lack of personnel is a factor preventing the diversification of educational activities. Science centers seek to find a solution to remove this barrier. Educational activities comprise guiding visiting school groups, preparing summer and winter camps, preparing workshops for both students and public people on a variety of concepts, giving science center experience for students in rural areas with limited access to the science center, and many other activities. Including organizational and educational aspects, *SCE*s are able to make the task distribution without a separate unit.

*SCE*s' verbal accounts showed that volunteer guides, among especially university students and student assistants are human resource providers way to compensate for this deficiency. In few science centers, educational and organizational processes are recognized as different units and human resources congruent to these departments can be supplied. Thus, effective workload distribution can be made within science center employees.

In addition to lack of human resources, barriers and needs related to *educational space* were mostly stated as an essential factor for providing different activities to satisfy learning objective needs and enrich conceptual diversities. First of all, lack of wet-ground laboratories which make it difficult to offer students different options for conducting experiments in the scope of their science courses, and lack of exhibition unit for various concepts and subject matter areas were stated as an issue for educational space. Wet-ground laboratories are essential in terms of providing a suitable environment for the concepts that can be tested by the experiment under the subject matters of chemistry and biology. Although there are schools with science laboratories, *SCE*s mentioned about their absence of functionality and effectiveness. Moreover, unsupplied materials and non-existence of experimental books regarding each concept make the use of wet-ground laboratory environment difficult within the school.

Science centers in Turkey seem that they are aiming to provide opportunities that students do not have in their schools, having wet-ground laboratories in the scope of science centers may also be envisaged to maintain sustainability. Besides, there are concepts that the present exhibition units do not meet in the school curriculum, or more than one exhibition unit occupies a wide area with a single focus regarding the subject matter area.

In addition to the educational space issue, *effective involvement of teachers in educational processes within science centers* was perceived by *SCE*s as providing a reciprocal feedback mechanism among school and science center regarding the improvement in knowledge, skills, and experiences for educational activities. In case the teachers cannot be actively involved in the educational processes within science centers, it imposes an impediment in itself regarding enhancing educational effectiveness. Science centers are disengaged from the school curriculum unless workshops and field-trips are made by resorting to the teachers' opinions.

Finally, *maintaining sustainability* can include the first three issues which can form the cornerstones of educational effectiveness. *SCE*s have already stated that they do not have sufficient knowledge to maintain sustainability in science centers, except for the efforts to organize summer or winter camps and to diversify their workshops for maintaining sustainability.

5.1.2 Multiple Case Study

Multiple case part of this study was conducted by a total of 111 students (for guidance session) and 72 students (for the collaborative session) currently from 7th grades. In parallel with the lesson units, students visited science centers for pre-determined learning objectives. Three lesson units, including *Work and Energy, Mirror and Light Absorption* and *Solar System and Beyond* and appropriate exhibition units to these lesson units, in either Feza Gürsey *SC* or Kocaeli *SC,* were selected. First, in the guidance phase, based on *SCE*s' and students' guidance phase video data, conceptual diagnostic paper and science dairies, the implicit metacognitive actions of *SCE*s and students' conceptual understanding were discussed. Second, the collaboration phase was examined under the scope of students' individual and inter-individual metacognitive processes. In this phase, students' exposure to the prepared worksheets and pre-determined exhibition units provided vital tools for the researcher. Thus, students' implicit and explicit metacognitive actions were discussed under the associated research questions.

The indicators of implicit metacognitive actions of SCEs interacting with students through the guidance phase (RQ2)

The results revealed differences between the sub-processes which are orientating, planning, monitoring, and evaluating. While planning had the lowest frequency for *SCE*s' metacognitive action, the highest frequency was for monitoring action. Under the *orientating* process, informing task subjects and constitution (ITSC), activating prior knowledge (APK), and relocating (RL) had the higher frequencies compared to other sub-themes. Besides, under the *planning* process, developing action plan *(DAP)* had higher frequencies compared to considering alternatives for conceptual understanding (CACU). And, under the *monitoring* process, claiming understanding (CU) and noticing a lack of comprehension (NLC) revealed the had higher frequencies during the guidance phase. Also, component structuring (CS) and demonstrating comprehension by repeating (DCP) under the *monitoring* process had the lowest frequencies. Finally, under the *evaluating* process, checking (CH) had higher frequency commpared to reflecting (RF).

The difference between the sub-themes under each theme might be caused by three issues: (a) *exhibition unit characteristics*, (b) *SCEs' way of instruction*, and (c) *the nature of the scientific concepts*.

(a) *Exhibition unit characteristics*: The characteristics of the exhibition units may influence *SCE*s' content orientation (CO). Thus, *SCE*s' content orientation might be affected either for they frequently refer to activating prior knowledge or refer to hypothesizing. Marek, Boram, Laubach and Gerber (2002) differentiated the exhibition units as an interactive science exhibition requiring hypothetical-inductive reasoning and requiring empirical-inductive reasoning. Based on this categorization, according to *SCE*s' implicit metacognitive actions during the guidance phase, out of 15 exhibition units, four of them could be categorized under the exhibition units requiring empirical-inductive reasoning; whereas, 11 of them could be categorized under the exhibition units requiring hypothetical-inductive reasoning.

    The exhibition units requiring empirical-inductive reasoning were "Air Bubble Race", "Bernoulli's Ball", "Pedal Force", and "Measure Your Power" that provide students active observation and participation to the conceptual understanding process. This *active observation* might decrease the need for hypothesizing. On the other hand, exhibition units requiring hypothetical-inductive reasoning had higher number of units selected for the guidance phase which were "Guess Who Wins", "Countless Colors", "Monochrome Room", "Touch the Spring", "3d Sand Pool", "Hot Air Balloon", "Sand Pendulum", "Infinite Views", "Color Shadows", "Color Removal", and "Press Test". Thus, the characteristics of exhibition units might be the weakest reason for *SCE*s' *use of hypothesizing* during the content orientation rather than activating prior knowledge.

(b) *SCEs' way of instruction (SCEs' instructional strategy*): At the study of the current practice, *SCE*s mentioned about their instructional strategies during the guidance period. Participated *SCE*s stated four instructional methods to be used during the guidance as collaborative learning, inquiry learning, learning by doing, and meaningful learning. Although within the current practices study, there was not any investigation on the instructional strategy of the science center educators during the guidance, the difference between *SCE*s' approach for instruction might be the reason for the difference in the number of frequencies that *content orientation* has. Activating prior knowledge was frequently used by the science center educators by using conceptual relations.

(c) *The nature of the related concepts:* The nature of the scientific concepts might influence the number of frequencies of *SCE*s' orientating activities. First of all, the work and energy unit includes force, air pressure, liquid pressure, solid pressure, energy, and energy transformation concepts to be understood by the students.

Conclusion for RQ3

*SCE*s' implicit metacognitive actions revealed four categories from a total of six videos, including three science center educators. These categories are (a) ***orientating****,* (b), ***planning*** (c), ***monitoring****,* and (d) ***evaluating***. During the guidance session, the number of frequencies that the orientating reached out was 248; whereas, the planning action reached out 66. On the other hand, the monitoring action revealed 387 occurrences, and the evaluating resulted in 230 occurrences. The results showed the highest number of frequencies for monitoring and the lowest quantity of frequencies for planning activities.

Orientating action resulted in three themes as *content orientation*, *guide orientation,* and *task analysis*. The results showed a balanced orientating activity of *SCE*s considering these three themes. However, there exist differences in the numbers of frequencies for their sub-themes. For the *content orientation*, activating prior knowledge had lower frequencies compared to hypothesizing. Also, for the *guide orientation*, relocating had higher frequencies compared to providing turn-taking. Finally, the *task analysis* sub-theme revealed a higher number of frequencies for informing task subjects and the task constitution.

Planning action resulted in two themes as *considering alternatives for conceptual understanding* and *developing an action plan*. *Developing an action plan* had a higher number of frequencies compared to *considering alternatives for conceptual understanding.* Although the second sub-theme might be thought under the *developing an action plan,* it differentiates. In detail, it refers to the connection of the subject matters and *SCE*s' influence on this relation by using a variety of thinking strategies.

Also, ***monitoring*** revealed three main themes as *monitoring of strategy use*, *monitoring of progress*, and *comprehension monitoring*. While *monitoring of strategy use* and *monitoring of progress* were directly related to *SCE*s' metacognitive activities, *comprehension monitoring* had an indirect relationship to *SCE*s' metacognitive activities. The indirect contact for *comprehension monitoring* means that students showed the stated activities which might be observed by the *SCE*s to specify the flow of the guidance. The results showed students noticed the lack of comprehension and claiming understanding during the guidance of *SCE*s. Showing the level of conceptual understanding might mean that during the guidance, students tended to indicate their levels of conceptual understanding to feed the *SCE*s' actions.

Finally, ***evaluating*** revealed two main themes as *checking* and *reflecting.* The results showed that *checking* action had a substantially higher number of frequencies compared to *reflecting* action. The higher number of checking might show that *SCE*s have a tendency to check students' level of conceptual understanding during the guidance rather than reflecting what they have done throughout the guidance. This *checking* activity might show a similar tendency with the *claiming understanding* and *noticing a lack of comprehension.* Since *SCE*s might check the levels of conceptual understanding of the students, they might monitor them as well for the flow of the guidance.

Baseline: Students' experience of the science center visit during their science lesson hour (RQ2ai)

RQ2ai was a baseline question to understand students' science center visit experience after the visit. The results acquired by the guidance science diaries of students revealed four main themes as (a) *exhibition unit preference*, (b) *limited interaction with science teacher*, (c) *making sense of exhibition units*, and (d) *evaluation of science center visit*.

Students' *exhibition unit preferences* were seen to depend on their conceptual interest, dynamicity of the exhibition unit, and the physical characteristics of the exhibition units. They mostly stated to prefer the exhibition units having the opportunity to use them actively. The reason for these preferences might be caused by three reasons such as (a) students' need for collaboration, (c) students' need for being motivated by a competitive environment, (d) students' need for active interaction with the exhibition units.

Students' *limited interaction with the accompanying science teacher* is caused by their interaction with peers, taking guidance from the science center educators and reading information on the exhibition unit. The students stated these interactive behaviors for their limited interaction with the science teacher during the science center visit.

The students stated that they are *making sense of exhibition units* by four ways which are (a) *reinforcement of learning for a science course*, (b) *relating exhibition units with scientific concepts*, (c) *relating science center experience with school course*, and (d) *transferring conceptual knowledge to daily life usage*.

Finally, students evaluated *their science center visits* based on either feelings or procedures. They stated they felt curious, exciting, happy, normal, and tired during and after the visit. On the other hand, they said they would want to have more exhibition units, more interaction with exhibition units, and more time to visit after their science center visit. 54 students out of 80 stated they were happy during the visit. However, five students did not mention their feelings as a positive one. Although the percentage of students indicating positive feelings after the science center visit had higher numbers compared to students who mentioned negative or neutral feelings, the reason for their non-positive feelings should be understood.

Change in scientific conceptual understanding levels for selected concepts of students in alignment with SCEs' implicit metacognitive actions (RQ2a)

For this research question, there were three distinct lesson units connected with previous knowledge to each other. These were *work and energy, mirrors and light absorption,* and *solar system and beyond.* However, due to technical problems, the association of *SCE*s' implicit metacognitive actions to the solar system and beyond lesson unit could not be done. Thus, although this part discusses the levels of students' conceptual understanding based on their diagnostic papers for each lesson unit, it will discuss the alignment of metacognitive actions to the levels of students' conceptual understanding for work and energy, and solar system and beyond lesson units.

Work and Energy

Work and energy lesson unit included two divided weeks as force and pressure and energy transformation. The related scientific concepts for the first part, force and pressure, were <height, pressure, surface area> for 3d Sand Pool, <density, liquid pressure, height, force> for Air Bubble Race, <air, pressure, force> for Bernoulli's Ball, <density, pressure, gas, gravity force, expansion, hot air> for Hot Air Balloon, and <force, friction force, resultant force, gravity force> for Sand Pendulum. On the other hand, the scientific concepts for the second part, energy transformation, were <energy, mass, weight> for 3d Sand Pool, <gravitational potential energy, kinetic energy, force, energy, pressure, work, air energy> for Measure Your Power, <potential energy, kinetic energy, force, mass, weight> for Guess Who Wins, and

<kinetic energy, force, energy, electrical energy, work, energy transformation> for Pedal Force.

The correct and incorrect uses of the scientific concepts within the conceptual diagnostic papers after the science center visit indicated in which manner students used the related scientific concepts whilethey were mentioning about their relation to the guided exhibition units. First, for the force and pressure part, <pressure, liquid pressure, density, air, gas, hot air, force, and resultant force> were frequently used in the correct way. On the other hand, <layer> was the concept often being used in an incorrect way for 3d Sand Pool. Also, students used <pressure, weight> concepts in an incorrect way for the Sand Pendulum. Although the number of frequency for the correct use of the force and pressure concepts was higher compared to the incorrect use of the concepts, it is vital to understand why students used the incorrect ones while they were relating them to the guided exhibition units.

3d Sand Pool was the exhibition unit to understand solid pressure and its relation to the surface area by referring to daily life examples. Although it did not directly intend for force and pressure lesson units, the science teacher offered to use it to acquire the causal relationship between these concepts. 3d Sand Pool originally intended to demonstrate a 3d physical map and to deliver instruction about what each layer on the map accounts for. Although the guidance of science center educators altered students' minds in constructing a causal relationship between the surface area and the solid pressure on the sand surface, there were many students for whom the instruction did not alter their mindset related to the exhibition unit. This might show that although physical relatedness to the instructed scientific concept is a vital variable in making sense of the exhibition unit to alter students' mindsets, it is most probable that most of the students use the physical appearance with the initial purpose of the exhibition unit regardless the delivered instruction.

Besides, Sand Pendulum was the exhibition unit to activate students' prior knowledge regarding the force concept. In addition to a few students' uses of friction force concept, they also mentioned pressure concept within their conceptual diagnostic papers. There may be more than one reason why the scientific concept, in the scope of the lesson unit, is associated with the non-relevant exhibition unit. These reasons might be collected under three issues as (a) *no retention of the exhibition unit's working principle*, (b) *misconception or no understanding of the scientific concept*, and (c) *ineffective guidance for different science learning performers*.

(a) *No retention of the exhibition unit's working principle*: Due to the hypothetical-inductive nature of the Sand Pendulum exhibition unit, students might not recall the working principle of the exhibition unit. Also, since it was the first exhibition unit to activate their prior knowledge on the force concept, they might not focus on the working principle of it during the guidance.

(b) *Misconception or no understanding of the scientific concept*: The incorrect use of the pressure concept might be due to students' misconceptions or no understanding of that concept.

(c) *Ineffective guidance for different science learning performers*: Science center educators' instructional strategy might not be effective as to reach out the low-performer students.

Second, the related concepts for the second part, energy transformation, were <energy, mass> for 3d Sand Pool, <kinetic energy, force> for Measure Your Power, <potential energy, kinetic energy, mass, weight> for Guess Who Wins, and <kinetic energy, energy, energy transformation, force, electrical energy> for Pedal Force. Besides, there were few incorrect uses of the scientific concepts related to the energy transformation part. Although they were few, it is essential to understand the reason why <force, pressure, and friction> concepts were used incorrectly.

In energy transformation week, the learning goal of the 3d Sand Pool was to make students distinguish potential energy and kinetic energy concepts and the dependent variables of them. One of the students used <pressure> concept within the conceptual diagnostic paper. Although this student was in a minority of incorrect users for the <pressure> concept, the reason why the student mentioned pressure might be the students' previous mindset related to the exhibition unit. Since in the first week, force and pressure, students were instructed for the <pressure, surface-area> concepts on 3d Sand Pool, the student might recall back the concepts from the previous week. There may more than one reason why a student recalls back the concepts of the prior instruction and does not connect the exhibition unit to the current subject matter. These reasons might be collected under two issues: (a) *the excessive amount of the information load*, and (b) *embedded affordances not belonged by the exhibition unit*.

(a) *The excessive amount of the information load*: The incorrect use of the pressure concept might be caused by the first week of the guidance period. Since students were instructed for different scientific concepts by using the same exhibition unit, this might cause a distraction on students' mindsets regarding the relatedness of concepts to the exhibition unit. Although these instructed concepts were conceptually contiguous, students might be distracted by the excessive information load. The elimination of the distractive elements might require a balanced instructional design to reduce the cognitive load.

(b) *Embedded affordances not belonged by the exhibition unit*: Since the science center educators used three balls as tools that are not a part of the exhibition unit for potential energy and kinetic energy concepts and their independent variables, this instruction might not create concept integrity with the exhibition unit.

Mirrors and Light Absorption

Mirrors and Light Absorption lesson unit had <color, reflection, mirror> concepts as being frequently used in the correct way. Although the stated concepts were used in the correct way, students rarely mentioned any specific concept related to the exhibition units. These concepts were <absorption, light reflection, concave mirror>, and <flat mirror>. The reasons why students did not indicate specific concepts to demonstrate their levels of conceptual understanding might be (a) *the dominant* *conceptual terms in everyday life usage*, and (b) *the abstract nature of the absorption concept*.

(a) *The dominant conceptual terms in everyday life usage*: Color, mirror and reflection concepts are few of the commonly used everyday concepts. This common usage might result in overgeneralization while students were answering regarding their science center visit experience for the instructed concepts. Although students gave examples regarding the specific scientific concepts from their daily life usage, they might prefer to state the generalized terms without mentioning the exact conceptual name. However, this could be counted as a problem since the learning objectives would not be satisfied by referring to the concept. Also, it might infer that students' levels of conceptual understanding did not go beyond the surface-level understanding. Thus, a rating scale was needed to differentiate students' levels of conceptual understanding.

(b) *The abstract nature of the absorption concept*: Although students frequently used general concepts of <color, reflection, mirror>, they rarely used <absorption> concept. Unwritten results and field-observation showed that although students mentioned light absorption and gave examples for it considering their daily life experiences and color-related terms, they rarely mentioned the absorption term. The abstract nature of the <absorption> concept might not trigger to use it while students were making sense of the exhibition units.

Solar System and Beyond

Solar System and Beyond lesson unit had <constellation, star, gravitational force, planet, black hole, distance to sun> concepts for the correct use of the scientific concepts. Whereas, just one student used the galaxy concept in an incorrect way for the Summer Sun Winter Sun exhibition unit. The reasons why the students frequently used correct concepts while they were relating the concepts to the exhibition units might be (a) *students' readiness levels*, (b) *exhibition units' comprehensibleness*, and (c) *the nature of the subject matter*.

(a) *Students' readiness levels*: Participant students did inquiry and presentation within groups on the solar system and beyond lesson unit before they visited the science center. Thus, this might increase their readiness levels for the subject matter and facilitated to relate the scientific concepts to the exhibition units. The guidance procedure was the same for all lesson units. However, in *Force and Energy* and *Mirrors and Light Absorption* cases, students did not engage in inquiry learning in-class activities. This difference in teachers' style of teaching might have a positive influence on students' readiness levels.

(b) *Exhibition units' comprehensibleness*: Exhibition units in *Solar System and Beyond* lesson unit targeted at acquiring the concepts of <constellation, black hole, solar system>, and <planets>. The physical appearance of the exhibition units fitted to the subject matter area within a close-distance environment. The proximity of the related exhibition units might provide conceptual integrity. Due to the closeness of the spatial locations of the exhibition units having the antecedent concepts under the solar system and beyond lesson unit, students might construct a complete mindset regarding the concepts.

(c) *The nature of the subject matter*: In addition to the comprehensibility of the exhibition units, the nature of the concepts included in the solar system and beyond lesson unit might result in a higher number for the correct use of the concepts.

Work and Energy, Mirrors and Light Absorption, and *Solar System and Beyond* lesson units had similarities and differences related to the correct and incorrect use of the associated concepts. By looking at the overall results, while *Solar System and Beyond* revealed the less incorrect use of the associated concepts, *Mirrors and Light Absorption* revealed the least correct use of the associated concepts. On the other hand, *Force and Energy* revealed the most incorrect use of the concept in addition to its higher number of frequencies for the correct use of the concepts. The reasons of the trend variabilities between these three subject matters might be collected under five reasons (a) *the nature of the concepts*, (b) *the nature of the associated exhibition units*, (c) *the science center educator's effect*, (d) *the guidance path*, and (e) *the teacher's effect.*

(a) *The nature of the concepts*: Concepts included in the *Force and Energy* lesson unit have the nature of directly observable by daily life experiences.

(b) *The nature of the associated exhibition units*: *Force and Energy* lesson unit included both empirical-inductive reasoning and hypothetical-inductive reasoning as a requirement during the students are experiencing the exhibition unit.

Also, *Mirrors and Light Absorption* lesson units included exhibition units requiring hypothetical-inductive reasoning.

Finally, the *Solar System and Beyond* exhibition units require hypothetical-inductive reasoning.

(c) *The science center educator's effect*: Science center educator's implicit metacognitive actions might have a vital role in students' correct use of the scientific concepts.

(d) *The guidance path*: The guidance path refers to the spatial location where students, science teachers, and science center educators took during the guidance period. It also includes the transitions between the selected exhibition units.

(e) *The teacher's effect*: Teacher's contribution before, during, and after the science center visit might affect how students used the scientific concepts in relation to the exhibition units.

In addition to correct and incorrect use of the scientific concepts, the levels of students' conceptual understanding were detected for each lesson unit. For the *Force and Pressure* week under *Force and Energy* lesson unit, Air Bubble Race resulted in the highest number of sound understanding levels and the least number of misconceptions. The reason why students made sense of the Air Bubble Race exhibition unit might be assigned to its empirical-inductive nature. However, it also resulted in a higher number of frequencies for no understanding. The higher number for the level of no understanding might demonstrate that although it is easier to make sense of Air Bubble Race, it might also result in no understanding but at least a few misconceptions on students' mindsets. Air Bubble Race provides a competitive environment for the students and facilitates the comparison between three liquids having different densities. Thus, students might have a chance to observe the differences between each liquid. They have an affordance, pump, to activate the bubbles and the tubes have the same height. Science center educators refer to these concepts that could be observable and provided a concrete schema for the students. Thus, students could compare the largeness and the velocity of the bubbles referring to the physical appearance of the exhibition unit underlying the independent variables which are density and height. It might divide students into two positions: (a) *enjoying the Air Bubble Race by observing the physical change,* and (b) *observing the physical change by referring to underlying variables for it*.

Besides, Hot Air Balloon revealed the highest number for the misconception. Besides, the results showed that most of the students had misconceptions for the Hot Air Balloon. However, a majority of the students had partial or sound conceptual understanding levels. The reason why Hot Air Balloon revealed the highest number of frequencies for the misconception could be the hypothetical-inductive nature of the exhibition unit. The students' misconceptions included the reverse association of the Air Balloon movement with the density.

For the *Energy Transformation* week under *Force and Energy* lesson unit, Pedal Force revealed the highest number of students having partial or sound understanding levels. On the other hand, a reputable amount of students was in the scope of the no understanding level. Misconception shown by the students included the matching of the unrelated concept with the working principle of the exhibition unit.

For the *Mirrors and Light Absorption* lesson unit, students had the highest understanding level for Touch the Spring. Also, students had emergent understanding levels for the Countless Color exhibition unit. However, Monochrome Room might be seen as difficult for the students to acquire the concepts due to the important number of students included in no understanding level.

For the *Solar System and Beyond* lesson unit, students neither had misconceptions nor were included in the level of no conceptual understanding for the Constellation Viewer exhibition unit. Also, students understood the concepts related to the Solar System Model exhibition unit partially or completely except one student.

Students' individual and inter-individual metacognitive processes (RQ3-RQ4)

The results revealed differences between the sub-processes which are orientating, planning, monitoring, and evaluating. While planning had the lowest frequency for *students*' metacognitive action, the highest frequency was for monitoring and evaluating actions. Under the *orientating* process, activating prior experience from the guidance session had the higher frequency compared to others. Besides, under the *planning* process, interim planning had higher frequencies for distributing the role of duties by referring to self-experience. And, under the *monitoring* process, detecting task demands by reading had the higher frequencies. Finally, under the *evaluating* process, checking completeness of their conceptual understanding had the higher frequencies compared to correctiveness and effectiveness of the conceptual understanding.

Besides, looking patterns also divided into four sub-groups referring to environmental factors as *looking at worksheet, looking at environment, looking at peer,* and *looking at the exhibition unit.* The results showed that the highest frequencies revealed for *looking at peers when matched-eyes occur, looking at the exhibition unit by focusing its components, looking at the image on the worksheet,* and *looking at worksheets during reading text alouds* and *tracking other's* reading.

The reason for the highest frequencies for looking at peer by matched-eyes might be caused by ***shared previous knowledge***. Richardson, Dale and Kirkham (2007) investigated whether the shared previous knowledge has an effect on conversants' shared visual context. They stated that shared background knowledge directed by given to each conversant before they are engaging in the conversation also leaded to eye movement coupling among conversants. On the other hand, the afformentioned study might be questionable to understand whether shared visual context is solely due to the same background knowledge or it might also depend on each conversant knows that they each know the same information. So, the need for understanding the shared previous knowledge or constructing a shared knowledge for the future actions might cause higher frequencies for the matched-eyes. As a complementary study, Choi (2010) investigated shared metacognition in integrative negotiation aiming at resolving the perceived difference of person's interest. He letted dyads to know whether they know the information or not. Results revealed that shared metacognitive manipulation made a difference on perceived attributes to others. So, not only sharing previous knowledge, but also ensuring other's knowledge might reason for the matched-eyes.

Besides, Gregory and Jackson (2018) stated that gaze cues influenced working memory in case that little goal-directed behaviors of others do not reveal engagement in perspective taking while loaded goal-directed behaviors result in perspective taking. This may be caused by adopting perspective taking strategy may be dependent on the person variable knowledge as a goal specific and unique behavior which may be reflected in case of the needs. And, this need may be also dependent on the fact that sharing the perspective of others may also lead to ***share their short-term goals to predict the next step*** in the social interaction episode. As a complementary finding, matched-eyes might serve more than one metacognitively oriented action. It might be for planning the future actions, or evaluating the short-term goals by trying to take a confirmation from the collaborative pair.

Looking at worksheet during reading the text aloud and *during tracking other's reading* had also higher frequencies. While *reading the text aloud* accounted for orientating behavior, *tracking other's reading* was about monitoring action. By these looking patterns, collaborator pairs tried to synchronize their situations and these actions might facilitate their argumentation and self-explanation. And, this reciprocal metacognitive activity might increase the conceptual understanding. Rittle-Johnson, Loehr and Durkin (2017) investigated as a meta-analysis in what conditions promoting self-explanation has positive impact on mathematics learning and proposed guidelines for the educators in using self-explanation as an instructional technique. Although many of the stated literatures assured that self-explanation is highly effective on increasing conceptual knowledge and retention of conceptual knowledge after a time-delay as well. In addition, they stated four guidelines for the educators which are to implement self-explanation techniques into their instructional designs as (1) scaffolding high-quality explanations, (2) designing self-explanation prompts considering allocation of attention among important contents, (3) prompting learners for the self-explanation of why correct answers are correct, and (4) prompting learners for the self-explanation of why common misconceptions are incorrect. Why the proposal of aforementioned guideline may be believed to be beneficial in far-transfer learning of conceptual and procedural knowledge is due to *activating learners' prior knowledge* and *monitoring their progress* related with the subject matter.

On the other hand, higher frequencies for *looking at exhibition unit by focusing on its components,* and *looking at the image on the worksheet* might be caused by the need for decomposition and decrease the instructional complexity. As a complementary study, Koedinger, Booth and Klahr (2013) mentioned about the constraints for reducing and decomposing the instructional complexity and the suggestions for instructional design regarding the enhancement of educational effectiveness. They stated intervention timing, dosage and instructional technique are the features showing the complexity of instructional design. Similarly, Roediger and Pyc (2012) reported on effective instructional strategies available in the cognitive psychology literature for the implementation into the classroom instruction. They assured that distribution, interleaving and spacing and exploratory interrogation and self-explanation are effective for the long-term learning even though it takes time to learn information in the short-time period. So, when the duration of the instructional sequence extends, then, the need for decomposition may occur for facilitating self-explanation.

In addition, collaborative pairs had higher frequencies for checking similar to metacognitive actions of science center educators. *Checking the correctness of conceptual understanding,* and *checking the completeness of conceptual understanding* were the primary evaluating actions during their collaborative activity. This checking behavior might be caused by students one time evaluation to continue for the next question and planning the future step. As a related study, Sobocinski, Malmberg and Jarvela (2017) investigated self-regulatory processes in a temporal manner based on macro-level processes during low and high-challenge collaborative learning situations. They divided regulation phases into three as forethought, performance and reflection phases while they associated these phases with the types of interactions including cognitive-focused collaborative interaction, socioemotional interaction, irrelevant interaction and no interaction. Results derived by process mining outcomes revealed that in low-challenge collaborative learning situations, learners have frequent switches between cognitive-focused and socioemotional interactions during performance phase after engaging in irrelevant interaction whereas in high-challenge collaborative learning situations, learners switched between forethought and performance phases more by showing higher cognitive-focused collaborative interaction.

5.2 Suggestions

While both educational and current organizational practices of the science centers faced problems due to human resources, educational space and collaborations with stakeholders, few of the science centers offer specific solutions and suggestions considering a holistic approach. Karademir et al. (2019), recently, figured out the problems for science activities among preschool children under four categories as material-related, teacher-related, child-related, and the conditions which shows a similarity with the other target groups. Although this current practices study represented similar findings for educational issues, it also underlied the organizational aspects that have impact on the science center activities as well. And, the perceived metacognitive processes of the students among science center educators and science teachers showed a difference in terms of their depth for the categorization of behaviors related to metacognitive processes.

Finally, three cases aiming at exploring science center educators' metacognitive actions during guidance session and students' metacognitive actions based on different scientific concepts during their collaborative works which tied to the guidance session resulted in differences for the frequencies of metacognitive actions for each subject matter. Also, field notes showed that collaborative pairs showed differences for elicited metacognitive actions regarding their collaboration qualities. Although the levels of collaboration quality was not coded and clustered throughout video analysis stage, researcher's observations during the field work and video analysis offered a decisive path for the emergence of the shared metacognition.

5.2.1 Suggestions for Policy Makers and Practitioners

Suggestions for policy implementations and practitioners were leveled up in the light of the findings of the first and second studies. These suggestions were grouped under five categories as *ensuring quality, distributing roles, extending budget, extending collaboration,* and *encouraging autonomy* (see Figure 5.5). Practitioners include *science teachers, science center educators, researchers* and *instructional designers.* Due to the need for engaging with policy makers, suggestions for both policy makers and practitioners were given in a condensed form.

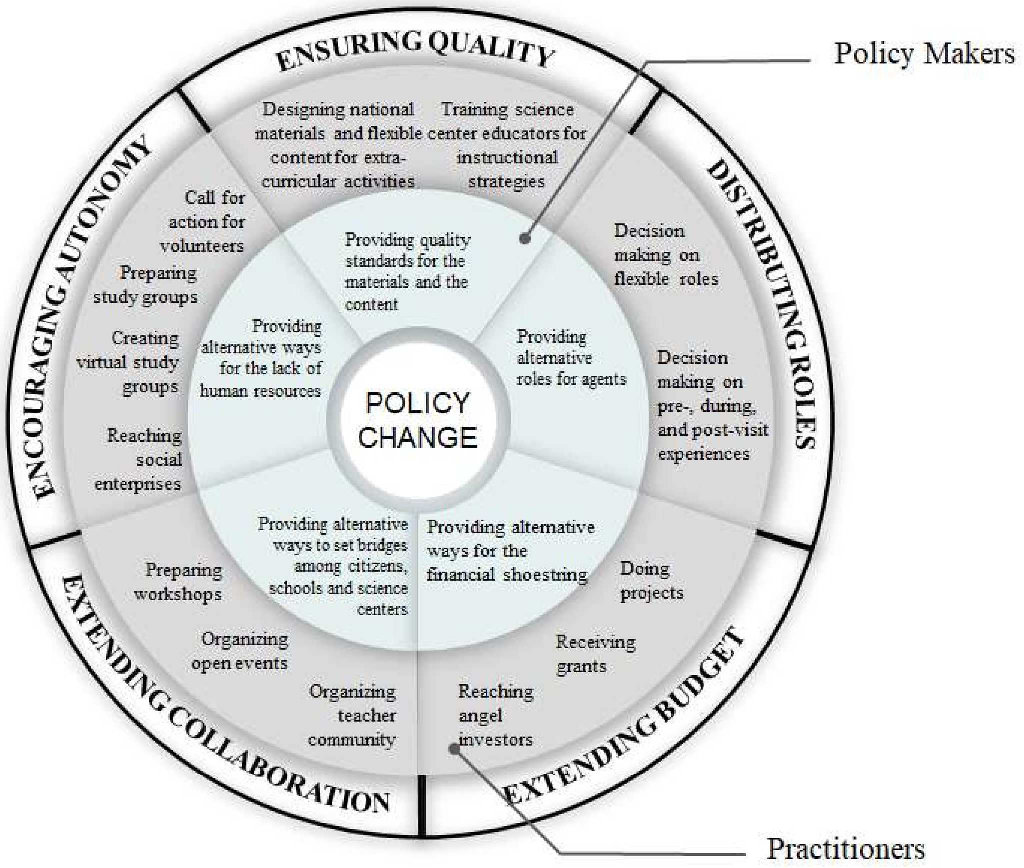


Figure 5.5 Diagrams of suggestions for policy makers and practitioners

Five categories of suggestions for policy makers and practioners pinpointed the alternative ways for filling the gaps to enhance educational effectiveness in science center contexts. However, since the purposes of the science centers and the school environment show differences regarding their motivational factors, nature of the content, nature of the instructional technology, human resource, financial concerns, and the roles adapted by the human agents, the following five categories take aforementioned factors into account for the policy implementations.

(1) ***Ensuring quality:*** Providing quality standards for the materials and the content might be one of the policy implications. Although each science center has experienced based insights on how to arrange exhibition units, how to fix them, and how to relate the curricular content with them, the quality standards for their functional and structural characteristics, and the linkage with the curricular content are considered as insufficient. Also, the lack of instructional materials related to science concepts in curriculum, the lack of guidance for teachers and students for orientating them to the available content, and the lack of time and human resource for science center educators to prepare specific events of instruction for the visit groups cause a barrier to enhance educational effectiveness of science center activities. The following suggestions might be offered for ways of providing quality standars.

a. Teachers accompanying to students were generally in visit-organizer role due to the lack of content related to scientific concepts and phenomena prepared for the science center visits. So, they had a passive role for preparing the students for the science center visits. With the exception of the two existing science centers, other science centers do not offer teachers guides to help students engage and internalize concepts while they are having fun. Even though the guides presented are related to the curriculum, it is not easy to apply the content effectiely in the process, since the teacher did not receive any training on this content before. For this reason, it is recommended that the roles of the teacher, students and science center should be defined flexibly and alternative teaching strategies should be included in these contents while preparing the content.

b. Teachers, while fulfilling the intensive curriculum requirements, do not have enough time to organize trips to the science center and produce materials that can be helpful for these trips. In addition, due to science center educators' lack of experience regarding the classroom dynamics and sufficient pedagogical implications at the first hand, potential activities or instructions during guiding create difficulties in making students active in the science center. For this reason, informing science center educators about teaching techniques and providing on-site orientations may increase the quality of the contents and facilitating making students more active during their guidance.

c. Science center educators and science teachers can also make students active by supporting their metacognitive activities. The results indicate that students prefer the experimental-inductive exhibition unit for being easier to grasp regarding the conceptual understanding compared to the hypothetical-inductive exhibition units. Based on this information, it can be suggested that the content to be prepared may contain directions that support students' metacognitive activities in compatible with the different exhibition units.

d. The content produced in cooperation with science center educators and teachers, Turkey may run on a platform where the used content of the school groups who have visited across the different science centers. EBA can play an important role for the transition to this platform.

e. With the COVID era, the need for content for science centers for different grade levels and supporting the metacognitive activities of students at these grade levels has also increased. Although science centers, which have a private outdoor area within their structural characteristics, produce contents for the workshops by keeping social distance during the implementation in the summer period, it is necessary to share the contents and to increase the qualities of the contents that make students learn while having fun. During this requirement, flexible activities that not only contain content but also serve as orientation should be designed by taking into account the characteristics of the available materials, the presence of the teacher, the number of students and the experience of the science center educator.

f. It may be important that instructional designers also play a role in the preparation of these quality contents. Instructional designers can be one of the pillars that manage the process in the content development and implication, taking into account the available human resource, material, content and target audience.

g. Researchers have a great role in the design of quality content as well. Research findings can be used for the training of science center educators and science teachers, by making researches such as reporting the exhibition units in which students are active or not, what kind of behaviors students demonstrate in the science center, how the readability of the materials are, or how effective the implication of different teaching strategies is for students to understand scientific concepts. Thus, researchers can indirectly support the preparation of qualified content.

h. Instructional design in science center environments in Turkey depends on both organizational and educational practices due to the issues related to human resources, educational space, and partnership with schools and universities. This multi-method study showed that guidence (or science communication), not only in guided-tours but also in free-exploration periods, is a critical factor in enhancing educational effectiveness in such out-of-school environments. So, guidance should be designed in partnerships with different agents.

(2) ***Distributing roles:*** Providing alternative roles for the critical agents of science center visits including teachers, science center educators, students, researchers, and instructional designers may be a suggestion for the policy makers. It seems from the findings that each agent has different but intersected roles; however, for achievning learning objectives in align with the science center fundamental purpose (learning during entertaining), there may be roles for each critical agent.

a. Decision making on flexible roles and decision making on pre-, during, and post-visit experiences may be two alternatives for including each agent for the decision process.

b. Distributing the roles may have a potential to provide easiness about three aspects which are *decreasing demanding workload for each agent, facilitating to prepare pre-visit, during visit and post-visit activities,* and *developing instructional strategies based on target concepts.*

c. Distributing roles may facilitate mutual understanding for each agent regarding the expectations from the science center visits. First of all, specifying the roles regarding the time-duration, skills, methods to use etc. may provide the information for context-related, content-related, and person-related factors. So, this decreases the excessive workload for each agent. Decreasing the demanding workload for them will eliminate the lack of human resources barrier for science center visits.

d. In order to decrease the demanding workload, there can be a partnership program *setting the roles for each agent*. First of all, teachers may have *pre-knowledge regarding the target concepts* and this agreement *defines their roles* about associated science center's expectations. Since each science center has unique educational and organizational practices in spite of their everyday practices, teachers might have differentiated roles for associated science centers. Teachers' functions might be collected under four groups as ***visit organizer, guide, co-guide***, and ***activity involver***.

e. First, the results showed that science centers preferring not to involve teachers in the guidance process want from teachers to ***organize the school visit*** due to the everlasting permission processes and the need for regulation of students. Moreover, science centers who prefer to involve teachers in the guidance process may *offer either guidance or co-guidance role for the teachers*. The ***guidance role*** refers to that full action belongs to the teacher during the school visits. The teacher with the guidance role, may have pre-structured activities targeting at the associated concepts with the lesson objectives. A hand-material distributed to the teachers might regulate this guidance processes for teachers and students. On the other hand, since the science centers have a lack of human resources, the guidance of teachers might compensate for this absence.

f. Besides, the **c*o-guidance role*** refers that teachers contribute to science center educators' guidance meaningfully to make students remember the relevant lesson objectives. Teachers may help to the guidance (a*) during the transfer from one exhibition unit to another to construct the connection between the concepts*, (b) *during the science center educators ask a critical question to recall the concept*, (c) and *after the visit occurs to summarize and connect the visit to in-class activities*.

g. Finally, ***activity involver role*** refers that teachers involve in workshop activities to co-guide students or attend the seminars in which science centers organize. Thus, teachers may contribute to the activity development process and connect in-class activities with the science center experience.

h. Current educational practices showed that a minority of teachers apply pre-visit, during visit, and post-visit to connect science center activities with the in-class activities. Although the science curriculum being prepared includes offered science center activities for teachers, the activity regulations are not familiar to teachers and students.

i. To include teachers in these school visit processes, *offered lesson activities within the current curriculum can be adapted to science center context* as an out-of-school activity so that teachers may get involved in pre-visit activities to know the science center context and how that teacher may deliver selected lesson objectives in that environment. And, *a list of activities targeting different concepts compatible with lesson objectives* prepared for teachers may be provided. Also, post-visit activities play an important role in testing the effectiveness of science center activities and provide long-lasting conceptual understanding. This is an essential part of the science center visits, and since science centers have inadequate human resources, *teachers may contribute to tracking students' performance*.

j. Moreover, there may be an ***interactive distance system*** to foster collaboration between science centers and teachers. Thus, science center educators may distribute their pre-forms or wishes from teachers throughout the system. And, teachers may ask their questions or state their experiences via the system. This would provide a diary for each science center visit activity.

k. Current educational practices showed that science center educators arrange their activities regarding their learner characteristics. Although science center educators take learner characteristics into account for the preparation and implication of guidance and workshop activities, students visiting the science center have time to explore the environment freely. Thus, there may be ***two ways of implication*** for this. First of all, the *interaction design of the exhibition units* should provide appropriate approaches for target concepts so that students will have an opportunity to interact with the exhibition units by acquiring relevant objectives for learning the concepts. Moreover, *guidance can be provided by embedding it into the adaptive technologies*. Design of exhibition units having clear and compatible objectives regarding the target concepts may foster students' planning, monitoring and evaluating acts during their engagement. To reach such kind of theory-driven knowledge, researches on students' cognitive and metacognitive processes during their interaction with exhibition units may shape the unit design in a way to foster their conceptual understanding.

(3) ***Extending budget:*** Providing alternative ways for the financial shoestring taking the needs of science centers into account may be a suggestion for the policy makers.

   a. Since many science center has barrier to extend the budget especially in order to use the budget for the renovation of the exhibition units, founding laboratories, accessing to students and increasing the number of the human resources, providing alternative ways such as calling angel investors for action and spreading the advertisemention may be a suggestion for solution.

   b. By doing projects for European (such as Erasmus +) and local networks (such as TUBITAK), both science centers may expend their budgets and provide an interdisciplinary work environment for science center educators, researchers, citizens, and schools.

   c. Also, the projects might receive international grants from voluntary actions. So, these provided ways may be useful for both science centers and schools to overcome the financial obstacle.

(4) ***Extending collaboration:*** Providing alternative ways to set bridges among schools, citizens, and the science centers may be a suggestion for the policy makers.

   a. Science center educators, on the other hands, may prepare workshops for citizens, teachers, students, and schools to provide collaborative activities among these agents.

   b. Also, instructional designers and researchers may get involved in the preparation and implementation of the workshops. It is important that workshops are prepared in collaboration with critical agents. However, online or face-to-face meetings are also needed to bring these agents together. It may be important that each year, with the contribution of policy makers, not only their works are presented, but also the critical agents collaborate via roundtables.

c. Researchers can be invited to conduct effectiveness studies before, during and after the workshops. In particular, it may be important to support faculty members working in the faculty of education for the assessment and evaluation activities in science centers. At the same time, by increasing the collaboration levels with the facult members, students in the graduate level can be directed to these centers to receive their voluntary supports during assessment and evaluation activities. So, this may play an important role in promoting the science center concept among Turkey.

d. Public events where content is shared with everyone, can increase collaboration. It may be important to share the content of the open events with other science centers, schools and teachers, and to make evaluations with other agents as well as the science center educators after the event.

e. Although science centers other than the two science centers interviewed said that they do not successfully continue their teacher community building activities, a teacher community is needed in order to facilitate the cooperation of science centers with teachers and to receive their support during the instructional design with the experiences to be learned from good examples. In addition to supporting their professional development, these teachers who join the community from different schools within the framework of a common goal, can also form a student committee and be a pioneer in selecting the science center student representative for each school.

(5) ***Encouraging autonomy:*** Providing alternative ways for the lack of human resources may a suggestion for the policy makers.

a. Virtual or face-to-face study groups can be a way to both increase collaboration and address the current lack of human resource in science centers. After the study group, people who have adapted to the science center environment can be expected to support the science center education and organization process. Thus, the supporters start working by being familiar with the processes.

b. It can be given as a suggestion that science center educators call for action for the volunteers in cooperation with universities, schools and other non-governmental organizations to meet the human resource need.

c. Besides, as well as collaborating with emerging social entrepreneurship ecosystem in Turkey may facilitate the attempt to reach students in rural areas. For this, each science center, together with volunteers, can reach children and teachers in the rural area by including the status of mobile science center. By collaborating with existing social entrepreneurs in the field of education (such as Village Schools Change Network, Education Reform Initiative, or Kodluyoruz), they can reach students and teachers from all levels in different areas from a variety of fields.

5.3 Suggestions for Further Researches

This thesis study revealed significant insights on how science center educators' and students' metacognitive processes occur in a dynamic informal learning environment while pinpointing the current practices for educational and organizational issues to increase the educational effectiveness in science center environments. Based on the conducted study and the researhers' observatory insights, suggestions for further researchers might offer studies in five categories as *suggestions for multi-method study, suggestions for instructional design models, suggestions for theoretical aspects, suggestions for methodological tools,* and *suggestions for educational policy* (see Figure 5.6).

Five categories of suggestions for future researches and researchers underlined the essential issues in research in informal learning environments especially focusing on the metacognition concept. This thesis study also offers suggestions to shed light on studies on metacognitive processes in different populations in science center environments. First, suggestions were listed on what kind of contribution a multi-method study can add to metacognition research, how the two different studies connect to each other in this study and what else can be considered. Second, insights on how to perform a metacognitive-oriented instructional design and how to integrate time-series data into these models was shared. In addition, although the study is based on metacognition and collaborative learning, suggestions were made that eye data, verbal data, and student behaviors collected for triangulation purposes can be examined in terms of embodied cognition, joint attention and shared undersanding concepts. In addition, suggestions are given about educational and organizational practices in science centers and how these practices can interact with each other, while making partnerships and the effects of these partnerships on the educational processes of science centers, and what kind of effects educational leadership skills can have in informal learning environments are briefly discussed. Finally, the methodological tools used in the study were summarized, and what kind of improvements could be made for which tools and design and research suggestions were given to enable different student groups to maximize the efficiency of these environments.

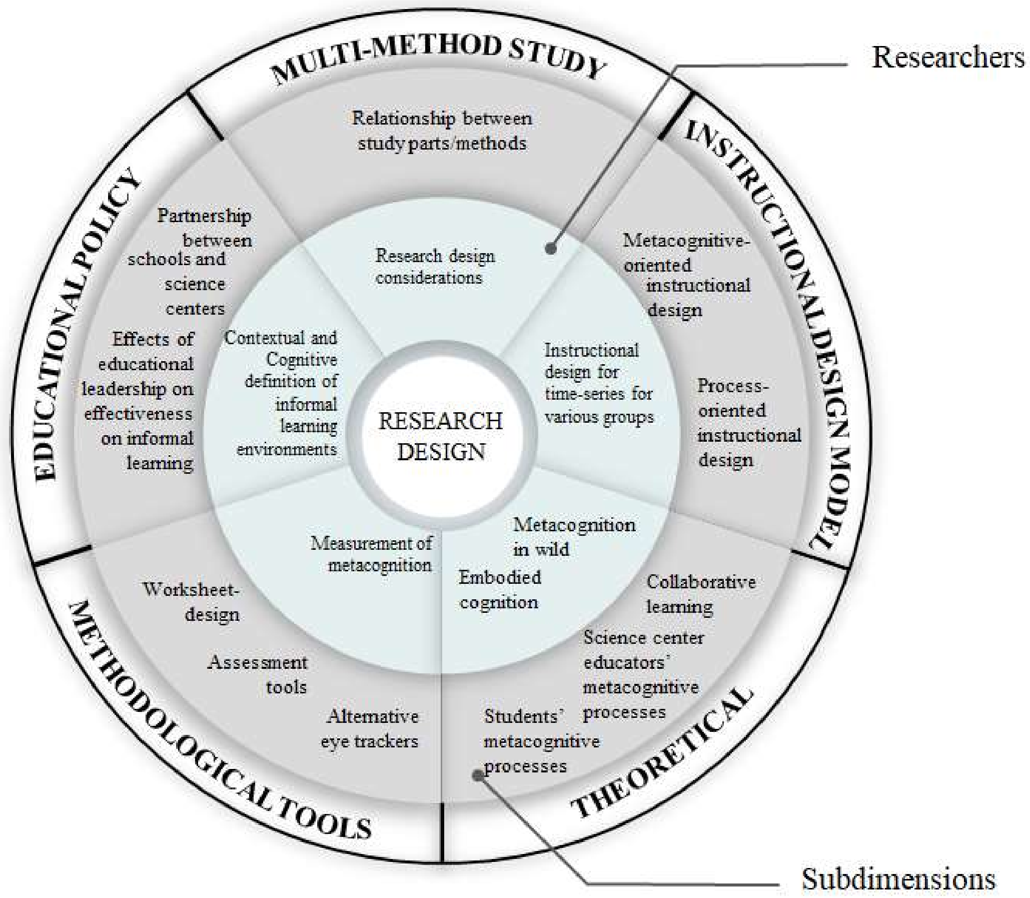


Figure 5.6 Diagram of the suggestions for future researches

(1) ***Multi-method Study*****:** Although this thesis consists of two sub-studies, these studies have been carried out both to increase the experience of the researcher about the science center and to determine the environment that provides the necessary and sufficient conditions for the investigation of metacognitive processes in the science center environment and to observe these processes. In this direction, the researcher used the results from the first stage to design the second stage research. From this experience, it was learned that the reflections of the studies carried out in the science center on education, the study of metacognitive processes in the science center, and how the metacognitive process depending on the situation was observed in the students in collaboration, and suggestions were given for multi-method study designs on these teachings.

a. Although the studies carried out in the science center are both related to the organizational processes and educational processes, especially in this study, this relatedness tried to understand whether the metacognitive interventions were performed by the science center educators and teachers. While touring the environment in the company of a science center educator, a checklist can be made regarding the features of the target exhibition units and whether the questions or tools that trigger metacognitive behaviors exist in these exhibition units.

b. In addition, although the science center instructors give information about the perceived metacognitive activities of the students during the oral interviews, the experiences of each target exhibition unit can be asked during the field trip. This may make it easier to remember their previous experiences.

c. In the study, teacher and science center educator auxiliary resources prepared by science centers were also examined. However, rather than containing information that supports and guides metacognition, these sources contain texts for the promotion of the exhibition units in the science center. By working on these documents separately, directions that support the metacognitive activities of science center educators and teachers can be added to each existing document. And, an additional research can be done on the effect of these edited booklets.

d. Although the multi-method study tries to link the first and second stages and eliminate the compounding variables as much as possible, it is possible to differentiate this research pattern. In the first stage, it may be important to take verbal expressions of the students about their own metacognitive activities after the guidance experience, apart from the verbal expressions of the teachers and science center instructors regarding the students' perceived metacognitive activities.

e. In addition, what students with different performance levels do in current activities in science lessons can be observed before the intervention. And, in the second study, by developing metacognitive interventions, it can be investigated what kind of metacognitive behaviors students at different performance levels exhibit in which exhibition units. Thus, the first and second studies may be matched on the basis of students' metacognitive processes.

f. Before examining the metacognitive processes of the collaborating students and what kind of metacognitive activities they demonstrate over time in individual and interindividual dimensions, preliminary activities for cooperation can also be done in the first study.

(2) ***Instructional Design Models:*** Although this study currently did not refer an integrative model for metacognitive-oriented instructional design, different instructional design approaches should be applied within the real context, and the comparison might offer effective strategies for the integration of school science curriculum into the science centers.

a. It may be important for students with different achievement levels in science classes to be included in the intervention development suggestions in these models. Thus, an instructional designer might have had prior knowledge of what kind of interventions he could develop while supporting the metacognitive activities of students at different levels.

b. In the study, it was observed that the students with low performance level followed an indecisive path while answering the questions on the worksheets while cooperating. Because of this unstable strategy, questions for low-performing students can be arranged from simple to complex. In addition, instead of leaving the choice to them in the first questions, it can be ensured that they take a determined path with directive texts.

c. In addition, in cases where low and high performance students match, while the student with low performance level tends to follow the student with high performance level without questioning, towards the end of the questions, students with high performance level prefer to answer the questions alone by monopolizing the leadership. For this reason, different roles should be assigned to students, as much as possible in the handouts during collaborative work. During the study, it was observed that the student who had a workheet and a pen was more effective. For this reason, in an instructional design model, it is important that the environment is guiding so that students can share work under equal conditions.

(3) ***Theoretical Aspects:*** Since a collaborative activity requies joint attention and shared understanding, interpersonal synchrony and interpersonal subjectivity are also significant theoretical aspects to discuss regarding to the construct "shared metacognition" . Also, level of collaboration is a significant factor may have a role in shared metacognition in the long-run, the interaction between the level of collaboration and students' metacognitive activity diversities would be a valuable research.

a. There may be a correlation between the metacognitive activities of the science center educators during the guided tour and the metacognitive activities of the students during cooperative learning. Therefore, research on metacognitive transition can be very valuable.

b. In addition, low-performing students, when matched, display metacognitive activities such as taking notes and crossing them, even though they read and answer questions in an indecisive way. However, it is difficult for students to adapt to the environment. This can also be about self-esteem. In the first study, a teacher stated that students of different performance levels were equal in the science center environment and that this low performance level improved their self-esteem. It can be examined how variables such as self-esteem and self-efficacy differ in students with different performance in such environments.

c. In addition, students also demonstrate metacognitive-oriented cognitive activities. Eye movements and student behavior can determine the nature of these activities. Therefore, the relationship between embodied perception and metacognition can be examined through cognitive tools in the science center environment.

(4) ***Methodological Tools:*** Current thesis study used multi-method study design to take holistic view perspective for the instructional design processes within the science centers. First, for the guidance and the collaborative activity, video camera recordings and glass eye-tracking devices were used. Although used methodological tools provided a time-series coding alternative for the researcher, an online science center environment may require event logs for each collaborative pair during their collaborative activity. Therefore, there might need for other methodological tools, such as mobile-based screen and movement recorders. How acquired information processed by using the event logs to see the interaction between each collaborative pairs may require log-based information processing systems. Second, changes in study designs considering the context, person, and the task variables might offer evidences for the dynamic and adaptive metacognitive processes within the science center environments. Also, different study designs might offer a better definition of the construct "metacognition". A longitudinal study-design, time-series analysis within different contexts (in experimental laboratories, in real context, and in virtual context) should be investigated. However, just using a different kind of tool does not mean to have meaningful data. So, there needs detailed theoretical findings.

(5) ***Educational Policy:*** Since science centers are among the leading alternative informal learning environments and they can gain experiences in parallel with the achievements in the school curriculum, studies can be carried out on how to integrate science center activity experiences into the lessons in the school.

REFERENCES

Abrahamson, D., Shayan, S., Bakker, A., & van der Schaaf, M. (2015). Eye-Tracking Piaget: Capturing the Emergence of Attentional Anchors in the Coordination of Proportional Motor Action. *Human Development, 58*(4-5), 218-244. doi: 10.1159/000443153

Achiam, M., Simony, L., & Lindow, B. E. K. (2016). Objects prompt authentic scientific activities among learners in a museum programme. *International Journal of Science Education, 38*(6), 1012-1035. doi: 10.1080/09500693.2016.1178869

Afonso, A. S., & Gilbert, J. K. (2006). The Use of Memories in Understanding Interactive Science and Technology Exhibits. *International Journal of Science Education, 28*(13), 1523-1544. doi: 10.1080/09500690600768828

Anderson, D., Nashon, S. M., & Thomas, G. P. (2008). Evolution of Research Methods for Probing and Understanding Metacognition. *Research in Science Education, 39*(2), 181-195. doi: 10.1007/s11165-007-9078-1

Atwood-Blaine, D., & Huffman, D. (2017). Mobile Gaming and Student Interactions in a Science Center: the Future of Gaming in Science Education. *International Journal of Science and Mathematics Education, 15*(S1), 45-65. doi: 10.1007/s10763-017-9801-y

Azevedo, R. (2015). Defining and Measuring Engagement and Learning in Science: Conceptual, Theoretical, Methodological, and Analytical Issues. *Educational Psychologist, 50*(1), 84-94. doi: 10.1080/00461520.2015.1004069

Baker, L. (1989). Metacognition, comprehension monitoring, and the adult reader. *Educational Psychology Review, 1*(1), 3-38.

Bamberger, Y., & Tal, T. (2008). An Experience for the Lifelong Journey: The Long-Term Effect of a Class Visit to a Science Center. *Visitor Studies, 11*(2), 198-212. doi: 10.1080/10645570802355760

Bannert, M., Sonnenberg, C., Mengelkamp, C., & Pieger, E. (2015). Short- and long-term effects of students' self-directed metacognitive prompts on navigation behavior and learning performance. *Computers in Human Behavior, 52*, 293-306.

Berg, B.L. (2001) Qualitative Research, Message for the Social Sciences. 4th Edition, Allin and Bacon, Boston, 15-35.

Bernard, J., Wilhelm, N., Scherer, M., May, T., & Schreck, T. (2012). *Reference list of 120 datasets from time series station Payerne used for exploratory search*. Retrieved from: https://doi.org/10.1594/PANGAEA.783598

Bogdan, R. J. (2001). Developing mental abilities by representing intentionality. Syntheses, 129(2), 233-258.

Bogdan, R., & Biklen, S. (2007). Qualitative research for education: An introduction to theory and practice (5th ed.). New York: Pearson Education, Inc.

Brown, A., Bransford, J., Ferrara, R., & Campione, J. (1983). Learning, remembering, and understanding. In JH Flavell and EM Markman (Eds.), Handbook of Child Psychology Vol. 3: Cognitive Development.

Brown, A. (1987) Metacognition, Executive Control, Self-Regulation and Other More Mysterious Mechanisms. In: Weinert, F.E. and Kluwe, R.H., Eds., Metacognition, Motivation and Understanding, Hillsdale, 65-116.

Butler, D., & Winne, P. (1995). Feedback and Self-Regulated Learning: A Theoretical Synthesis. *Review of Educational Research - REV EDUC RES, 65*, 245-281. doi: 10.2307/1170684

Corsini, R. J. (1999). The dictionary of psychology, Publishing office: Brunner, Mazel.

Creswell, J. W., & Poth, C. N. (2016). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*: SAGE Publications.

De Backer, L., Keer, H., & Valcke, M. (2016). Eliciting Reciprocal Peer-Tutoring Groups' Metacognitive Regulation Through Structuring and Problematizing Scaffolds. *The Journal of Experimental Education*, 1-20. doi: 10.1080/00220973.2015.1134419

De Backer, L., Van Keer, H., & Valcke, M. (2015a). Exploring evolutions in reciprocal peer tutoring groups' socially shared metacognitive regulation and identifying its metacognitive correlates. *Learning and Instruction, 38*, 63-78. doi: 10.1016/j.learninstruc.2015.04.001

De Backer, L., Van Keer, H., & Valcke, M. (2015b). Socially shared metacognitive regulation during reciprocal peer tutoring: identifying its relationship with students' content processing and transactive discussions. *Instructional Science, 43*(3), 323-344.

Denzin, N. K., & Lincoln, Y. S. (1994). *Handbook of qualitative research*. Thousand Oaks, CA, US: Sage Publications, Inc.

Denzin, N. K., & Lincoln, Y. S. (Eds.). (2018). *The SAGE handbook of qualitative research*. Los Angeles: SAGE.

Dewey, J. (1933) How We Think, New York: D. C. Heath. Classic and highly influential discussion of thinking.

di Gregorio, S., & Davidson, J. (2008). *Qualitative Research Design for Software Users*.

Dinsmore, D., Alexander, P., & Loughlin, S. (2008). Focusing the Conceptual Lens on Metacognition, Self-regulation, and Self-regulated Learning. *Educational Psychology Review, 20*, 391-409. doi: 10.1007/s10648-008-9083-6

Efklides, A. (2002). Feelings as subjective evaluations of cognitive processing: How reliable are they? *Psychology: The Journal of the Hellenic Psychological Society, 9*, 163-184.

Falk, J. (2004). The director's cut: Toward an improved understanding of learning from museums. *Science Education, 88*(S1), S83-S96. doi: 10.1002/sce.20014

Falk, J. H. (2011). Contextualizing Falk's Identity-Related Visitor Motivation Model. *Visitor Studies, 14*(2), 141-157. doi: 10.1080/10645578.2011.608002

Falk, J. H., & Dierking, L. D. (1997). School Field Trips: Assessing Their Long-Term Impact. *Curator: The Museum Journal, 40*(3), 211-218. doi: 10.1111/j.2151-6952.1997.tb01304.x

Falk, J. H., & Needham, M. D. (2011). Measuring the impact of a science center on its community. *Journal of Research in Science Teaching, 48*(1), 1-12. doi: 10.1002/tea.20394

Flavell, J. H. (1979). Meta-Cognition and Cognitive Monitoring - New Area of Cognitive-Developmental Inquiry. *American Psychologist, 34*(10), 906-911.

Fries, L., Son, J. Y., Givvin, K. B., & Stigler, J. W. (2020). Practicing Connections: A Framework to Guide Instructional Design for Developing Understanding in Complex Domains. *Educational Psychology Review*. doi: 10.1007/s10648-020-09561-x

Gentner, D., Levine, S. C., Ping, R., Isaia, A., Dhillon, S., Bradley, C., . . . Honke, G. (2016). Rapid Learning in a Children's Museum via Analogical Comparison. *Cognitive Science*. doi: 10.1111/cogs.12248

Gerring, J. (2004). What Is a Case Study and What Is It Good for. *American Political Science Review, 98*, 341-354.

Glaser, B. (1978) Theoretical sensitivity: Advances in the methodology of grounded theory. Sociology Press, Mill Valley.

Goos, M., Galbraith, P., & Renshaw, P. (2002). Socially mediated metacognition: creating collaborative zones of proximal development in small group problem solving. *Educational Studies in Mathematics, 49*(2), 193-223. doi: 10.1023/A:1016209010120

Guest, G., Bunce, A., & Johnson, L. (2006). How Many Interviews Are Enough?:An Experiment with Data Saturation and Variability. *Field Methods, 18*(1), 59-82. doi: 10.1177/1525822x05279903

Guisasola, J., Solbes, J., Barragues, J. I., Morentin, M., & Moreno, A. (2009). Students' Understanding of the Special Theory of Relativity and Design for a Guided Visit to a Science Museum. *International Journal of Science Education, 31*(15), 2085-2104. doi: 10.1080/09500690802353536

Hauan, N. P., & DeWitt, J. (2017). Comparing Materials for Self-Guided Learning in Interactive Science Exhibitions. *Visitor Studies, 20*(2), 165-186. doi: 10.1080/10645578.2017.1404349

Hodson, R. (1999). *Analyzing Documentary Accounts*: SAGE Publications.

Hogan, K. (2001). Collective metacognition: The interplay of individual, social, and cultural meanings in small groups' reflective thinking *Advances in psychology research, Vol. 7.* (pp. 199-239). Hauppauge, NY, US: Nova Science Publishers.

Holmes, J. A. (2011). Informal learning: Student achievement and motivation in science through museum-based learning. *Learning Environments Research, 14*(3), 263-277. doi: 10.1007/s10984-011-9094-y

Holmqvist, K., Nyström, M., Andersson, R., Dewhurst, R., Jarodzka, H., & van de Weijer, J. (2011). Eye Tracking: A Comprehensive Guide To Methods And Measures.

Houseal, A., Abd-El-Khalick, F., & Destefano, L. (2014). Impact of a Student-Teacher-Scientist Partnership on Students' and Teachers' Content Knowledge, Attitudes Toward Science, and Pedagogical Practices. *Journal of Research in Science Teaching, 51*. doi: 10.1002/tea.21126

Hwang, A. D., Wang, H. C., & Pomplun, M. (2011). Semantic guidance of eye movements in real-world scenes. *Vision Res, 51*(10), 1192-1205. doi: 10.1016/j.visres.2011.03.010

Iiskala, T., Vauras, M., & Lehtinen, E. (2004). Socially-shared metacognition in peer learning. Hellenic Journal of Psychology, 1, 147–178.

Iiskala, T., Vauras, M., Lehtinen, E., & Salonen, P. (2011). Socially shared metacognition of dyads of pupils in collaborative mathematical problem-solving processes. *Learning and Instruction, 21*(3), 379-393.

Itzek-Greulich, H., Flunger, B., Vollmer, C., Nagengast, B., Rehm, M., & Trautwein, U. (2015). Effects of a science center outreach lab on school students' achievement – Are student lab visits needed when they teach what students can learn at school? *Learning and Instruction, 38*, 43-52. doi: 10.1016/j.learninstruc.2015.03.003

Itzek-Greulich, H., & Vollmer, C. (2017). Emotional and motivational outcomes of lab work in the secondary intermediate track: The contribution of a science center outreach lab. *Journal of Research in Science Teaching, 54*(1), 3-28. doi: 10.1002/tea.21334

James, W. (1992). Writings 1878–1899. New York: The Library of America.

Junttila, N., Voeten, M., Kaukiainen, A., & Vauras, M. (2006). Multisource Assessment of Children's Social Competence. *Educational and Psychological Measurement, 66*(5), 874-895. doi: 10.1177/0013164405285546

Kant, I. (1933). The critique of pure reason. London: George Allan and Unwin.

Karademir, A., Kartal, A., & Türk, C. (2019). Science Education Activities in Turkey: A Qualitative Comparison Study in Preschool Classrooms. *Early Childhood Education Journal, 48*(3), 285-304. doi: 10.1007/s10643-019-00981-1

Kim, M., Dillon, J., & Song, J. (2018). The Factors and Features of Museum Fatigue in Science Centres Felt by Korean Students. *Research in Science Education, 50*(2), 419-436. doi: 10.1007/s11165-018-9695-x

Kim, Y., Park, M., Moore, T. J., & Varma, S. (2013). Multiple levels of metacognition and their elicitation through complex problem-solving tasks. *The Journal of Mathematical Behavior, 32*(3), 377-396. doi: 10.1016/j.jmathb.2013.04.002

Krange, I., Silseth, K., & Pierroux, P. (2019). Peers, teachers and guides: a study of three conditions for scaffolding conceptual learning in science centers. *Cultural Studies of Science Education, 15*(1), 241-263. doi: 10.1007/s11422-018-9905-x

Kuhn, D. (2000). *Theory of mind, metacognition, and reasoning: A life-span perspective.* In P. Mitchell & K. J. Riggs (Eds.), *Children's reasoning and the mind* (p. 301–326). Psychology Press/Taylor & Francis (UK).

Kvale, S. and Brinkmann, S. (2015) Interviews: Learning the Craft of Qualitative Research Interviewing. 3rd Edition, Sage Publications, Thousand Oaks, CA.

Lesh, R., Lester, F. K., & Hjalmarson, M. (2003). A models and modeling perspective on metacognitive functioning in everyday situations where problem solvers develop mathematical constructs. In R. Lesh & H. M. Doerr (Eds.), *Beyond Constructivisim: Models and modeling perspective on mathematics problem solving, learning, and teaching*.

Leighton, J. P., & Gierl, M. J. (Eds.). (2007). *Cognitive diagnostic assessment for education: Theory and applications.* Cambridge University Press. https://doi.org/10.1017/CBO9780511611186

Lesh, R., & Zawojewski, J. (2007). Problem Solving and Modeling. In F. K. L. Jr. (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 763-804).

Liu, G.-Z., Chen, J.-Y., & Hwang, G.-J. (2018). Mobile-based collaborative learning in the fitness center: A case study on the development of English listening comprehension with a context-aware application. *British Journal of Educational Technology, 49*(2), 305-320. doi: 10.1111/bjet.12581

Marshall, C. and Rossman, G. (2016) Designing Qualitative Research. 6th Edition, SAGE, Thousand Oaks.

Maxwell, J. A. (2013). Applied social research methods series: Vol. 41. *Qualitative research design: An interactive approach*, 3.

Meijer, J., Veenman, M. V. J., & van Hout-Wolters, B. H. A. M. (2006). Metacognitive Activities in Text-Studying and Problem-Solving: Development of a Taxonomy. *Educational Research and Evaluation, 12*(3), 209-237. doi: 10.1080/13803610500479991

Merriam, S. B. (2009). *Qualitative Research: A Guide to Design and Implementation*: John Wiley & Sons.

Merriam, S. B., & Tisdell, E. J. (2016). Qualitative Research: A Guide to Design and Implementation (4th ed.). San Francisco, CA: Jossey Bass.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook, 2nd ed*. Thousand Oaks, CA, US: Sage Publications, Inc.

Morse, J. (2003). Principles of Mixed Methods and Multimethod Research Design.

Nelson, K. R. (2015). Application of Merrill's First Principles of Instruction in a Museum Education Context. *Journal of Museum Education, 40*(3), 304-313. doi: 10.1179/1059865015Z.000000000106

Neuman, W.L. (2009) Social Research Methods: Qualitative and Quantitative Approaches. 7th Edition, Pearson Education, Chandler.

Newell, A. (1994). *Unified Theories of Cognition*: Harvard University Press.

Nyamupangedengu, E., & Lelliott, A. (2012). An exploration of learners' use of worksheets during a science museum visit. *African Journal of Research in Mathematics, Science and Technology Education, 16*(1), 82-99. doi: 10.1080/10288457.2012.10740731

O'Leary, Z. (2004). *The Essential Guide to Doing Research*: SAGE Publications.

Patton, M. Q. (2002). Two Decades of Developments in Qualitative Inquiry:A Personal, Experiential Perspective. *Qualitative Social Work, 1*(3), 261-283. doi: 10.1177/1473325002001003636

Perry, D. (2012). *What Makes Learning Fun? Principles for the Design of Intrinsically Motivation Museum Exhibits*.

Pressley, M., Borkowski, J., & Schneider, W. (1987). Cognitive Strategies: Good Strategy Users Coordinate Metacognition and Knowledge. *In: Annals of child development (1987) 4, 89-129., 4*.

Ragin, C. C. (1987). *The Comparative Method: Moving Beyond Qualitative and Quantitative Strategies*: University of California Press.

Ritchie, J., Lewis, J., Lewis, P. S. P. J., Nicholls, C. M. N., & Ormston, R. (2013). *Qualitative Research Practice: A Guide for Social Science Students and Researchers*: SAGE Publications.

Roberts, J., & Lyons, L. (2020). Examining Spontaneous Perspective Taking and Fluid Self-to-Data Relationships in Informal Open-Ended Data Exploration. *Journal of the Learning Sciences, 29*(1), 32-56. doi: 10.1080/10508406.2019.1651317

Salomon, G. (1997). *Distributed Cognitions: Psychological and Educational Considerations*: Cambridge University Press.

Schraw, G. (1998). Promoting General Metacognitive Awareness. *Instructional Science, 26*, 113-125. doi: 10.1023/A:1003044231033

Schraw, G., & Dennison, R. S. (1994). Assessing Metacognitive Awareness. *Contemporary Educational Psychology, 19*(4), 460-475. doi: https://doi.org/10.1006/ceps.1994.1033

Schraw, G., Olafson, L., Weibel, M., & Sewing, D. (2012). Metacognitive Knowledge and Field-based Science Learning in an Outdoor Environmental Education Program. In A. Zohar & J. Y. Dori (Eds.), *Metacognition in Science Education: Trends in Current Research* (pp. 57-77). Dordrecht: Springer Netherlands.

Schunk, D. H. (2008). Metacognition, self-regulation, and self-regulated learning: Research recommendations. *Educational Psychology Review, 20*(4), 463-467. doi: 10.1007/s10648-008-9086-3

Sfard, A., & Kieran, C. (2001). Cognition as Communication: Rethinking Learning-by-Talking Through MultiFaceted Analysis of Students' Mathematical Interactions. *Mind, Culture, and Activity, 8*, 42-76. doi: 10.1207/S15327884MCA0801_04

Stake, R. E. (2010). *Qualitative Research: Studying how Things Work*: Guilford Publications.

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory, 2nd ed*. Thousand Oaks, CA, US: Sage Publications, Inc.

Tal, T., & Steiner, L. (2006). Patterns of teacher-museum staff relationships: School visits to the educational centre of a science museum. *Canadian Journal of Science, Mathematics and Technology Education, 6*(1), 25-46. doi: 10.1080/14926150609556686

Tanner, K. D. (2012). Promoting Student Metacognition. *CBE-Life Sciences Education, 11*(2), 113-120. doi: 10.1187/cbe.12-03-0033

Tashakkori, A., & Teddlie, C. (2010). *Sage handbook of mixed methods in social & behavioral research*: sage.

Thomas, G. P., & Anderson, D. (2013). Parents' Metacognitive Knowledge: Influences on Parent–Child Interactions in a Science Museum Setting. *Research in Science Education, 43*(3), 1245-1265. doi: 10.1007/s11165-012-9308-z

Vayne, J. (2012). *Wonderful Things: Learning with Museum Objects*: Museums.

Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*: Harvard university press.

Webster, E. A., & Hadwin, A. F. (2015). Emotions and emotion regulation in undergraduate studying: examining students reports from a self-regulated learning perspective. *Educational Psychology, 35*, 794 - 818.

Weinert, F. E. and Kluwe, R. H. (1987) Metacognition, motivation and understanding Erlbaum , Hillsdale, NJ

Wellman, H. (1985). The Origins of Metacognition. In D. L. Forrest-Pressley, G. E. MacKinnon, and T. G. Waller, (eds.). Metacognition, Cognition, and Human Performance. Volume 1. Academic Press, New York, NY

White, B., & Frederiksen, J. (2005). A Theoretical Framework and Approach for Fostering Metacognitive Development. *Educational Psychologist, 40*(4), 211-223. doi: 10.1207/s15326985ep4004_3

White, T., & Pea, R. (2011). Distributed by Design: On the Promises and Pitfalls of Collaborative Learning with Multiple Representations. *Journal of the Learning Sciences, 20*(3), 489-547.

Woods, D., & Fassnacht, C. (2007). *Transana*.

Wolters, C. A. (2003). Understanding procrastination from a self-regulated learning perspective. *Journal of Educational Psychology, 95*(1), 179–187.

Yıldırım A, Şimşek H. (2013). Sosyal Bilimlerde Nitel Araştırma Yöntemleri. (9. Baskı). Ankara: Seçkin Yayıncılık.

Yin, R. K. (2009). Case study research: Design and methods (4th Ed.). Thousand Oaks, CA: Sage.

Yoon, S. A., Elinich, K., Wang, J., Steinmeier, C., & Tucker, S. (2012). Using augmented reality and knowledge-building scaffolds to improve learning in a science museum. *International Journal of Computer-Supported Collaborative Learning, 7*(4), 519-541. doi: 10.1007/s11412-012-9156-x

Zimmerman, B. (1989). Models of Self-Regulated Learning and Academic Achievement. *Zimmerman and Schunk, 1989*. doi: 10.1007/978-1-4612-3618-4_1

Zimmerman, H., Reeve, S., & Bell, P. (2008). Distributed Expertise in a Science Center. *Journal of Museum Education, 33*(2), 143-152. doi: 10.1080/10598650.2008.11510595

Zohar, A., & Barzilai, S. (2013). A review of research on metacognition in science education: current and future directions. *Studies in Science Education, 49*(2), 121-169. doi: 10.1080/03057267.2013.847261

APPENDICES

A. Interview Protocol for Science Center Educators (*Turkish Version*)

Sözlü Görüşme Protokolü

Tarih: Görüşmeye katılan:

Mekân:

Bu ön araştırmada sözlü görüşme için gönüllü olduğunuzdan dolayı teşekkür ederim. Bu çalışmada, bilim merkezlerinin hâlihazırdaki durumu ve bilim merkezinde uygulanmakta olan etkinliklerin öğrencilerin üst bilişlerini ne ölçüde desteklediğini araştırıyorum.

Lütfen bu görüşmede sizi değerlendirmediğimi ve yaptığınız tüm uygulamalarla ilgili soru soramayacağımı hatırlayınız. Görüşme sırasında alınacak tüm verilerin gizli tutulacağını ve araştırma süresi tamamlandıktan sonra imha edileceğini size bildirmek isterim. Ayrıca, görüşmeyi gerçekleştirdiğim her bir bilim merkezi çalışanı ve eğitimcisinin bir mahlasla adlandırılacağını bilmenizi isterim. Sizin tercih ettiğiniz bir mahlas varsa, gturkmen@metu.edu.tr adresinden beni haberdar edebilirsiniz.

Elinizde bulunan ikinci kâğıt, gönüllü katılım formudur. Lütfen dikkatlice okuyup sizin için de uygunsa bu formu imzalayınız. Görüşme oturumumuz sırasında ses kaydı almam sizin için uygun mu? Son olarak, başlamadan önce sormak istediğiniz bir soru var mı?

1. Bilim merkeziniz için işbirliği sağladığınız kişi ve kurumlar bulunmakta mı?
    a. Bilim merkezinin tasarımı, materyallerin seçimi ve etkinlikler ile ilgili işbirliği sağlamakta mısınız?
    b. Öğrencilerle işbirliği yapıyor musunuz?
    c. Öğretmenlerle işbirliği yapıyor musunuz?
    d. Merkez eğitimcileriyle işbirliği sağlamakta mısınız?
2. İşbirliğini nasıl sağlamaktasınız?
    a. Etkinlikleri tasarlamadan önce işbirliği sağlamakta mısınız?
    b. Etkinlikleri tasarladıktan sonra işbirliği sağlamakta mısınız?
    c. Etkinliklerde yenileme yapıyor musunuz?

d. Etkinliklerdeki yenilemeleri neye göre yapıyorsunuz?

3. Bilim merkezinize ne tür ziyaretleri kabul etmektesiniz?
    a. Okul ziyaretleri öncesi merkez eğitimcileri, fen öğretmenleri ve öğrenciler ne yapıyor?
    b. Okul ziyaretleri sırasında merkez eğitimcileri, fen öğretmenleri ve öğrenciler ne yapıyor?
    c. Okul ziyaretleri sonrasında merkez eğitimcileri, fen öğretmenleri ve öğrenciler ne yapıyor?
4. Bilim merkezinizde ne tür etkinlikler düzenlemektesiniz?
5. Bilim merkezindeki etkinlik planlarınızı yaparken ne tür faktörleri göz önünde bulunduruyorsunuz?
    a. Merkezin türü ve öğrencilerin türü gibi.
6. Bu etkinlikler için ana amaçlarınız nelerdir?
7. Bu etkinlikleri geliştirme sürecinizden bahsedebilir misiniz?
    - Konuları neye göre belirlemektesiniz?
    - Ortamda bulunan materyalleri seçme kriterleriniz nelerdir?
    - Materyalleri etkinliklere nasıl entegre ediyorsunuz?
    - Etkinliklerinizde öğrencilerin yönlendirildikleri roller var mı? (Bireysel ve işbirlikçi gibi)
8. Bu etkinliklerin amaçlarına ulaşmak için ne tür bir plan ve prosedür kullanıyorsunuz?

Etkinlikler sırasında

9. Öğrencileri bir öğrenme görevi için amaç saptarken nasıl ve ne ile destekliyorsunuz?
10. Öğrencileri bir öğrenme görevini planlamaları için nasıl ve ne ile destekliyorsunuz?
11. Öğrencilerin öğrenmelerini geliştirmek için onların motivasyonlarını nasıl artırıyorsunuz?
12. Öğrencilerin kendi öğrenmelerini izlemeye / kontrol etmeye teşvik etmek için ne tür teknikler kullanıyorsunuz?
    a. Betimleme
    b. Dikkat odaklanması
    c. Özel görev stratejileri
13. Aklınıza gelen bir örneği verebilir misiniz?
14. (Yapmıyorsanız) Etkinlikler sırasında öğrencilerin kendi öğrenme süreçlerini izlemeye teşvik etmek için ne tür uygulamalar yapardınız?
15. Öğrencilerin bir öğrenme görevi sırasında kendi gelişimlerini takip etmeyi nasıl sağlıyorsunuz?

16. Bir öğrenme görevi sonrasında öğrencileri yansıtma ve değerlendirmeye teşvik edecek etkinlikler tasarlıyor musunuz? Bunlar nelerdir?
17. Bir öğrenme görevini tamamladıktan sonra, öğrencileri görevin öğrenme çıktılarına göre kendi memnuniyetlerini değerlendirmelerini nasıl destekliyorsunuz?

Etkinlikler sonrasında

18. Bu zamana kadarki deneyimlerinize göre eğer etkinliklerinizi tekrar düzenlemek isteseydiniz nelerde değişiklik yapardınız?
19. Etkinlikler haricinde bilim merkezi ortamının tasarımında herhangi bir değişiklik yapar mıydınız? Bunlar neler olurdu?
20. Sanal bir platformda bilim merkeziniz var mı?
    - -Yoksa- Olmasını ister miydiniz?
    - Merkezinizin sanal bir platformda temsili olmasının getirileri nelerdir?

Son notlar:

Etkinlik plan ve örneklerinizden doküman incelemesi yapmak üzere bir kopya verebilir misiniz?

Bilim merkezinde görev yapmış veya yapmakta olan başka eğitimcileri röportaj için önerebilir misiniz?

B. Interview Protocol for Science Teachers (*Turkish Version*)

Bireysel Görüşme Protokolü

Tarih: Görüşmeye katılan:

Mekân:

Bu ön araştırmada sözlü görüşme için gönüllü olduğunuzdan dolayı teşekkür ederim.

Bu ön araştırmada sözlü görüşme için gönüllü olduğunuzdan dolayı teşekkür ederim. Bu çalışma, Orta Doğu Teknik Üniversitesi Fen Bilimleri Enstitüsü Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü'nde doktora öğrenimine devam etmekte bulunan Gamze Türkmen tarafından Prof. Dr. Zahide YILDIRIM danışmanlığında ortaokul 7. sınıf düzeyindeki öğrencilerin bilim müzelerin kapsamında yapılan fen bilimleri etkinlikleri boyunca üst biliş bilgi ve regülasyonlarının gelişimini gözlemlemek amacıyla yapılmaktadır.

Lütfen bu görüşmede sizi değerlendirmediğimi ve yaptığınız tüm uygulamalarla ilgili soru soramayacağımı hatırlayınız. Görüşme sırasında alınacak tüm verilerin gizli tutulacağını ve araştırma süresi tamamlandıktan sonra imha edileceğini size bildirmek isterim. Ayrıca, görüşmeyi gerçekleştirdiğim her bir bilim merkezi çalışanı ve eğitimcisinin bir mahlasla adlandırılacağını bilmenizi isterim. Sizin tercih ettiğiniz bir mahlas varsa, gturkmen@metu.edu.tr adresinden beni haberdar edebilirsiniz.

Görüşmemiz yaklaşık olarak 45-50 dakika sürecektir. Görüşme sırasında ara vermek isterseniz, bu durumla ilgili beni bilgilendirmeniz yeterlidir. Elinizde bulunan ikinci kâğıt, gönüllü katılım formudur. Lütfen dikkatlice okuyup sizin için de uygunsa bu formu imzalayınız. Görüşme oturumumuz sırasında ses kaydı almam sizin için uygun mu? Son olarak, başlamadan önce sormak istediğiniz bir soru var mı?

Başlayabilir miyiz?

Arka plan Soruları:

1. Ne kadar süredir öğretmen olarak görev yapıyorsunuz?
2. Şu anki öğretim ortamınıza yönelik kısa bir tanımlama yapabilir misiniz?
    a. öğrenci sayınız
    b. öğrencilerinizle birlikte yaptığınız sosyal etkinlikler
    c. Öğretmen olarak sınıf dışındaki görevleriniz
3. Hangi bilim merkezini ziyaret ettiniz?

4. Bu ziyaretiniz bir defaya mahsus muydu?
    a. Hayır ise… ne zaman, kiminle, nerede?

Bilim Merkezi Ziyaretine Yönelik Sorular:

5. Bilim merkezini öğrencilerinizle ziyaret etme kararını nasıl aldınız? Niçin bu kararı aldınız?
   Anımsatmalar
    a. Amacınız neydi?
    b. Sizin için itici güçler neydi?/teşvik ediciler nelerdi?
    c. Bu süreçte zorluklar nelerdi?
    d. Sizin ve öğrencileriniz için yararları nelerdi?
6. Ziyaretiniz için genel bir tanım yapabilir misiniz? Öğretmen olarak ne yaptınız?
   Anımsatıcılar:
    a. Ziyaret öncesinde…
        i. Bilim merkeziyle nasıl iletişim kuruyorsunuz?
        ii. Onlardan ne tür bilgiler alıyorsunuz?
        iii. Onlardan herhangi bir ricanız oluyor mu? Bunlar neler?
        iv. Ziyaret öncesinde öğrencilerinizi nasıl yönlendiriyorsunuz?
    b. Ziyaret sırasında…
        i. Ziyaret boyunca öğrencilere rehberlik sağlıyor musunuz?
        ii. Bilim merkezi eğitimcileriyle ziyaret boyunca herhangi bir işbirliği yapıyor musunuz?
    c. Ziyaret sonrasında…
        i. Ne tür etkinlikler yapıyorsunuz?
            - öğrencilerle
            - bilim merkeziyle (eğitimciler ya da diğer çalışanlarla)
7. (Ziyaret öncesinde, etkinlikleriniz…) Öğrencilerinizle ziyaret öncesi ne tür etkinlikler yapıyorsunuz?
    a. Neden bu etkinlikleri yürütüyorsunuz?
    b. Ziyaretler öncesinde bu etkinliklerin öğrencilere katkısı konusunda ne düşünüyorsunuz?
    c. Bu etkinlikleri nasıl uyguluyorsunuz?
8. Ziyaret öncesinde kendinizi nasıl hissediyorsunuz?
9. Sizce öğrencileriniz nasıl hissediyorlar? Bunu nasıl anlıyorsunuz?
10. (Ziyaret sırasında siz…) Ziyaret sırasında ne tür etkinlikler yapıyorsunuz?
    a. Bu etkinliklerde sizin rolünüz nedir?
    b. Bu etkinliklerin öğrencilerinize katkısı nedir?
    c. Bu etkinlikler okul derslerinizle nasıl ilişkili?
    d. Bu etkinlikleri nasıl uyguluyorsunuz?

11. (Ziyaret sırasında öğrencileriniz…) Öğrencilerinizin ne tür davranışları üstbilişsel süreçlerini yansıtmaktadır?

Anımsatıcılar

a. Öğrencilerin sordukları sorular onların üstbilişsel süreçlerinde etkili mi? Neden?
b. Öğrencilerin akranlarıyla işbirliği yapması onları üstbilişsel süreçlerinde etkili mi? Neden?
c. Öğrenciler ziyaretleri sırasında not alıyorlar mı? Nasıl?
    i. Öğrencilerin not alması (sözlü ya da sözsüz biçimde) onların üstbilişsel süreçlerinde etkili mi? Neden?
d. Öğrenciler ziyaret sırasında herhangi bir çalışma kağıdı kullanıyor mu? Ne tür bir çalışma kağıdı? Nasıl kullanıyor?
    i. Öğrencilerin üstbilişsel süreçlerinde etkili mi? Neden?
e. Bilim merkezi eğitimcisi ve öğrenciler arasında ne tür bir etkileşim meydana geliyor?
    i. Bu tür etkileşimler öğrencilerin üstbilişsel süreçlerinde etkili mi? Neden?
f. Öğrenci ve öğretmen arasında ne tür bir etkileşim oluyor?
    i. Bu tür etkileşimler öğrencilerin üstbilişsel süreçlerinde etkili mi? Neden?

12. (Ziyaret sırasında, öğrencileriniz…) Öğrencileriniz bu stratejileri nasıl kullanıyor?
    a. Öğrencileriniz göreve nasıl yönlendiriliyor?
        i. Ön bilgi
        ii. Hipotez kurma
        iii. Önemli bilgileri tanımlama
        iv. Soruyu başka kelimelerle ifade etme (sizin veya bilim merkezi eğitimcisi tarafından sorulan)
    b. Öğrencileriniz görev için planlarını nasıl yapıyor?
        i. Looking for an information (they knew previously – *connection to prior knowledge*) Bilgi arama (önceden bildikleri olabilir – *ön bilgiyle bağlantı*)
        ii. Alt nedenler kurma
        iii. Soru sorarak düşünceleri düzenleme (kendisinin ya da diğerlerinin)
    c. Öğrencileriniz görevi nasıl yerine getiriyor?
        i. Sesli okuyarak
        ii. Tekrar okuyarak
        iii. Not alarak

        iv. Tahmin ederek
    d. Öğrencileriniz kendi eylemlerini nasıl gözlüyor?
        i. Hata tespiti
        ii. Görev yükleri üzerine yorumlamalarda bulunma
    e. Öğrencileriniz kendi eylemlerini nasıl değerlendiriyor?

13. Ziyaret sırasında kendinizi nasıl hissediyorsunuz?
14. Sizce öğrencileriniz kendilerini nasıl hissediyorlar? Bunu nasıl anlıyorsunuz?
15. (Ziyaret sonrasında, siz…) Ziyaret sonrasında ne tür etkinlikler yürütmektesiniz?
    a. (Ziyaret sonrasında) Bu etkinlikleri nasıl yürütüyorsunuz?
    b. Öğrencilerinizin deneyimlerini ders planıyla nasıl ilişkilendiriyorsunuz?
16. Ziyaret sonrasında kendinizi nasıl hissediyorsunuz?
17. Sizce öğrencileriniz kendilerini nasıl hissediyorlar? Bunu nasıl anlıyorsunuz?

C. Research Approval from Applied Ethics Research Center at METU

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
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05 NİSAN 2017

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof.Dr. Zahide YILDIRIM ;

Danışmanlığını yaptığınız doktora öğrencisi Gamze TÜRKMEN' in *"Ortaokul Öğrencilerinin Sosyal-Paylaşımlı Üstbilişsel Süreçlerinin İşbirlikçi Öğrenme Sırasında ve Sonrasında İncelenmesi: Bilim Merkezi Bağlamında Çoklu Yöntem Çalışması"* başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2017-EGT-061** protokol numarası ile **05.04.2017 – 30.12.2017** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Ş. Halil TURAN
Başkan V

Prof. Dr. Ayhan SOL
Üye

Prof. Dr. Ayhan Gürbüz DEMİR
Üye

Doç. Dr. Yaşar KONDAKÇI
Üye

Doç. Dr. Zana ÇITAK
Üye

Yrd. Doç. Dr. Pınar KAYGAN
Üye

Yrd. Doç. Dr. Emre SELÇUK
Üye

D. Research Approval from Innovation and Educational Technologies General Directorate of Ministry of National Education

T.C.
MİLLÎ EĞİTİM BAKANLIĞI
Yenilik ve Eğitim Teknolojileri Genel Müdürlüğü

Sayı : 81576613/605.01/4096238 26.02.2018
Konu: Araştırma İzni

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE
(Öğrenci İşleri Daire Başkanlığı)

İlgi: a) Orta Doğu Teknik Üniversitesi Öğrenci İşleri Daire Başkanlığın 20/02/2018 tarihli ve 54850036-300-903 sayılı yazısı
b) Millî Eğitim Bakanlığının 22/08/2017 tarihli ve 35558626-10.06.01-E.12607291 (2017/25) sayılı genelge

İlgi yazı (a) ile Orta Doğu Teknik Üniversitesi Bilgisayar ve Öğretim Teknolojileri Eğitimi EABD Doktora Programı öğrencisi Gamze TÜRKMENin "Ortaokul Öğrencilerinin Sosyal-Paylaşımlı Üst Bilişsel Süreçlerinin İş Birlikçi Öğrenme Sırasında ve Sonrasında İncelenmesi" konulu doktora tezi kapsamında hazırladığı veri toplama araçlarının Ankara, Eskişehir, Bursa, Kayseri, Konya, Manisa, Kocaeli, İzmir, İstanbul, Kırşehir ve Kırıkkale illerinde bulunan resmi ve özel her tür ve derecedeki ortaokullarda görev yapmakta olan öğretmenlere ve öğretim görmekte olan öğrencilere uygulanmasına yönelik izin talebi Genel Müdürlüğümüz tarafından incelenmiştir.

Denetimi il, ilçe milli eğitim müdürlükleri ve okul/kurum idaresinde olmak üzere, eğitim öğretim faaliyetlerini aksatmadan, gönüllülük esasına göre; onaylı bir örneği Bakanlığımızda muhafaza edilen ve uygulama sırasında da mühürlü ve imzalı örnekten çoğaltılmış veri toplama araçlarının ilgi (b) genelge doğrultusunda uygulanmasına izin verilmiştir.

Gereğini bilgilerinize rica ederim.

Gürhan ÇİÇEK
Bakan a.
Genel Müdür V.

Ek: Veri Toplama Aracı (13 Sayfa)

Emniyet Mahallesi Milas Sokak No:8 06560 Yenimahalle-ANKARA
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Öğretmen Koordinatör
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E. The Sent E-mail to Participants for Member-Check

XXX merhaba,

Geçtiğimiz XXX tarihinde bir görüşme gerçekleştirmiştik.
Görüşmedeki ses kaydını ve yazıya dökülmüş halini sırasıyla bağlantıda ve ekte bulabilirsiniz.

//Bağlantı adresi

Görüşmenin kullanılmasını onaylar mısınız? Yanlış anladığım veya çıkarılmasını talep ettiğiniz metinler var mı?

İlgi ve bilginiz için teşekkür ederim.

Saygılarımla,
Gamze Türkmen

F. Science Diary

Bilim Günlüğüm

Herbir bilim gezisi ve etkinliği sonrasında, aynı gün içerisinde düşüncelerinizi / duygularınızı / deneyimlerinizi yazarak bilim günlüğü tutmaya ne dersiniz? Daha kolay yazabilmek için deneyimleriniz sırasında notlar alabilirsiniz.

Günlüğünüzü yazarken:

- Adınızı Soyadınızı, günlüğü yazdığınız tarihi ve saati yazınız.
- Dürüst olun.
- Sadece deneyimlerinizi değil aynı zamanda fikirlerinizi ve duygularınızı da paylaşın.
- Gerektiğini düşündüğünüz yerlerde örnekler verin.

1. Hangi deney düzeneklerini seçeceğime nasıl karar verdim?

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2. Öğretmenimle iletişim kurdum mu? Öğretmenime hangi soruları soracağıma nasıl karar verdim?

____
____
____
____

3. Deneyimim sırasında arkadaşlarımla iletişimim nasıldı? Onlarla iletişim kurmaya nasıl karar verdim?

Arkadaşlarıma soru sordum mu? Bunlar nelerdi?

Arkadaşlarıma deneyimlerimden bahsettim mi? Bunlar nelerdi?

Arkadaşlarıma gösterdiğim deney düzenekleri oldu mu? Bunlar nelerdi?

Arkadaşlarımın sergi düzeneklerini denerken arkadaşımın herhangi bir hatasını fark ettim mi? Bunlar nelerdi?

Arkadaşlarımla dikkat ettiklerimi paylaştım mı? Bunları paylaşmaya nasıl karar verdim?

4. **Deneyim sonunda neler yaptım?**

Arkadaşlarımla öğrendiklerimi paylaştım mı? Bunlar nelerdi? Bunları paylaşmaya nasıl karar verdim?

Gezi sonunda değerlendirme yaptım mı? Bunlar nelerdi?

5. **Gezi sürecinde kendimi nasıl hissettim?**

6. Diğer gözlemlerim ve eklemek istediklerim:

G. Interview Protocols for Multiple Case Study

Interview Protocol for Video Edition Phase

Bireysel Görüşme Protokolü

Tarih: Görüşmeye katılan:

Araştırmanın sonlandırılması aşamasına katıldığın için teşekkür ederim. Aşağıda, katılmış olduğun çalışmanın son aşamasına yönelik sorular göreceksin.

Görüşme sorularına cevaben yazacağın metni, öğretmeninin mail adresiyle birlikte (...@ttmail.com), bana göndermen (gturkmen@metu.edu.tr) yeterlidir. Eğer bir mail adresi kullanmıyorsan, soruların cevaplarını yazdıktan sonra, cevap kağıdının fotoğrafını çekerek WhatsApp'tan gönderebilirsin.

Video Düzenleme Aşamasına Yönelik Sorular:

Geçmişe Dönük Sorular:

1. Video düzenleme sırasında, hatırlamadığını düşündüğün bir an oldu mu? Bunlar nelerdi?
2. Video düzenleme sırasında, soruları cevaplarken yaptığınız herhangi bir hatayı fark ettiniz mi? Bunlar nelerdi?
3. Video düzenleme sırasında, en çok hatırladığını düşündüğün deney düzeneği hangisiydi? Neden?
4. Video düzenleme sırasında, en az hatırladığını düşündüğün deney düzeneği hangisiydi? Neden?

Genel Sorular:

1. Kendi ürettiğin videonu düzenlerken nelere dikkat ettin?
2. Videonu düzenlerken en çok dikkatini çeken şey neydi?
3. Videonu düzenlerken yaşadığın zorluklar nelerdi?
4. Videonu düzenlemenin sana ne tür yararları oldu?

Fen Bilgisi Dersine Yönelik Sorular:

5. Video düzenlemenin bilim merkezinde yaptığın deneyleri öğrenmene katkısı olduğunu düşünüyor musun? Nedenlerini anlatır mısın?
6. Video düzenlemenin en iyi hangi deney uygulamasını öğrendiğini düşünüyorsun? Nedenlerini açıklar mısın?

7. Video düzenlemenin en az hangi deney uygulamasını öğrendiğini düşünüyorsun? Nedenlerini açıklar mısın?

Sonlandırma Soruları:

8. Video düzenleme aşamasının nasıl olmasını isterdin?
9. Video düzenleme aşamasının fen bilgisi dersindeki kavramları anlamaya yardımcı oldu mu? Nedenlerini açıklar mısın?

H. Tables for Research Design

Research Questions	Research Components		Descriptions
RQ1. What are the current practices of science centers for providing educational effectiveness according to science center educators' and science teachers' experiences?	**Method**		
		Research Methodology	A qualitative research to investigate current practices via needs assessment and task analysis
		Context	Science centers in Turkey
		Central Phenomenon	Science teachers' and science center educators' experiences of science centers
	Data		
		Data Sources	Semi-structured interview protocols Example documents from science centers
		Data Collection	Research permissions Interview protocols Direct observations throughout science center visits Creating a case study database
		Data Analysis	Content Analysis: Data driven thematic analysis Document Analysis: Data driven thematic analysis
	Sampling		
		Participants	20 science center educators Three science teachers
		Sampling method	Purposive sampling Snowballing
		Selection of participants, schools and/or science centers	Web searching Receiving suggestions from each science center educator

Research Questions	Research Components		Descriptions
RQ2. What are the indicators of metacognitive activities of science center educators through guidance period of the exhibition units related with science concepts in curriculum?	**Method**		
		Research Methodology	A qualitative research to investigate science center educators' metacognitive activities during guidance
		Context	Exhibition units in relation with current science lesson unit within science center
		Central Phenomenon	Science center educators' metacognitive activities during guidance and students' conceptual understanding and perceived experiences after guidance
	Data		
		Data Sources	Video recordings Conceptual diagnostic paper Science diary
		Data Collection	Research permissions Science diary Conceptual diagnostic test
		Data Analysis	Content Analysis Video Analysis Sequential time analysis
	Sampling		
		Participants	Six recorded videos during guidance for two science concepts Six science center educators and students Students as a whole class
		Sampling method	Purposive sampling for science centers and science lesson units Convenient sampling for schools
		Selection of participants, schools and/or science centers	Science centers: Availability of exhibition units in relation with selected science lesson units. Participants: Web searching and contacting by telephone to understand the willingness of participation in study before face-to-face meeting

Research Questions	Research Components		Descriptions
RQ3. What are the indicators of individual and inter-individual metacognitive processes in response to collaborative activities in science center environments across three cases?	**Method**		
		Research Methodology	A qualitative research to investigate students' individual and inter-individual metacognitive processes during collaborative activity period
		Context	Exhibition units in relation with c
		Central Phenomenon	Students' metacognitive processes during collaborative activity
	Data		
		Data Sources	Video recordings Retrospective interviews Think-aloud protocols
		Data Collection	Research permissions Tobii Glass Eye-trackers Third-view cameras Direct and indirect observations during collaborative activity Audio recordings for retrospective interviews after collaborative activities Edited video products by students
		Data Analysis	Content Analysis Conversation Analysis Sequential time analysis Video analysis
	Sampling		
		Participants	70 seventh grade students (35 collaborative matched-pairs)
		Sampling method	Convenience sampling Purposive sampling
		Selection of participants, schools and/or science centers	Voluntary students

I. Conceptual Diagnostic Paper for Each Science Center Visit

Lesson Unit: Work and Energy

Week: Force and Pressure

KAVRAM DEĞERLENDİRMESİ

Değerli öğrenciler,

Aşağıdaki tablolarda bilim merkezi gezisi sırasında konu kazanımlarınıza yönelik anlatımların yapıldığı sergi ünitelerini görmektesiniz. Lütfen üst kutucuklarda bulunan soruları uygun boşluklara kendi cümlelerinizle cevaplayınız.

Sergi ünitesi	**Çalıştırırken neler gözlemlediniz?**	**İlişkili fen kavramları nelerdir?**	**Çalışma prensibini ilişkili kavramları kullanarak açıklayınız**
			
			

Sergi ünitesi	**Çalıştırırken neler gözlemlediniz?**	**İlişkili fen kavramları nelerdir?**	**Çalışma prensibini ilişkili kavramları kullanarak açıklayınız**
			
			
			

Lesson Unit: Work and Energy

Week: Work and Energy

KAVRAM DEĞERLENDİRMESİ

Değerli öğrenciler,

Aşağıdaki tablolarda bilim merkezi gezisi sırasında konu kazanımlarınıza yönelik anlatımların yapıldığı sergi ünitelerini görmektesiniz. Lütfen üst kutucuklarda bulunan soruları uygun boşluklara kendi cümlelerinizle cevaplayınız.

Sergi ünitesi	**Çalıştırırken neler gözlemlediniz?**	**İlişkili fen kavramları nelerdir?**	**Çalışma prensibini ilişkili kavramları kullanarak açıklayınız**
			
			

Sergi ünitesi	Çalıştırırken neler gözlemlediniz?	İlişkili fen kavramları nelerdir?	Çalışma prensibini ilişkili kavramları kullanarak açıklayınız
			
			

Lesson Unit: Mirrors and Light Absorption

KAVRAM DEĞERLENDİRMESİ

Değerli öğrenciler,

Aşağıdaki tablolarda bilim merkezi gezisi sırasında konu kazanımlarınıza yönelik anlatımların yapıldığı sergi ünitelerini görmektesiniz. Lütfen üst kutucuklarda bulunan soruları uygun boşluklara kendi cümlelerinizle cevaplayınız.

Sergi ünitesi	Çalıştırırken neler gözlemlediniz?	İlişkili fen kavramları nelerdir?	Çalışma prensibini ilişkili kavramları kullanarak açıklayınız
			
			
			

Lesson Unit: Solar System and Beyond

KAVRAM DEĞERLENDİRMESİ

Değerli öğrenciler,

Aşağıdaki tablolarda bilim merkezi gezisi sırasında konu kazanımlarınıza yönelik anlatımların yapıldığı sergi ünitelerini görmektesiniz. Lütfen üst kutucuklarda bulunan soruları uygun boşluklara kendi cümlelerinizle cevaplayınız.

Sergi ünitesi	**Çalıştırırken neler gözlemlediniz?**	**İlişkili fen kavramları nelerdir?**	**Çalışma prensibini ilişkili kavramları kullanarak açıklayınız**
			
			

Sergi ünitesi	Çalıştırırken neler gözlemlediniz?	İlişkili fen kavramları nelerdir?	Çalışma prensibini ilişkili kavramları kullanarak açıklayınız
			
			

J. Worksheets for Collaborative Pairs for Each Case

Lesson Unit: Work and Energy

Worksheet: Force and Pressure

Kuvvet ve Basınç

Değerli arkadaşlar,

Bu etkinlikte, Kuvvet ve Enerji ünitesine yönelik okul gezilerinizde incelediğiniz sergi ünitelerini, bilim merkezine gelemeyen arkadaşlarınızla çekilen videoları paylaşmak üzere deneyimleyeceksiniz. Etkinlik sırasında, mümkün olduğunca her adımınızı sesli düşünün ve gerektiği takdirde notlar alın. Böylece videoları paylaşmadan önce gözden geçirirken, tüm sürecinize yönelik ipuçları edinebilirsiniz.

Etkinlik sürecinde, size verilen el kağıtlarını etkinliğe başlamadan önce plan oluşturmak, oluşturduğunuz planları takip ettiğinizi anlamak ve planınıza uyup uymadığınızı kontrol etmek üzere kullanabilirsiniz.

Etkinlik 1:

Tüm gücünüzle zıpladığınızda yerden ne kadar uzaklaşabiliyorsunuz? Zıpladığınızda çok kısa bir süre sonra yere düşersiniz. Buna göre zıplayınca yerden çok fazla uzaklaşmamanızın ve kısa süre sonra yere düşmenizin nedeni ne olabilir? Yukarı doğru attığınız bir top tekrar yere düşerken yerde yuvarlanan top neden geri gelmez?

Hatırlayalım: Günlük hayatta varlıklara sayısız kuvvet uygularsınız ve birçok kuvvetin etkisinde kalırsınız. Bir kuvvetin etkisindeki varlıklarda hızlanma, yavaşlama, dönme, yön değiştirme, şekil değiştirme gibi etkiler ortaya çıkabilir.

Zıt kutuplu mıknatıslar birbirini yaklaştırıldığında birbirine çekme kuvveti uygular. Buna göre dünya; üzerindeki cisimlere, Dünya üzerindeki cisimler de Dünya'ya çekme kuvveti uygular. Ancak Dünya'nın kütlesi çok büyük olduğundan Dünya hareket etmezken üzerindeki cisim Dünya'ya doğru hareket eder. Dünya ile üzerindeki cisimler arasındaki bu kuvvete **yer çekimi kuvveti** adı verilir.

Bu etkinlikte amacınız kuvvet kavramını, bilim merkezini ziyaret etmemiş olan bir akranınıza anlatabilmeniz. Bunun için lütfen aşağıdaki soruları gözden geçiriniz.

1. Kuvvet kavramını **hatırlatmak** ve arkadaşlarınıza **önbilgi sağlamak** için hangi düzeneği/düzenekleri kullanırdınız?

2. Neden bu düzeneği/düzenekleri seçerdiniz?

3. Hangi sırada anlatırdınız? Lütfen aşağıda alt amaçlarınızı listeleyiniz.

Bir veya birden fazla düzenek seçtiniz. Bu düzeneği / düzenekleri arkadaşlarınıza anlatmak için alt amaçlar belirleyin.

4. Seçtiğiniz düzenekler arasında  düzeneği var mıydı? Eğer yoksa, bu düzeneği arkadaşlarınıza anlatmak için alt amaçlar belirleyin.

a. Düzeneğin amacı:

b. Alt amaçlarınız:

c. Nasıl çalışıyor?

d. Günlük hayatla ilişkilendirilebilir mi? Nasıl?

5. Eğer başka bir düzenek seçtiyseniz, arkadaşlarınıza bu düzeneği nasıl anlatırdınız?

Soruları cevapladıktan sonra, lütfen kendinizi değerlendiriniz:

1. Etkinlik başında yazdığınız alt amaçları gözden geçiriniz. Bu amaçların ne kadarını sağladınız?

2. Amaçlarınızı yenilemek isteseniz, eklemek/çıkarmak istedikleriniz olur muydu? Bunlar neler olurdu?

Etkinlik 2:

Yukarıdaki görselde el izlerinin derinliği aynı mı? El izleri derinliğinin birbirinden farklı olmasının nedeni nedir? Bunu hangi kavramla açıklayabiliriz?

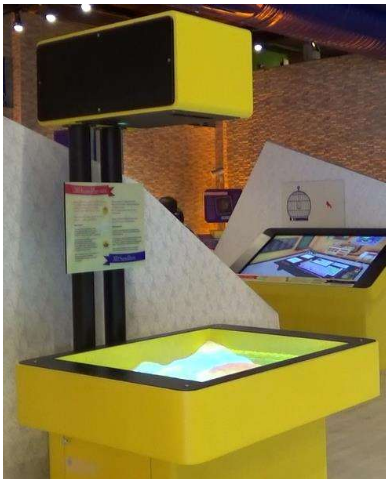
Bu etkinlikte amacınız basınç kavramını, bilim merkezini ziyaret etmemiş olan bir akranınıza anlatabilmeniz. Bunun için lütfen aşağıdaki soruları gözden geçiriniz.

1. Basıncın **bağlı olduğu değişkenleri** göstermek ve basınç kavramını **tanımlamak** için hangi düzeneği/düzenekleri kullanırdınız?

2. Neden bu düzeneği/düzenekleri seçerdiniz?

3. Hangi sırada anlatırdınız? Lütfen aşağıda alt amaçlarınızı listeleyiniz.

Bir veya birden fazla düzenek seçtiniz. Bu düzeneği / düzenekleri arkadaşlarınıza anlatmak için alt amaçlar belirleyin.

6. Seçtiğiniz düzenekler arasında  düzeneği var mıydı? Eğer yoksa, bu düzeneği arkadaşlarınıza anlatmak için alt amaçlar belirleyin.

e. Düzeneğin amacı:

f. Alt amaçlarınız:

g. Günlük hayatla ilişkilendirilebilir mi? Nasıl?

7. Bu düzenek yardımıyla aşağıdaki sorulara cevap bulmaya çalışınız:

a. Tüm katı cisimler ağırlıklarından dolayı temas ettikleri yüzeylere kuvvet uygular. Elimizle bir kumun üzerine dik ve yatay olarak eş kuvvetler uyguladığımızda farklı derinlikler gözlemleriz. Bu farklı yüzeylerin kumda oluşturdukları derinliklerin farklı olmasının nedeni nedir?

b. Basıncın bağlı olduğu değişkenler nelerdir?

c. Bu değişkenleri kullanarak basıncı nasıl tanımlarız?

Soruları cevapladıktan sonra, lütfen kendinizi değerlendiriniz:

3. Etkinlik başında yazdığınız alt amaçları gözden geçiriniz. Bu amaçların ne kadarını sağladınız?

4. Amaçlarınızı yenilemek isteseniz, eklemek/çıkarmak istedikleriniz olur muydu? Bunlar neler olurdu?

Etkinlik 3:

Bu etkinlikte amacınız, yukarıdaki görselde bulunan düzeneği kullanarak sıvı basıncının hangi değişkenlere bağlı olduğunu açıklamak ve sıvı basıncını bu değişkenler aracılığıyla tanımlamaktır.

1. Alt amaçlarınız nelerdir?

2. Düzeneği tanımlayınız. Nasıl çalışır? Tüplerdeki sıvılarda herhangi bir farklılık var mı?

3. Düzeneği çalıştırdığınızda ne görüyorsunuz? Bunun nedeni nedir?

4. Bu tüplerde birer delik olsaydı, sıvıların fışkırma mesafeleri nasıl değişirdi?

Soruları cevapladıktan sonra, lütfen kendinizi değerlendiriniz:

1. Etkinlik başında yazdığınız alt amaçları gözden geçiriniz. Bu amaçların ne kadarını sağladınız?

2. Amaçlarınızı yenilemek isteseniz, eklemek/çıkarmak istedikleriniz olur muydu? Bunlar neler olurdu?

Etkinlik 4:


Bu etkinlikte amacınız, yukarıdaki görselde bulunan düzeneği kullanarak açık hava basıncının hangi değişkenlere bağlı olduğunu açıklamak ve açık hava basıncını bu değişkenler yardımıyla tanımlamaktır.

1. Alt amaçlarınız nelerdir?

2. Düzeneği/düzenekleri tanımlayınız. Adları nedir? Nasıl çalışır?

3. Düzeneği/düzenekleri çalıştırdığınızda ne görüyorsunuz? Bunun nedeni nedir?

4. İlk düzenek için:
    a. Topun sağ ve sol tarafına uygulanan basınçlar arasında bir fark var mı?
    b. Top nasıl havada kalıyor?

5. İkinci düzenek için:
    a. Balon hangi faktörler yardımıyla yükseliyor? Neden?

6. Açık hava basıncının bağlı olduğu değişkenler nelerdir?

Soruları cevapladıktan sonra, lütfen kendinizi değerlendiriniz:

1. Etkinlik başında yazdığınız alt amaçları gözden geçiriniz. Bu amaçların ne kadarını sağladınız?

2. Amaçlarınızı yenilemek isteseniz, eklemek/çıkarmak istedikleriniz olur muydu? Bunlar neler olurdu?

Worksheet: Energy and Energy Transformation

1

ENERJİ

Amacınız, **fiziksel anlamda yapılan iş** ve **enerji** kavramını anlatabileceğiniz düzenekleri belirlemek ve enerji ve fiziksel anlamda yapılan iş arasındaki ilişkiyi not etmektir.

1. Hangi düzeneği/düzenekleri seçerdiniz?

____

____

2. Neden bu düzeneği/düzenekleri seçerdiniz?

____

____

3. Bu düzenek/düzeneklerle kavramları anlatırken belirleyeceğini alt amaçlar nelerdir?

____

____

4. Enerji ve fiziksel anlamda yapılan iş arasındaki ilişkiden bahsediniz.

____

____

2

KİNETİK ENERJİ

Amacınız, **kinetik enerjinin bağlı olduğu değişkenler**i belirlemek ve bu değişkenlerle arasında nasıl bir ilişki olduğunu ifade etmektir.

1. Resimdeki deney düzeneğini kullanmadan önce alt amaçlarınızı yazınız.

____

____

a. Hangi disk sonuca en erken varıyor? Neden?

____

____

b. Eğik düzlemin sürtünme kuvveti arttırıldığında disklerin varış süreleri nasıl değişir?

____

c. Kinetik enerjinin bağlı olduğu değişkenler nelerdir? Aralarındaki ilişkiyi tanımlayınız.

____

____

Kendinizi değerlendirmek için arka sayfayı çeviriniz. ⇨

KİNETİK ENERJİ: DEĞERLENDİRME

Amacınız, **kinetik enerjinin bağlı olduğu değişkenleri** belirlemek ve bu değişkenlerle arasında nasıl bir ilişki olduğunu ifade etmektir.

1. Sunulan deney düzeneği haricinde hangi deney düzeneğini/düzeneklerini kullanırdınız?

____

____

2. Sizce yazdığınız alt amaçların ne kadarını sağladınız? Neden?

____

____

3. Soruları cevaplarken nasıl bir strateji kullandınız?

____

____

4. Amaçlarınızı yenilemek isteseniz eklemek/çıkarmak istedikleriniz olur muydu? Bunlar nelerdir?

____

____

3

POTANSİYEL ENERJİ

Amacınız, **çekim potansiyel enerjisinin bağlı olduğu değişkenleri** belirlemek ve bu değişkenlerle arasında nasıl bir ilişki olduğunu ifade etmektir.

1. Resimdeki deney düzeneğini kullanmadan önce alt amaçlarınızı yazınız.

____

____

a. Farklı ağırlıklardaki iki topu aynı yükseklikten bıraktığınızda ne gözlemliyorsunuz? Nedeni nedir?

____

b. Aynı ağırlıklardaki iki topu farklı yükseklikten bıraktığınızda ne gözlemliyorsunuz? Nedeni nedir?

____

c. Çekim potansiyel enerjisinin bağlı olduğu değişkenler nelerdir? Aralarındaki ilişkiyi tanımlayınız.

____

____

Kendinizi değerlendirmek için arka sayfayı çeviriniz. ⇨

POTANSİYEL ENERJİ: DEĞERLENDİRME

Amacınız, **çekim potansiyel enerjisinin bağlı olduğu değişkenleri** belirlemek ve bu değişkenlerle arasında nasıl bir ilişki olduğunu ifade etmektir.

1. Sunulan deney düzeneği haricinde hangi deney düzeneğini/düzeneklerini kullanırdınız?

____

____

2. Sizce yazdığınız alt amaçların ne kadarını sağladınız? Neden?

____

____

3. Soruları cevaplarken nasıl bir strateji kullandınız?

____

____

4. Amaçlarınızı yenilemek isteseniz eklemek/çıkarmak istedikleriniz olur muydu? Bunlar nelerdir?

____

____

4 ENERJİ DÖNÜŞÜMLERİ

Amacınız, günlük yaşamdaki **enerji türleri**ni listelemek, **enerji dönüşümleri**ni örneklemek ve **enerjinin yok edilip edilemeyeceğini** ifade etmektir.

1. Resimdeki deney düzeneğini kullanmadan önce alt amaçlarınızı yazınız.

____

____

a. Düzeneği çalıştırdığınızda hangi enerji türlerini gözlemliyorsunuz? Bu enerji türlerinin hangi sırayla birbirine dönüştüğünü yazınız.

____

____

____

b. Sizce enerji yok edilebilir mi? Neden?

____

____

Kendinizi değerlendirmek için arka sayfayı çeviriniz. ⇒

ENERJİ DÖNÜŞÜMLERİ: DEĞERLENDİRME

Amacınız, günlük yaşamdaki **enerji türleri**ni listelemek, **enerji dönüşümleri**ni örneklemek ve **enerjinin yok edilip edilemeyeceğini** ifade etmektir.

1. Sunulan deney düzeneği haricinde hangi deney düzeneğini/düzeneklerini kullanırdınız?

____

____

2. Sizce yazdığınız alt amaçların ne kadarını sağladınız? Neden?

____

____

3. Soruları cevaplarken nasıl bir strateji kullandınız?

____

____

4. Amaçlarınızı yenilemek isteseniz eklemek/çıkarmak istedikleriniz olur muydu? Bunlar nelerdir?

____

____

5

ENERJİ DÖNÜŞÜMLERİ II

Amacınız, günlük yaşamdaki **enerji dönüşümleri**ni örneklendirmektir.

1. Resimdeki deney düzeneğini kullanmadan önce alt amaçlarınızı yazınız.

____

____

2. Pedalları çevirdiğinizde ne gözlemliyorsunuz?

____

____

3. Uyguladığınız kuvveti arttırdıkça ne gözlemliyorsunuz? Neden?

____

____

____

____

Kendinizi değerlendirmek için arka sayfayı çeviriniz.

ENERJİ DÖNÜŞÜMLERİ II: DEĞERLENDİRME

Amacınız, günlük yaşamdaki **enerji dönüşümleri**ni örneklendirmektir.

1. Sunulan deney düzeneği haricinde hangi deney düzeneğini/düzeneklerini kullanırdınız?

____

____

2. Sizce yazdığınız alt amaçların ne kadarını sağladınız? Neden?

____

____

3. Soruları cevaplarken nasıl bir strateji kullandınız?

____

____

4. Amaçlarınızı yenilemek isteseniz eklemek/çıkarmak istedikleriniz olur muydu? Bunlar nelerdir?

____

____

Worksheet: Mirrors and Light Absorption

(5) **AYNALAR II: DEĞERLENDİRME**

Amacınız, **ayna çeşitlerini gözlemleyerek düz, çukur ve tümsek aynalarda oluşan görüntüleri** alt amaçlar belirleyerek karşılaştırmaktır.

1. Sunulan deney düzeneği haricinde yukarıdaki amacı sağlamak için hangi deney düzeneğini/ düzeneklerini kullanırdınız? Neden?

2. Yazdığınız alt amaçlarınıza neye göre karar verdiniz?

3. Herbir alt amacınızı gerçekleştirirken neler fark ettiniz?

4. Soruları cevaplarken nasıl bir yöntem belirlediniz?

5. Amaçlarınızı yenilemek isteseniz eklemek/çıkarmak istedikleriniz olur muydu? Bunlar nelerdir?

Worksheet (Cont.): Mirrors and Light Absorption

5 AYNALAR II

Amacınız, **ayna çeşitlerini gözlemleyerek düz, çukur ve tümsek aynalarda oluşan görüntüleri** alt amaçlar belirleyerek karşılaştırmaktır.

1. Fotoğrafta gördüğünüz "Sonsuz görüntü" düzeneğini bulunuz. Sizce bu deney düzeneği yukarıdaki amacı sağlıyor mu? Neden?

2. Bu deney düzeneğini kullanmadan önce beyaz ışık ve renk kavramlarını nasıl anlatacağınıza karar veriniz. Anlatacaklarınızı sıralayınız.

3. Amacınıza yönelik alt amaçlar belirleyiniz. Herbir alt amacınızı gerçekleştirirken neler fark ettiniz?

4. Bu düzenekte kaç ayna var? Bu düzenekteki ayna, ne tür aynalara örnektir?

5. Bu düzenekteki sonsuz görüntü nasıl oluşuyor?

6. İki tümsek aynayı birbirine paralel yerleştirsek yine sonsuz görüntü oluşur muydu? Neler olurdu?

Worksheet (Cont.): Mirrors and Light Absorption

(4) AYNALAR: DEĞERLENDİRME

Amacınız, **ayna çeşitlerini gözlemleyerek düz, çukur ve tümsek aynalarda oluşan görüntüleri** alt amaçlar belirleyerek karşılaştırmaktır.

1. Sunulan deney düzeneği haricinde yukarıdaki amacı sağlamak için hangi deney düzeneğini/düzeneklerini kullanırdınız? Neden?

2. Yazdığınız alt amaçlarınıza neye göre karar verdiniz?

3. Herbir alt amacınızı gerçekleştirirken neler fark ettiniz?

4. Soruları cevaplarken nasıl bir yöntem belirlediniz?

5. Amaçlarınızı yenilemek isteseniz eklemek/çıkarmak istedikleriniz olur muydu? Bunlar nelerdir?

Worksheet (Cont.): Mirrors and Light Absorption

(4) **AYNALAR**

Amacınız, **ayna çeşitlerini gözlemleyerek düz, çukur ve tümsek aynalarda oluşan görüntüleri** alt amaçlar belirleyerek karşılaştırmaktır.

1. Fotoğrafta gördüğünüz "Yaya Dokunun" düzeneğini bulunuz. Sizce bu deney düzeneği yukarıdaki amacı sağlıyor mu? Neden?

2. Bu deney düzeneğini kullanmadan önce beyaz ışık ve renk kavramlarını nasıl anlatacağınıza karar veriniz. Anlatacaklarınızı sıralayınız.

3. Amacınıza yönelik alt amaçlar belirleyiniz. Herbir alt amacınızı gerçekleştirirken neler fark ettiniz?

4. Bu düzenekteki yayın görüntüsü nasıl oluşuyor?

5. Bu düzenekteki ayna, ne tür aynalara örnektir?

6. Bu düzenekte diğer ayna türleri kullanılsa nasıl bir görüntü oluşurdu? (*Düzenekte kullanılan ayna türü haricindeki*)

7. Bu düzenekte yay değil başka bir cisim kullanılsa, yine aynı görüntü oluşur mu? Neden?

Worksheet (Cont.): Mirrors and Light Absorption

3 RENKLİ GÖRÜNME: DEĞERLENDİRME

Amacınız, **gözlemleriniz sonucunda cisimlerin, siyah, beyaz ve renkli görünmesinin nedenini**, alt amaçlar belirleyerek **ışığın yansıması ve soğrulmasıyla** ilişkilendirmektir.

1. Sunulan deney düzeneği haricinde yukarıdaki amacı sağlamak için hangi deney düzeneğini/ düzeneklerini kullanırdınız? Neden?

2. Yazdığınız alt amaçlarınıza nasıl karar verdiniz?

3. Herbir alt amacınızı gerçekleştirirken neler fark ettiniz?

4. Soruları cevaplarken nasıl bir yöntem belirlediniz?

5. Amaçlarınızı yenilemek isteseniz eklemek/çıkarmak istedikleriniz olur muydu? Bunlar nelerdir?

Worksheet (Cont.): Mirrors and Light Absorption

3 RENKLİ GÖRÜNME

Amacınız, **gözlemleriniz sonucunda cisimlerin, siyah, beyaz ve renkli görünmesinin nedenini**, alt amaçlar belirleyerek **ışığın yansıması ve soğrulmasıyla** ilişkilendirmektir.

1. Fotoğrafta gördüğünüz "Tek renkli oda" düzeneğini bulunuz. Sizce bu deney düzeneği yukarıdaki amacı sağlıyor mu? Neden?

2. Bu deney düzeneğini kullanmadan önce beyaz ışık ve renk kavramlarını nasıl anlatacağınıza karar veriniz. Anlatacaklarınızı sıralayınız.

3. Amacınıza yönelik alt amaçlar belirleyiniz. Herbir alt amacınızı gerçekleştirirken neler fark ettiniz?

4. Bu düzenekteki cisimler sizce hep aynı tonda mı? Neden?

5. Düzenekteki boğa cismi neden kırmızı renkli?

6. Düzenekteki tüm cisimler başka bir renk tonunda görünebilir miydi? Nasıl?

7. Sıcaklık gibi fiziksel etmenler değiştiğinde neler olurdu?

Worksheet (Cont.): Mirrors and Light Absorption

② BEYAZ IŞIK: DEĞERLENDİRME

Amacınız, **beyaz ışığın tüm ışık renklerinin bileşiminden oluştuğu** sonucunu belirleyeceğiniz deney düzeneklerine yönelik alt amaçlarla birlikte çıkarmaktır.

1. Sunulan deney düzeneği haricinde yukarıdaki amacı sağlamak için hangi deney düzeneğini/ düzeneklerini kullanırdınız? Neden?

2. Yazdığınız alt amaçlarınıza nasıl karar verdiniz?

3. Herbir alt amacınızı gerçekleştirirken neler fark ettiniz?

4. Soruları cevaplarken nasıl bir yöntem belirlediniz?

5. Amaçlarınızı yenilemek isteseniz eklemek/çıkarmak istedikleriniz olur muydu? Bunlar nelerdir?

Worksheet (Cont.): Mirrors and Light Absorption

② BEYAZ IŞIK

Amacınız, **beyaz ışığın tüm ışık renklerinin bileşiminden oluştuğu** sonucunu belirleyeceğiniz deney düzeneklerine yönelik alt amaçlarla birlikte çıkarmaktır.

1. Fotoğrafta gördüğünüz "Sayısız renk" düzeneğini bulunuz. Sizce bu deney düzeneği yukarıdaki amacı sağlıyor mu? Neden?

2. Bu deney düzeneğini kullanmadan önce beyaz ışık ve renk kavramlarını nasıl anlatacağınıza karar veriniz. Anlatacaklarınızı sıralayınız.

3. Amacınıza yönelik alt amaçlar belirleyiniz. Herbir alt amacınızı gerçekleştirirken neler fark ettiniz?

4. Düzenekteki mavi, yeşil ve kırmızı renkteki ışıkları açarak bir renk elde etmeye çalışın? Ne renk elde ettiniz?

5. Düzenekteki mavi, kırmızı, yeşil renkteki ışıkları kapatarak bir renk oluşturmaya çalışın. Ne renk oluşturdunuz?

6. Düzenekteki ışıkların tonlarını ışık seviyeleriyle oynayarak birinden az birinden çok olacak şekilde karıştırın? Hangi ana renklerden hangi renkleri ve tonları elde ettiniz?

Worksheet (Cont.): Mirrors and Light Absorption

① BEYAZ IŞIK: SERBEST SEÇİM

Amacınız, **beyaz ışığın tüm ışık renklerinin bileşiminden oluştuğu** sonucunu belirleyeceğiniz deney düzeneklerine yönelik alt amaçlarla birlikte çıkarmaktır.

1. Hangi düzeneği/düzenekleri seçerdiniz?

2. Neden bu düzenekleri seçmeye karar verdiniz?

3. Bu düzenek/düzeneklerle ilgili kavramları hangi aşamalarla anlatırdınız? Amacınıza yönelik alt amaçlar belirleyiniz.

4. Beyaz ışık ve renkler arasındaki ilişkiden bahsediniz.

6 SERBEST SEÇİM

Amacınız, **size verilen deney düzenekleri haricindeki başka bir deney düzeneğini** anlatımınıza eklemek ve ilgili kavram ve konuları keşfetmektir.

1. Hangi düzeneği seçerdiniz?

2. Neden bu düzenekleri seçmeye karar verdiniz?

3. Bu düzenek hangi kavramlarla ilişkili? Bu kavramları nasıl anlatırdınız?

4. Düzenekle ilgili gözlemlerinizi ve düzeneğin çalışma prensibini yazınız.

Worksheet: Solar System and Beyond

1

GÜNEŞ SİSTEMİ VE ÖTESİ

Amacınız, güneş sistemi ve ötesine yönelik **deney düzeneklerini belirlemek** ve bu konu ile ilgili **hangi kavramları kullanacağınıza karar vermektir.**

1. Hangi düzeneği/düzenekleri seçerdiniz?

____

____

2. Neden bu düzeneği/düzenekleri seçmeye karar verdiniz?

____

____

3. Gökyüzüne baktığınızda hangi cisimleri gözlemlersiniz? Uzay, gezegen, yıldız kavramlarını nasıl açıklarsınız?

____

____

____

____

____

Worksheet (Cont.): Solar System and Beyond

2

YILDIZLAR

Amacınız, **yıldız ve takımyıldız kavramlarını** açıklamak ve uzaklıkları ile parlaklıkları arasındaki ilişkiyi anlamaktır.

1. Yıldızlar ile ilgili tüm deney düzeneklerini bulunuz.
2. Yıldız nedir? Yıldızlar nasıl görünür?

____

____

3. Takımyıldız nedir? Neden takımyıldız adını almıştır?

____

____

4. Gökcisimleri arasındaki uzaklık ne cinsinden ifade edilir? Yıldızların birbirinden uzaklıklarını nasıl anlarız?

____

5. En parlak yıldız, en yakındaki yıldız mıdır? Neden?

____

____

Kendinizi değerlendirmek için arka sayfayı çeviriniz. →

YILDIZLAR: DEĞERLENDİRME

Amacınız, **yıldız ve takımyıldız kavramlarını** açıklamak ve uzaklıkları ile parlaklıkları arasındaki ilişkiyi anlamaktır.

1. Sunulan deney düzeneği haricinde hangi deney düzeneğini/düzeneklerini kullanırdınız?

____

____

2. Neden bu deney düzeneklerine karar verirdiniz?

____

____

3. Soruları cevaplarken nasıl bir strateji kullandınız?

____

____

4. Başka hangi soruların eklenmesini isterdiniz?

____

____

Worksheet (Cont.): Solar System and Beyond

3

GEZEGENLER

Amacınız, **güneş sistemindeki gezegenleri** tanımlamak ve onların **arasındaki farkları not etmektir.**

1. Gezegenler ile ilgili tüm deney düzeneklerini bulun.
2. Gezegen nedir? Güneş etrafında dönen kaç gezegen vardır?

3. Dünya ve Neptün gezegenleri arasındaki uzaklık nedir?

4. Dünya ve Mars arasındaki farkları düzeneklerdeki bilgilerden yararlanarak bulunuz.

4. Yıldız ve gezegenler arasındaki farklar nelerdir?

Kendinizi değerlendirmek için arka sayfayı çeviriniz.

GEZEGENLER: DEĞERLENDİRME

Amacınız, **güneş sistemindeki gezegenleri** tanımlamak ve onların **arasındaki farkları**

1. Sunulan deney düzeneği haricinde hangi deney düzeneğini/düzeneklerini kullanırdınız?

2. Neden bu deney düzeneklerine karar verirdiniz?

3. Soruları cevaplarken nasıl bir strateji kullandınız?

4. Başka hangi soruların eklenmesini isterdiniz?

Worksheet (Cont.): Solar System and Beyond

4

YAZ / KIŞ GÜNEŞİ

Amacınız, yaz ve kış güneşi arasındaki farkları güneşin ışık ışınlarına olan uzaklığına göre belirlemektir.

1. Güneş ile ilgili tüm düzenekleri bulunuz.
2. Güneşten gelen ışık miktarının, diğer yıldızlardan gelen ışık miktarından farkları nelerdir?

____

____

3. Düzenekteki ibreyi kaydırdıkça ne gözlemliyorsunuz? Neden?

____

____

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____

Kendinizi değerlendirmek için arka sayfayı çeviriniz. →

YAZ / KIŞ GÜNEŞİ: DEĞERLENDİRME

Amacınız, yaz ve kış güneşi arasındaki farkları güneşin ışık ışınlarına olan uzaklığına göre belirlemektir.

1. Sunulan deney düzeneği haricinde hangi deney düzeneğini/düzeneklerini kullanırdınız?

____

____

2. Neden bu deney düzeneklerine karar verdiniz?

____

____

3. Soruları cevaplarken nasıl bir strateji kullandınız?

____

____

4. Başka hangi soruların eklenmesini isterdiniz?

____

____

Worksheet (Cont.): Solar System and Beyond

5

GEZEGENLERİN DÖNÜŞÜ

Amacınız, güneşin etrafında dönen gezegenlerin dönüşünü gözlemlemek ve farklı uzaklıklardaki dönüş hızlarını karşılaştırmaktır.

1. Topu ilk attığınızda ne gözlemliyorsunuz?

____

____

2. Top merkeze yaklaştığında ne gözlemliyorsunuz?

____

____

3. Gezegenlerin güneşin etrafında dönmesiyle nasıl ilişkili?

____

____

____

____

____

Kendinizi değerlendirmek için arka sayfayı çeviriniz. ➡

GEZEGENLERİN DÖNÜŞÜ: DEĞERLENDİRME

Amacınız, güneşin etrafında dönen gezegenlerin dönüşünü gözlemlemek ve farklı uzaklıklardaki dönüş hızlarını karşılaştırmaktır.

1. Sunulan deney düzeneği haricinde hangi deney düzeneğini/düzeneklerini kullanırdınız?

____

____

2. Neden bu deney düzeneklerine karar verdiniz?

____

____

3. Soruları cevaplarken nasıl bir strateji kullandınız?

____

____

4. Başka hangi soruların eklenmesini isterdiniz?

____

____

Worksheet (Cont.): Solar System and Beyond

6

SERBEST SEÇİM

Amacınız, size verilen deney düzenekleri haricindeki başka bir deney düzeneğini anlatımınıza eklemek ve ilgili kavram ve konuları keşfetmektir.

1. Hangi düzeneği seçtiniz?

____

2. Bu düzenek hangi kavramlarla ilgili?

____

3. Neden bu düzeneği seçmeye karar verdiniz?

____

4. Düzenekle ilgili hangi soruları sormak isterdiniz?

____

____

____

Kendinizi değerlendirmek için arka sayfayı çeviriniz. ➡

K. Rubrics

Force and Pressure Exhibition Units	No Understanding	Misconception / Comprehension Failure	Partial Understanding	Sound / Complete Understanding
Sand Pendulum	You can put sand in the box and it will draw shapes with the sand.	Shapes of the sand show difference based on the force that you have applied.	These two strings are coming together at the end of the long spring so they will constitute a resultant force. The shapes will change along the applied force direction.	After you apply a force, the air friction will decrease the speed of the spring and also the shapes will be drawn referring to the vectoral direction.
3d Sand Pool	You can draw mountains, sea, and rivers by sand.	When you push the sand with inside of your hand, the pressure is greater compared to pushing the sand with the finger.	The solid pressure is greater when you use your ginger like it is a woman with topuklu shoes.	The solid pressure is greater when the surface area is smaller. The air pressure decreases when you are going up from the sea level.
Air Bubble Race	You push the pomp and the air bubble reaches to the end of the tube	You push the pomp and the air bubble's weight is different so that they reach it in difference phases.	Pomp apply a pressure to the liquid and because the liquids are different, bubbles reach to the end in different velocities.	Pomp apply a pressure to liquids. Since the density of water is greater compared to other liquids, bubbles are smaller and acting in high velocity.
Hot Air Balloon	You push the button and it will go up.	"Heat comes up and heats, it's like helium, and it pushes out. The helium makes it go up" and "hot air makes it go up and there is a string on the end that pulls it up."	"Fire makes the things bigger. Heat warms it up to make it bigger. Heat comes from the fire." And "the flame goes up and it heats that tube and the air goes into the balloon"	The fire coming up from the tube makes hot air and the hot air rises and it makes the balloon rise.
Bernoulli's Ball	No references to air movement.	The air goals under the ball and makes it rise.	The air, the actual air, is pushing down. And the one from the tube is going up so then it's making it float cause it was pushing on the sides.	The air goes up here and goes down here faster and makes the ball lift.

Energy Transformation Exhibition Units	**No Understanding**	**Misconception / Comprehension Failure**	**Partial Understanding**	**Sound / Complete Understanding**
3d Sand Pool	You can draw mountains, sea, rivers by sand.	Kinetic energy is less for the object thrown from an above location (more height for the distance) compared to the other object having the same weight.	Objects thrown from a different height would have different potential and kinetic energies.	If an object having the same weight were thrown from an above location compared to the other object, it would have a higher potential energy. Thus, it would have a higher kinetic energy so that the trace on the
Pedal Force	You can pedal and then the radio turns on.	Friction force transforms to the sound and heat energy.	By applying force to the pedals, the electrical energy occurs.	Kinetic energy transforms to the electrical energy and the radio and the light turns on.
Guess Who Wins	When you leave two objects, one of them will win the race.	One of the two objects with different weights will arrive earlier to the finish line.	One of the two objects with different weight distributions will arrive earlier to the finish line.	There are two objects that are equal in weight, height, and hence potential energies. When both objects are released, this potential energy turns into kinetic energy. However, the object having the weight distribution in the middle
Measure Your Power	You can see different height after the ball raises.	Air pressure makes the ball raise.	By applying force to the pedals, air will make the ball raise.	By applying force to the pedals, our kinetic energy will transform the potential energy by lifting the ball with the help of air caused by the fan.

Mirrors and Light Absorption	**No Understanding**	**Misconception / Comprehension Failure**	**Partial Understanding**	**Sound / Complete Understanding**
Monochrome Room	The room is yellow.	Yellow light causes objects to appear colorless.	In the room, the colors of objects can be observed in both white and yellow light. In yellow light, most of the objects appear gray, while	Since the white light reflects all colors, the objects in the room appear in the colors they reflect. However, in yellow light,
Countless Color	There are three colors.	All the lights absorb the colors.	When the buttons are turned into different colors, mixing of them would give a different color.	There are three buttons and we may observe countless colors, when we turn the buttons for the main colors so that we will observe the
Touch the Spring	There is a spring in the box.	The spring in the box is resulted by a flat mirror.	The spring that we see is a reflection.	The spring is a mirror reflection. The type of the mirrors is concave.
Infinite Views	We see more than one views.	There is one mirror.	There are two flat mirrors.	There are two parallel flat mirrors and it results in an infinite view.

Solar System and Beyond Exhibition Units	No Understanding	Misconception / Comprehension Failure	Partial Understanding	Sound / Complete Understanding
Solar System Model	The planets are in order.	Student's confusion exists related to the distance to the sun.	Student's observation of the distance of the planets to the sun and the properties of the planets.	The planets in the solar system have seen their distance from the sun, eight planets. We have seen the planets in the solar system, their distance from the sun, their size, and which planets are rings.
Constellation Viewer	There are stars.	The stars are in order in align with their brightness.	We saw the stars unite and form a shape. The stars merged with each other to form the big bear constellation.	I saw the stars coming side by side to form constellations. I have made it clear that we cannot understand the distances of stars in constellations according to their dimmer or luminosity.
Summer Sun / Winter Sun	Clock by summer Clock by winter	In our world, because the axis is inclined, we saw that the summer is closer to the sun, and the winter is farther away from the sun and warmer. It shows that the inclination of the axis is closer to the sun in summer and farther away in winter.	In summer and winter, I saw what percentage of the sun we use. I saw the distance and proximity of sunlight in summer and winter.	Since the earth inclines the axis, we have seen that in winter, it is closer to the sun, and in summer, it is farther and warmer. We saw the inclination of the axis to be farther in winter and warmer in summer.
Gravity Well	Acceleration of the ball as it moves down.	Planets in the solar system revolve around the black hole.	The proximity of the planets in the solar system to the sun, is directly proportional to the rotation speed. The planets in the solar system have a greater gravitational force than the other planets.	With the force of gravity, I saw the objects being drawn into the well. I observed that a ball in the gravity well spins over the object for a long time and then falls into the well after a while.

L. Looking Patterns Coding Scheme

General Area of Interest	Looking pattern	Related Metacognitive Process	Explanation
Environment			
	Visual search for complementary exhibition unit	Developing action plan	Student is searching visually for a complementary exhibition unit for the current subject domain.
	Visual search for related exhibition unit	Developing action plan	Student had visual search for a related exhibition unit for a conceptual match for the related subject domain.
	Visual search for an information	Developing reading plan	Student had visual search for a related information conceptually match for the related subject domain.
	Visual search for a knowleadgeable person	Developing action plan	Student had visual search for a knowleadgeable person after detection of their error or confusion and clarifying what to ask.
	Focusing on exhibition unit at a distance	Developing action plan	Student focused on an exhibition unit at a distance which would be conceptually related to the current subject domain.
	Blank during coversation pause	Checking completeness of conceptual understanding	Student focused on a blank area during the conversation pauses.
	Decisive scanpath	Evaluating learning outcomes	Student looked at the environment for recapitulating the visited exhibition units.

Worksheet			
	Global screening	Establishing task demands	Student scans the worksheet globally.
	Question	Exploring task demands	Student looks the question on the worksheet.
	Purpose statement	Exploring task demands	Student looks the purpose statement on the worksheet.
	Answer area	Exploring task demands	Student looks the answer area on the worksheet.
	Image	Exploring task demands	Student looks the image on the worksheet.
	Number	Exploring task demands	Student looks the number on the worksheet.
	Tracking of other's writing	Checking of progress	Student tracks of other student's writing during they were answering the question.
	Tracking of other's reading	Checking of progress	Student tracks of other student's reading during the student was reading the question.
	(Re)visiting subsequent text	Developing action plan	Student (re)visits the subsequent text/question close to the end of other's writing.
	Decisive scanpath	Evaluating learning outcomes	Student looked at the worksheet for recapitulating the answered questions.
Peer	No eye-contact track of looking direction	Developing action plan	Student looked at other's looking direction to plan the subsequent action.
	Tracking of other's hand movement	Developing action plan	Student looked at other's hand movement to plan the subsequent action.
	Tracking of other's pointing	Developing action plan	Student looks at other's pointing to plan the subsequent action

	Looking eye/face with not eye contact	Checking of progress	Student looks at other's face without eye contact
	Matched-eyes	Comprehension monitoring - DCE - DCR - DCQ	Students' eyes match during their elaboration, repetition, and questioning proceses.
Exhibition-unit	Global screening	Establishing task demands	Student scans the exhibition unit globally.
	Title on information card	Exploring task demands	Student looks at the title on the information card.
	Explanation on informationcard	Exploring task demands	Student looks at the explanation on the information card.
	Focusing on components	Exploring task demands	Student focuses on the components
	Acting without instruction	Processing task demands	Student acts without instruction.
	Tracking other's explanation during looking	Checking of progress	Student tracks other's explanation during looking the exhibition unit
	Tracking other's direction during acting	Checking of progress	Student tracks other's direction during interacting with the exhibition unit
	Tracking self-direction during acting	Checking of progress	Student tracks self-direction during interacting with exhibition unit.
	Noticing differences after acting	Demonstrating comprehension by elaborating	Student demonstrates comprehension by noticing differences between specific exhibition unit components after interacting with it.

	Decisive scanpath	Evaluating learning outcomes	Student recapitulates the visited components by decided scanpath.

CURRICULUM VITAE

PERSONAL INFORMATION

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EDUCATION

Degree	**Institution**	**Year of Graduation**
MS	METU Cognitive Science	2013
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2014-Present	METU Computer Edu. Inst. Tech.	Research Assistant
2013-2014	MCBU Computer Edu. Inst. Tech.	Research Assistant
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2011-2012	Userspots	Usability Tester

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PUBLICATIONS

Türkmen, G , Caner, S . (2020). THE INVESTIGATION OF NOVICE PROGRAMMERS' DEBUGGING BEHAVIORS TO INFORM INTELLIGENT E-LEARNING ENVIRONMENTS: A CASE STUDY. Turkish Online Journal of Distance Education, 21(3), 142-155. DOI: 10.17718/tojde.762039

Türkmen, G., Yıldırım, Z. (2018, August). *Socially-shared metacognition processes of 7th graders throughout science museum context in Turkey*. Poster session presented at the conference Metacognition SIG 16, Zurich, Switzerland.

Türkmen, G., Yıldırım, Z. (2017, August). *Socially-shared metacognition processes of 7th graders throughout science museum context in Turkey*. Round table session presented at the conference European Association for Research on Learning and Instruction (EARLI), Tampere, Finland.

Türkmen, G., Çakır, M.P. (2016, July). *Visuospatial problem solving: A simultaneous observation via eye-tracking and functional near-infrared spectroscopy (fNIRS).* Paper presented at the Junior Researchers of European Association for Research on Learning and Instruction, Helsinki, Finland.

HOBBIES

Classical Kemenche, Volunteering

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