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Original Article

Discourse Analysis of In-Service Teachers' Interdisciplinary Collaboration for Decision-Making through Design-Based Integrated STEM Activities

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Abstract

The goal of this study was to examine the nature of the reflective decision-making processes of a group of teachers participating in the engineering design part of integrated STEM activities, and the argumentation schemes they use in the reflective decision-making part of integrated STEM activities. Eleven in-service teachers, all from the same institution, with expertise in different STEM disciplines, participated in the study. A STEM professional development program was applied over five days. Each day, one design-based integrated STEM activity was employed lasting about four hours, in two rotating groups of participants. For discourse analysis, each group's data were collected using a voice-recorder and transcribed by applying Jefferson (2004)'s Transcription Notation. During the professional development program, the researchers walked around the groups, listened to their discourse, and observed the group members' participation. Furthermore, the analysis steps defined by the literature were employed. The results showed that the engineering design process was carried out in two ways, namely, "joint design" and "existence of a dominant member." Joint design was conducted during the pre-design, design, and post-design stages. The existence of the dominant member is seen in non - joint-design-oriented discourses and in the post-design stages. We found that one of the essential factors in shaping the activity within the group and managing it was the existence of a dominant character in the group. In our case, the dominant character was not the same participant for all activities. Rather, different characters dominated in different design activities and took the lead/initiative. The teachers made use of four argumentation schemes -- position to know (personal), position to know (research), consequences, and popular opinion -- in the reflective decision-making part of integrated STEM activities. By implication, integrated STEM professional development programs should support teachers' development of collaborative

Keywords

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reflective decision-making and group work skills to teach them how to handle such students in class. Moreover, teachers should attend professional development programs to see how the members of small groups interact with each other.

Introduction

Since the release of Next Generation Science Standards (NGSS Lead States, 2013), educational reforms have embraced "the teaching and learning of the content and practices of disciplinary knowledge which include science and/or mathematics through the integration of the practices of engineering and engineering design of relevant technologies" (Bryan, Moore, Johnson, & Roehrig, 2015, p. 24). The basic motivation behind the reforms has been attributed to changes in the skills necessary for future jobs, a decrease in young people's interest in Science, Technology, Engineering, and Mathematics (STEM) jobs, the need to develop cooperative skills among learners, and the United States' drive to be a pioneer in the global economic race (European Commission, 2014; National Association of Colleges and Employers, 2016; National Research Council [NRC], 2012).

Placing emphasis on combining engineering design with positive sciences and mathematics results in this combination gaining prominence across the range of different disciplines (Moore, Tank, Glancy, & Kersten, 2015; Roehrig, Moore, Wang, & Park, 2012). Engineering design is ''a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function fulfill clients' objectives or users' needs while paying regard to a specified set of constraints" (Dym, Agogino, Eris, Frey, & Leifer, 2005, p. 104). Moreover, engineering design is an iterative process consists of reflective decision-making, argumentation, and group work (Couso & Simarro, 2020; Wendell, Wright, & Paugh, 2017). As Wendell et al. (2017) stated, the word reflective has different meanings depending on the context it is used in (e.g., reflective practice of teachers). In this study, we employ the term in the sense of ''reflection that occurs during the engineering design process'' (Wendell et al., 2017, p. 357). Wendell et al. (2017) revealed that ''taking stock of prior actions, analyzing input gathered from teammates and designs, and taking a further step'' purposefully and collectively are actions essential for making reflective decisions (p. 376). Although it is known that reflective decision-making entails dialogue and argumentation among group members (Kim, Anthony, & Blades, 2014), to implement integrated STEM activities (i.e., activities/practices that draw on real-world problems and require solutions to be designed that involve two or more fields of expertise/disciplines and teamwork) (Bryan et al., 2015), teachers need to know and experience how reflective decision-making develops in a group, how different participants contribute to it, how evidence from different STEM disciplines directs the movement of the process, and how to support and manage group obstacles collaboratively (Kelley & Knowles, 2016; Wendell et al., 2017).

Despite the importance of teacher preparation for the engineering integration emphasized by the integrated STEM approach, limited effort has been spent on teacher education (Cunningham & Kelly, 2017; Rinke, Gladstone-Brown, Kinlaw, & Cappiello, 2016). Although some studies have focused on how students participate in the decision-making process while finding better design solutions (e.g., Rusk & Rønning, 2020; Wendell et al., 2017) and on college students' decision-making in socio-scientific issues (e.g., Kim et al., 2014; Sadler & Zeidler, 2005), little is known about how teachers employ reflective decision-making and which argumentation schemes they use to make decisions in engineering design activities. Moreover, the extent to which teachers' reflective decision-making differs from students' reflective decision-making is a valuable area of focus. As teachers have expertise in a specific field, they may use a different decision-making process based on scientific, mathematical, or technical knowledge that is more readily available to teachers than students. Furthermore, although science education researchers have conducted argumentation studies with learners, that research did not yield information about the teachers' use of argumentation for robust design decisions (i.e., that are informed by scientific knowledge, and evidence collected through experiments) (Crismond & Adams, 2012) to solve a challenge provided in integrated STEM practices. Also, another gap has been indicated by

Mathis, Siverling, Glancy, and Moore (2017), namely, the limited number of studies shedding light on the use of argumentation throughout the engineering design process. In light of those points, we aimed to address the gaps identified in the literature and study the design arguments and reflective decision-making processes of 11 in-service teachers with different backgrounds by using discourse analysis. Teachers with different backgrounds such as science, technology, mathematics, and art participated in a five-day long integrated STEM professional development program through which the nature of teachers' reflective decision-making and their use of argumentation schemes were analyzed.

Theoretical Framework

Integrated STEM Education and Engineering Design Process

There is still no consensus in the relevant literature on a definition for integrated STEM approach (Martín-Páez, Aguilera, Perales-Palacios, & Vílchez-González, 2019; Moore, Johnston, & Glancy, 2020). Kelley and Knowles (2016) described integrated STEM education as ''the approach to teaching the STEM content of two or more STEM domains bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning'' (p. 3). Moore et al. (2014) defined integrated STEM education as ''an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems'' (p. 36). To conclude, integrated STEM implementation highlights integrating engineering into science and mathematics classrooms with a focus on addressing real-world problems (Bryan et al., 2015; Wang, Charoenmuang, Knobloch, & Tormoehlen, 2020). The engineering discipline provides the real-world problems to be solved (Moore et al., 2015).

Regarding the arguments behind the usefulness of integrating engineering into science and mathematics lessons through the use of engineering design can be examined under three basic points, namely, (i) engineering thinking helps learners develop 21st century skills, (ii) engineering design requiring the use of concepts from science and mathematics has the potential to increase learners' science and mathematics achievement, and (iii) entering the engineering context increases the probability of learner career choice from among STEM disciplines (Moore et al., 2015; NRC, 2012). Engineering design is viewed as a useful pedagogy for integrating engineering into science teaching (Moore et al., 2015; Wheeler, Whitworth, & Gonczi, 2014). Although different models of engineering design exist, those models mostly include problem-scoping, brainstorming, researching, planning and building, testing, redesigning, evaluating, and sharing the solution steps (Wheeler et al., 2014). To conclude, STEM activities integrated with engineering design (known as design-based integrated STEM activities) provide a great opportunity for participants to address the problem given, conduct research to learn and use concepts from science or mathematics to inform their design decisions, work together, collaborate and communicate, produce design ideas, prove or disprove the ideas presented by group members, build the groups' design product, test it by collecting data, and redesign the product in light of the data collected (Capobianco, DeLisi, & Radloff, 2018; Moore et al., 2014, 2015; Wendell et al., 2017).

Argumentation and Reflective Decision-Making

Teaching learners to be able to make informed decisions, use evidence in decision-making, and justify their reasoning is the main purpose of science education (Kim et al., 2014). Argumentation has been acknowledged as a valuable approach to equip learners with those skills and to provide opportunities to participate in a scientific practice (Driver, Newton, & Osborne, 2000; Jiménez-Aleixandre & Erduran, 2007). The literature contains different argumentation definitions with different emphases and social/individual meanings (van Eemeren & Grootendorst, 2004). There are also both scientific and real-world versions of the idea, such as process vs. product (Simon, Erduran, & Osborn, 2006; Walton, 2006). Overall, however, "argumentation is a rational process that relies on the rigorous application of knowledge evaluation criteria" (Jiménez-Aleixandre & Erduran, 2007, p. 13). Likewise, van Eemeren and Grootendorst (2004) defined argumentation as ''a verbal, social and rational activity aimed at convincing a reasonable critic of the acceptability of a standpoint by putting forward a constellation of propositions justifying or refuting the proposition expressed in the standpoint" (p. 1).

Furthermore, Kim et al. (2014) highlighted the collaborative, problem-solving, and dialogical interaction aspects of the argumentation process.

Making informed decisions depends on "coordinating evidence and knowledge claims to support an explanatory conclusion" (Kim et al., 2014, p. 904). In other words, the decision-making process requires weighing the pros and cons of the available solutions in light of existing evidence or data (Jiménez-Aleixandre & Pereiro-Munoz, 2002; Kortland, 1996; Wendell et al., 2017). Similarly, Rieke, Sillars, and Peterson (2013) stated that a "choice is made on the basis of clearly articulated arguments that have been held open to refutation or disagreement" (p. 10). In this way, reflective decision-making and argumentation intertwine. To make reflective decisions, people need to employ argumentative skills—for example, in an engineering design process, group members need to develop claims backed by scientific or mathematical evidence, evaluate all alternatives, develop counterarguments for better designs, and persuade others to choose a sound claim that will be referenced in the group's design. Wendell et al. (2017) revealed the necessary actions taken to make a decision reflectively, particularly in the engineering design process. These are articulating multiple solutions, weighing up pros and cons, intentionally selecting solutions, retelling the performance of the solution, analyzing the solution based on specific evidence, and purposefully choosing improvements.

Argumentative discourse is found throughout the collaborative reflective decision-making process that aggregates, rather than compromises, the understandings of decision makers. It makes explicit the aggregation of individuals' understandings of the frame of the decision to be made, the alternatives to be considered, the sources of value and risk, and, finally, the reasons for the resulting collaborative choice. (Owen, 2015, p. 29)

Leitão (2000) explained how an arguer's discourse might continue after a counterargument, breaking down four possible replies. First, *dismissal*, where the speaker focuses on only a certain part of the counterargument and rejects it. The second is *local agreement*, in which the speaker explains that he or she partly agrees with the counterargument. In this reply, the speaker does not change ideas, but tries to refurbish the original assertion with the help of the counterargument by using different and new evidence. In the third reply, *conditional agreement*, "the speakers integrate the content of the counterargument into their argument by *allowing for some exceptions or conditions* to be added to their original position" (p. 349, italics in the original). Finally, the speaker may *withdraw* the initial idea and go with the counterargument. During the reflective decision-making process, then, group members may handle alternative ideas by denying them, integrating them, or withdrawing the existing idea.

In collaborative reflective decision-making, two disciplinary practices of engineering are employed: designing solutions and engaging in argument from evidence (Wright, Wendell, & Paugh, 2018). While it has been emphasized in the NGSS that argumentation has a role in the engineering design process—which requires evidence-based decisions and consideration of alternative design ideas—argumentation in engineering education has not been studied as much as it has in the science education field (Mathis et al., 2017). Although limited emphasis is put on the use of argumentation in the engineering design process, Antink-Meyer and Brown (2019) argued that engineers collect data about their initial design through testing, analyze the data to collect evidence for the success of the design, and use the data for re-design. ''The analysis and interpretation of data, and its role in making claims, is a shared characteristic of science and engineering.'' (p. 553). The recent integrated STEM approach that highlights integrating engineering into science teaching provides an opportunity for researchers to focus on this gap.

Walton's Presumptive Reasoning Schemes

In argumentation literature, different frameworks are used as theoretical or analytical lenses (e.g., Toulmin's Argument Pattern, Sandoval's framework, and Lawson's framework) (Duschl, 2007; Nussbaum, 2011). Toulmin's model focuses on the components of simple and strong arguments, including both field-dependent and field-independent arguments (Kim et al., 2014). However, the model has been criticized due to a lack of information about "the appropriate level of detail that should be expected for the reasons given to make an argument" (Duschl, 2007, p. 164). Critics note that the model's categories are not limited enough to provide specific data. Likewise, Erduran, Simon, and Osborne (2004) and Kim et al. (2014) stated that although Toulmin's Argument Pattern is successful in describing what argument is, it encounters obstacles in analyzing verbal discourse. Therefore, to be able to dig into participants' reasoning—how they use evidence in constructing explanations, how new evidence shifts their presumptions, how the argumentative exchanges happen among group members through dynamic discourse, and how group members act during critical moves—Walton provides a different framework. The Presumptive Reasoning framework, which consists of different argumentation schemes, evaluates how the participants use evidence in argumentation discourse and reasoning sequences (Duschl, 2007; Kim et al., 2014). Therefore, it can be said that people (e.g., teachers in this study) participate in the reflective decision-making process using different argumentation schemes. Moreover, clear-cut schemes for making arguments, and their definitions, exist and are very useful and strong aspects of Walton's framework for data analysis (Duschl, 2007). Given the strengths of the Presumptive Reasoning framework proposed by Walton, Reed, and Macagno (2008) and the limitations of the other ones, the researchers preferred to utilize that framework in this study.

In Walton's framework, presumptive reasoning is defined as taking place during a dialogue, at the end of which people need to decide on using the limited evidence offered. Although there are many different argumentation schemes under the different classifications given by Walton et al. (2008), Duschl (2007) adapted Walton's framework and focused only on nine schemes that "serve to illuminate the approach and knowledge students use to make arguments and the influences that contribute to how they evaluate competing arguments when forming a conclusion" (Kim et al., 2014, p. 905). These schemes are *position to know (personal), position to know (research), consequences, popular opinion, correlations, sign, commitment, analogy,* and *bias.*

According to Walton, throughout discourse, members of a group provide diverse arguments based on different sources, resulting in critical moves in the group dialogue. "The general character of the dialogue is influenced by the initial situation and especially the goals of the interaction" (Kim et al., 2014, p. 906). Dynamic dialogue includes many schemes that form patterns, such as persuading other members; inquiry (i.e., looking for evidence to support a claim or refute it); information seeking; deliberation (i.e., deciding the best course of action and creating a plan); and eristic discourse (i.e., conflicts among members) (Walton, 2006). Looking at Walton's schemes, it is possible to analyze how people make an argument, how they react to others' arguments, and how they focus on the credibility of the arguments in the process. According to Chen and Qiao (2020), the production of schemes in the dialogic argumentation process can also provide interactional evidence for the participants' epistemic status (i.e., their knowledge about specific area). Epistemic status can be displayed by responses to a request for information, disagreements, expansions, corrections, and accounts (Herder, Berenst, Glopper, & Koole, 2020).

Review of Related Research

Argumentation and Reflective Decision-Making

Recent studies have focused on how group members make collaborative decisions and the factors influencing the group members' decision making (e.g., epistemic status, activity type). However, the participants in those studies have generally been young learners rather than in- or pre-service teachers. Therefore, in this part of the study, the studies focusing on learners' discourse and collaborative decision making, which is different from our target sample, will be summarized.

Rusk and Rønning (2020) examined how 11-year-old learners worked in groups during a robot design and coding activity. The researchers reported the difficulty in categorizing the groups (i.e., cooperative, or not), which may stem from the dynamic nature of group interactions influenced by factors such as availability of physical resources, access to new knowledge, and participants' inclination to express their epistemic status. In another study, an analysis of peer-to-peer discourse narratives during the planning and redesign phases revealed that elementary students employed reflective decision-making elements (e.g., articulating different solutions, weighing up solutions' pros and cons, and analyzing the strong and weak aspects of the solution in light of the evidence received from tests) (Wendell et al., 2017). Furthermore, some of the students did not take part in collaborative reflective decision-making, and this was explained by three hindrances: "social competition, unnoticed failure, and technical and everyday vocabulary demands" (Wendell et al., 2017, p. 377). In a similar vein, Wright et al. (2018) examined fifth-grade students' collaborative reflective decision-making processes throughout engineering design. They found that rather than negotiating the pros or cons of each idea, students preferred to combine different design ideas, which resulted in their limited engagement in argumentation practice. Interviews revealed that this strategy was used to avoid negative outcomes such as being reprimanded by the teacher, pushing peers away from design decision-making, and proposing wrong ideas. Similar results were also reported by Purzer (2011), who studied engineering students' team discourse. The groups often opted against challenge-oriented discourse, in which group members are supposed to make different claims, evaluate them with evidence, and experience disagreement. Rather, they accepted the ideas presented by peers and avoided making counterarguments.

Regarding the factors influencing small group decision-making (i.e., 3-5 members in general), the activity type (i.e., scientific or engineering) was reported as a factor that makes a difference in the patterns employed (Wieselmann, Dare, Ring-Whalen, & Roehrig, 2020). Finally, participants' gender was reported as another factor shaping their participation and role in group decision-making (Bianchini, 1997). In small groups, boys tend to dominate group decisions and take a leadership role, whereas girls generally have passive roles. Likewise, participants' academic ability and social status are other variables determining individuals' participation in the group work, decision-making, access to materials used, and the extent to which they learn from the group work.

Research on Collaboration/Partnership in Integrated STEM Education

The integrated STEM movement is ''an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems'' (Moore et al., 2014, p. 36). Due to its integrated nature, that movement necessitates teacher collaboration. Despite this, Wang et al. (2020) notes that "teachers are traditionally trained to teach domain-specific knowledge. There is a growing concern regarding how teachers trained in one of the STEM domains are not equipped to incorporate less familiar practices into their teaching" (p. 2). To address this critical issue, raised in the existing literature, some limited research studies have focused on teacher collaboration and provided evidence of the benefits of collaboration between participants with different backgrounds. For instance, Pinnell et al. (2013) designed a program highlighting partnership among 10 in-service and five pre-service teachers, an engineering student, the engineering faculty, and an industrial mentor throughout a six-week-long professional development course. Results showed the usefulness of collaboration, including improvement in participants' knowledge about engineering, its importance for society, the need for integrating engineering into lessons, and how to integrate engineering into their plans. In another study, Asghar, Ellington, Rice, Johnson, and Prime (2012) worked with 25 in-service teachers with different STEM backgrounds in a problem-based STEM professional development program. The results revealed that participation in this type of activity—which included an opportunity to work with teachers with different content knowledge—improved and enriched the participants' vision about the interdisciplinary nature of STEM (i.e., how to integrate STEM disciplines into an activity). Moreover, collaboration among the participants in solving real-world problems and the exchange of ideas between group members with different areas of expertise resulted in positive attitudes toward the integrated STEM approach. Likewise, Basista and Mathews (2002) reported similar gains in the ability to integrate other STEM disciplines into lessons, use cooperative group work, and engage students in reflective thinking. Moreover, participants transferred what they learned and experienced in the training into their classroom practice. Finally, Aslan-Tutak, Akaygun, and Tezsezen (2017) examined the influence of the Collaboratively Learning to Teach STEM (CLT-STEM) module on preservice chemistry and mathematics teachers' integrated STEM awareness. The results showed that the participants' integrated STEM awareness improved throughout the six-week training. The participants' definitions of integrated STEM after the training included more emphasis on integration.

To conclude, studies with a focus on teacher collaboration with colleagues and other experts (e.g., engineers) revealed the contribution made by and the usefulness of collaboration and group work in participants' development. Hence, to be able to dig into the nature of teachers' collaborative reflective decision-making for group designs and their use of argumentation schemes, it would be reasonable and valuable to include teachers with different backgrounds (e.g., science, mathematics, technology). In addition, the collaboration of teachers working in the same school is another important issue that requires further attention (Wang et al., 2020). In light of those important points, the areas that require more attention are teacher collaboration, teachers' reflective decision-making for group designs, group discourse and argumentation schemes used by teachers who have expertise in different fields, and how teachers from the same institution collaborate. This is what motivated the authors of this study.

Significance and Contribution of the Study

Argumentation is a valuable approach for fostering learners' decision-making, and higher-order thinking skills (Jiménez-Aleixandre & Erduran, 2007). Given the role of reflective decision-making and argumentation in science and engineering design (Jordan & McDaniel, 2014; Kim et al., 2014; Wendell et al., 2017), teachers are expected to use both strategies in their classrooms (Crismond & Adams, 2012; Erduran & Jiménez-Aleixandre, 2008). However, research has reported that teachers have difficulties in incorporating those practices into science classrooms, in addition to having a limited pedagogical repertoire (Driver et al., 2000). That expectation can be realized through explicit emphasis on argumentation and the reflective decision-making process, both in pre-service science teacher education and in professional development programs (Wendell et al., 2017). Moreover, although argumentation in science education has frequently been a focus of study, there is a gap in research on the nature of teachers' collaborative decision-making and which argumentation schemes are used throughout the engineering design process. This gap highlights the need for studies that focus on the use of argumentation schemes in integrated STEM training, including the engineering design process, because argumentation is an important practice of engineers, who "use arguments for finding the best solution for a problem with a given set of constraints" (Mathis et al., 2017, p. 78). Therefore, to draw a better picture of integrated STEM approach that integrates engineering and design processes into science, technology, and mathematics education in teachers' minds, the gap identified by Mathis et al. (2017) should be taken into account. Teachers should know how to implement integrated STEM lessons that have opportunities for students to construct arguments, make reflective decisions about problems, and prove the validity of claims for better design solutions (Kim et al., 2014). To achieve this goal, teachers should experience the application of the design activities (Desimone, 2009), as this provides a chance to participate in the argumentation process with evidence, data, and justifications from some or all STEM disciplines.

Considering these points raised by the literature, in the current study 11 in-service teachers with different backgrounds participated in verbal argumentation practices during five integrated STEM activities over five days. The argumentation discourse and the nature of collaborative reflective decision-making process were analyzed using the discourse analysis method. By doing so, we intended to delve into how teachers with different backgrounds participate in the collaborative reflective decision-making process, how they form arguments, how other teachers with different backgrounds react to that argument, how individuals contribute to the group design, and which argumentation schemes are used throughout the design process. This type of group organization (i.e., including teachers from different STEM disciplines) is not common in the literature. Teachers from the same discipline may have similar perspectives; teachers with different backgrounds have the potential to enrich the group discourse, challenge others' claims, make counterarguments, or provide backing from different disciplines. Hence, the study is designed to provide a rich description of group design, the argumentation schemes used throughout the design process, and how participants with different backgrounds contribute to the decision-making process for better design solutions. This will also indicate how teachers incorporate evidence from different disciplines, something that cannot be done through common training with teachers from the same discipline. Specifically, the research questions directing the study are:

1. What is the nature of the reflective decision-making processes of a group of teachers participating in the engineering design process of integrated STEM activities?
2. Which argumentation schemes do in-service teachers use in the reflective decision-making process of integrated STEM activities?

Method

Thinking and talking are two facts that affect each other. Thought cannot be explained without taking into account linguistic activities and talking cannot be made sense without paying attention to manifestations of thought (Lantolf, 2000). Therefore, to reveal the nature of the reflective decision-making processes of a group of teachers for the engineering design and argumentation schemes that were employed in different parts of the process, the researchers carried out discourse analysis by considering thinking and talking together in a qualitative way. By doing so, the researchers could reveal the internal dynamics of the teacher contributions to the process of designing activities. Since discourse analysis lets researchers "shed light on how meaning can be created via the arrangement of chunks of information across a series of sentences or via the details of how a conversationalist takes up and responds to what has just been said" (Johnstone, 2018, p. 5).

Setting

In this study, the researchers gave integrated STEM professional development training to 11 in-service teachers (eight male, three female) working at a Science and Art Center in eastern Turkey. The goal of the professional development program was to introduce the integrated STEM approach in theory, to provide strong examples of integrated STEM activities that require the integration of different STEM disciplines, and to motivate teachers to implement student-focused, integrated STEM activities. The professional development program was organized during the Center's fall break week, designated for professional development support in the 2019-2020 academic year. In these centers, teachers work with gifted students after school and/or on weekends to motivate them to do research, develop projects, and improve their 21st century skills.

The participant teachers had backgrounds from different STEM disciplines (Table 1). The participants were purposefully selected to include (i) teachers from different disciplines, (ii) from the same center. They were motivated to learn what integrated STEM approach is and how integrated STEM activities are employed, however, they had received no prior professional development training in integrated STEM or engineering design.

Table 1. The Participants' Details

Teachers' expertise	Number of the participant/s	Education status	Abbreviation
Mathematics	1	Master's degree	Math Teacher, MT
Elementary science	1	Master's degree	Science Teacher, ST
Technological design	2	1 Bachelor's degree 2 Master's degree	Tech Teacher, TT
Chemistry	1	Master's degree	Chemistry Teacher, CT
Physics	1	Master's degree	Physics Teacher, PT
Biology	1	Bachelor's degree	Biology Teacher, BT
Elementary teacher	3	1 Master's degree 2 Bachelor's degree 3 Master's degree	Elementary Teacher, ET
Art	1	Master's degree	Art Teacher, AT

Importantly, all participants worked in the same center. This is a key factor affecting the success of the professional development program (Asghar et al., 2012; Desimone, 2009). We think that this choice has the potential to allow participant teachers to cooperate with colleagues from different disciplines to plan and/or implement integrated STEM activities in the future.

One of the challenges teachers report during integrated STEM implementation is a limited understanding of interdisciplinary teaching (Ryu, Mentzer, & Knobloch, 2019). Teachers also experience difficulty in integrating other STEM disciplines into their own fields (Couso & Simarro, 2020; Roehrig et al., 2012). Accordingly, to address those challenges in this study, groups of teachers with different STEM field backgrounds were formed. Parallel to Akaygun and Aslan-Tutak (2016), the researchers thought that experts in different STEM fields would provide different claims, supported by various evidence, to design a sound, effective, and efficient product at the end of the integrated STEM activity. To conclude, the literature guided our participant selection, group organization, and solutions for the challenges reported.

Implementation

The integrated STEM professional development program was provided over five days and included activities. The activities were intentionally selected due to the differences in the participants' STEM backgrounds and the grade level that they are teaching. Parallel to this, the activities were related to different STEM disciplines and learning outcome levels (see Appendix for detailed information about the related outcomes of activities from Turkish Curriculum). The activities also had common working issues for teachers in different disciplines and integrated at least two STEM disciplines in an authentic context to solve a design problem (e.g., thermos design or DNA genetic code and message sending system design). The activities began with an authentic real-world problem scenario given by the researchers. For example, for the thermos design, the scenario involved a mountain climber who needed to keep his coffee or tea hot while climbing. The constraints regarding the duration, material, the sizes of the thermos were given in the scenario. Each day, a design-based integrated STEM activity was employed, taking about four hours (Table 2). In total, the participants received more than 20 hours of integrated STEM professional development. During the activities (i.e., except the early stage of the first one, which introduced the integrated STEM approach in theory), each participant was required to participate actively. "[A]s opposed to passive learning typically characterized by listening to a lecture, [active learning] can take a number of forms, including observing expert teachers" (Desimone, 2009, p. 184). Active participation has been mentioned as another key factor in increasing the usefulness and efficiency of professional development programs (Desimone, 2009). The participant teachers could experience integrated STEM activities, face difficulties, and participate in the decision-making process. In other words, the participants focused on the design problem, did research, argued with peers, made decisions for better design solutions, and re-designed the project in light of the data gathered when testing.

For each integrated STEM activity, Wi-Fi and tablets were available for each participant. A design log was prepared and given to the groups for each activity (details about the design log will be given in the data sources section). Two groups with different participants were formed by rotation every day. In this way, the researchers intended to guarantee that different teachers from different branches worked together in the activities and enrich interaction among them. In addition, since teachers working in Science and Art Centers may work together to guide students' projects from all levels of education in the centers, the rotation may also let teachers cooperate with colleagues from different disciplines to plan and/or implement integrated STEM activities in the future.

Table 2. Professional Development Program Details

Day	STEM Activity employed	The description of the activity	The STEM disciplines that can be integrated into the activity
1	Introduction to STEM Approach (in theory) & Vacuum cleaner design	The researchers introduce the STEM approach, descriptions, goals, and starting point of the approach Participants are supposed to design a vacuum cleaner that will remove the dirt on the desk.	Science (physics), engineering, technology,
2	Water purification design	Participants are supposed to design a water purifier that is to be tested by filtering dirty water prepared earlier. The criteria are color, pH, presence of salts, and organic waste in the filtered water.	Science (chemistry), engineering, technology,
3	Thermos design	Participants are supposed to design a thermos that should keep the hot water hot and lose less heat over the time interval given (i.e., 40 minutes).	Science (physics), mathematics, engineering, technology, art (aesthetic design for attracting client)
4	Polymer Design	Participants are supposed to design a bouncy polymer. Slow-motion video recording used to measure the, bounciness.	Science (chemistry), engineering, technology, mathematics
5	DNA Genetic Code and Message Sending System Design (Şardağ & Kaya, 2021)	Participants are supposed to design a message sending system using the four main DNA bases, namely adenine, thymine, guanine, and cytosine.	Science (biology and physics), engineering, technology, mathematics

Regarding ethical issues, the necessary permissions were obtained from the institution and the center's administration. The teachers participated in the activities voluntarily. The aim of the professional development program was also explained to the teachers. To protect anonymity, teachers will be identified by their background rather than their names.

Data Sources

Data sources included voice records recorded during the five design-based integrated STEM activities for each group (10 records in total), design logs, and observation notes taken by the researchers. The primary data sources were the group voice records. The researchers put a voice recorder on each group's desk. In total, 21 hours and 40 minutes of audio were recorded.

To prepare the design logs, the researchers utilized Wheeler et al. (2014)'s design model due to its clear-cut steps. Moreover, Wheeler et al. (2014) provided questions directing each step for the group members. It includes six steps: brainstorming, research, design, construction and testing, re-design, and evaluation. A printed design log was provided to each group and the participants were asked to fill it in during the activity each day. The design log has questions that help participants to follow the design process. For instance, for thermos design, in the research step, participants were asked, "What do you want to know about designing a thermos prototype? What materials might be the best for thermos design? Find out what there is to know about the thermos challenge." For the construction and testing step, participants were instructed, "Design your prototype and test it. Before testing your design, you should record data and assess its effectiveness in regard to the criteria given at the start." After testing, the prompt read, "What can be done to improve your design? Try to write at least one suggestion to improve it, go back to the design stage, and write it in a different color." The questions asked in the design logs have the potential to catalyze group discourse throughout the design process.

During the professional development program, the researchers walked around the groups, listened to the groups' discourse, and observed the group members' participation, including how they reacted to each other's arguments and how members with different STEM backgrounds contributed to the group design. Design logs and observation notes served as the secondary data sources for the study, so that the primary data source could be triangulated. Inferences made from the main data source were checked and triangulated with the secondary data sources. Data triangulation is an important means of ensuring the reliability of the qualitative studies (Miller & Fox, 2004).

Data Analysis, Validity, and Reliability

The data collected from the first two days were not used in the analysis because the participant teachers were not yet familiar with integrated STEM activities or the design process. As a result, the researchers had more influence over group work during those integrated STEM activities. In other words, the researchers aimed to eliminate their influence over the group decision-making and discourse. Except for the first day, the researchers' role was that of observer as participant (Patton, 2002), that is. the participants were aware that the researchers were observing. However, the researchers' interaction was limited. Moreover, the voice-recorder could have been a little disturbing for the participants when the professional development program began. To address those issues, the researchers did not analyze the data collected on the first day. In other words, any researcher input and outside disturbances were made almost non-existent in the data. The 12 hours and 20 minutes recorded were analyzed.

The data analyzed by the researchers and presented in this study focused mainly on the nature of the reflective decision-making processes of a group of teachers and the argumentation schemes they used in the reflective decision-making process of integrated STEM activities. We focused on teacher-teacher interaction rather than trainer-teacher interaction as this could reveal different patterns.

The data received from the voice-recorder were transcribed by the researchers by applying Jefferson (2004)'s Transcription Notation. Furthermore, the analysis steps defined by Pomerantz and Fehr (2011) were employed for data analysis to study the first research question. The following excerpt and its analytical presentation (Figure 1) can be given as an example of the analysis process.

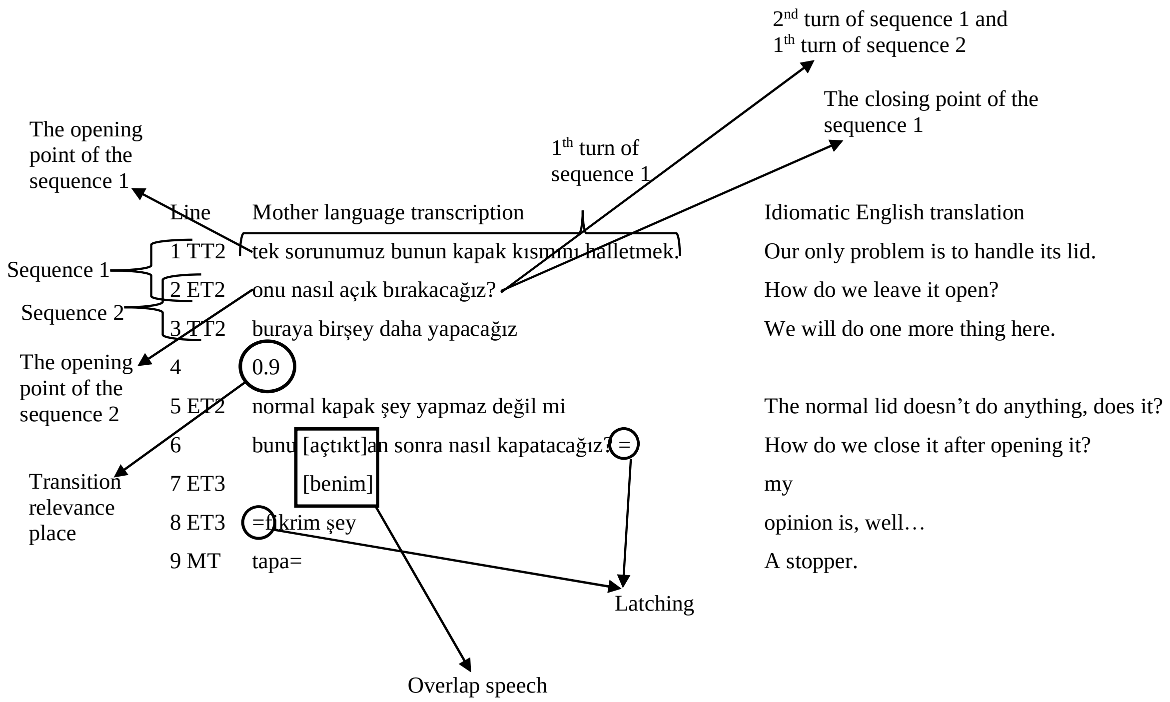

Figure 1. An Analytical Examination of the Data

In the data analysis process (Figure 1), the sequences, their opening and closing points, and the turns that constitute the sequences were established. The actions carried out during turns were examined in terms of their nature, such as stating an argument, counterargument, and displaying epistemic status. The researchers also note an action's purpose and contribution to the interaction and overall process. Additionally, the researchers recorded the methods, that is, some interactional elements. These are transition-related places where the participants had a chance to take a turn, overlap in speech, and latch, which the teacher used to take the turn employed to carry out the actions.

While performing the analysis, the researchers grouped similar interactions into "collections," which provided evidence for the nature of the reflective decision-making processes of a group of teachers and the argumentation schemes they use in the reflective decision-making process. Other interactions, which may have been revealing but did not serve the purpose of the research, were excluded from the collections. The collections were examined holistically. This helped the researchers to see different patterns that reflect distinct purposes or have various discourse features. Thus, the collections provided opportunities to answer the first research question by describing the features of interactions among group members, Lastly, the researchers determined the total number of patterns found in the collections and their percentages so that they could present discourse tendencies. When presenting transcripts, a multi-column transcription was used. The first column represented the participants' mother language, and the second column gave an idiomatic English translation. For conciseness, the results section will use only the translated discourse.

To address the second research question, the researchers drew on schemes constructed by Walton et al. (2008) and adapted by Kim et al. (2014) due to their aforementioned advantages, such as the availability of clear-cut schemes (see Theoretical Framework section). These schemes are *position to know (personal), position to know (research), consequences, popular opinion, correlations, sign, commitment, analogy*, and *bias.* Among these schemes, *position to know (personal)* refers to the situation that information based on personal experience is correct. The *position to know (research)* scheme includes situations in which the information provided is based on external sources, such as an expert or research. The *consequences* scheme contains points about the possible outcomes of an action. Finally, the *popular opinion* scheme is related to group members' agreement on certain social and cultural norms. Each pattern determined and examined for the first research question was re-examined to reveal which argumentation schemes were employed. The researchers also calculated the total number of schemes revealed and their percentages to provide evidence for the basic structure of the arguments produced.

To guarantee the validity of the results obtained in the research, the researchers focused on the transparency of analytic claims and quantification. According to Peräkylä (2004), when a researcher presents their results in as much detail as possible, then s/he can convince a reader that the results are transparently true. For this reason, the researchers presented all results with all the details available and with context. In addition, the researchers presented a percentage account as quantification.

Reliability is an essential matter to be addressed in qualitative research (Silverman, 2004). To put forth reliability in discourse or conversation analysis research, researchers intend to ensure maximum inclusiveness of collected data by taking into account ambulatory events and documentary realities (Peräkylä, 2004). In this study, although the researchers avoided losing the richness of ambulatory interaction by using voice recorders, they could not capture all the interaction the among teachers. To prevent this from affecting reliability, the researchers focused on a certain part of the interaction and performed their analysis. The researchers thus analyzed and presented specific parts of the implementation process for each activity, the pre-design and design process. For documentary realities, the researchers used design logs and observation notes to understand interactions' context. Through these documents, the researchers intended to support the reliability of the analytical claims made by looking at the interactions within groups. In addition to the mentioned reliability issues, a member check was utilized (Creswell, 2007). The researchers talked to a volunteer teacher about the results briefly. The researchers and him talked about the different participants' roles and contribution to group decision-making. He agreed with the researchers' interpretations of the data. Moreover, the researchers spent a long time with the participants both during the professional development program, and out of the professional development program (i.e., coffee breaks, before/after the program). The researchers also calculated the reliability index of coding using Miles and Huberman (1994) understanding for nearly 20% of all data. The index was determined as .90. Additionally, the second researcher who analyzed all data, re-examined nearly 20% of all data and calculated the consistency of the coding using the same understanding in different times. The consistency was put forward as .95.

Finally, for the credibility of the research, Patton (2002) mentioned one important point that increases the credibility of the research, namely, "credibility of researcher, which is dependent on training, experience" (p. 552). The researchers in this study are experts in qualitative research methods, integrated STEM teacher education, and decision-making.

Results

First, the researchers provide an overall summary of the results (Figure 2). This shows the nature of the teachers' discourse of collaborative and reflective decision-making (i.e., patterns regarding the parts of the design and the level of the collaboration). Later, they present the participants' use of argumentation schemes.

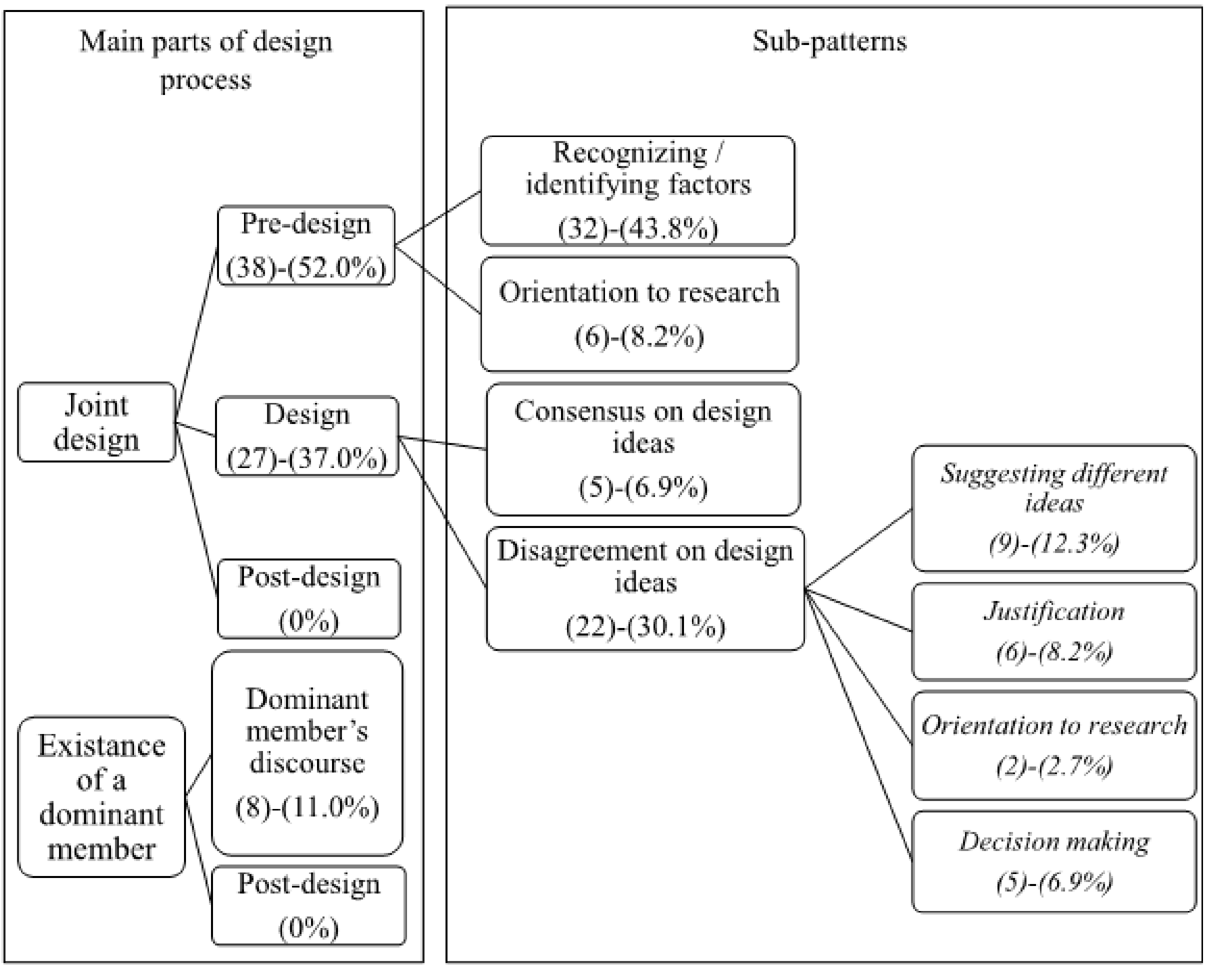

Figure 2. Synopsis of the Results for Different Stages of the Design Process

For the first research question, the nature of the reflective decision-making processes of a group of teachers for the engineering design process, Figure 2 shows that the design process in the current study was carried out in two ways, namely, "joint design" and "existence of a dominant member." Of the patterns that shed light on the research questions, 89.0% fell under joint design and 11.0% of them under the existence of a dominant member. Joint design consists of three main stages, namely, the pre-design (52.0%), design (37.0%), and post-design (0%) stages. Existence of a dominant member consists of two main stages, namely, the discourse of the dominant participant in the group (11.0%) and the post-design (0%) stages. Joint design is more collaborative whereas the existence of a dominant member means very limited collaboration. Both methods have common patterns that were determined by micro-analyzing line by line. The patterns are presented below through the example of a common, naturally occurring teacher interaction.

Joint Design

Pre-Design Stage

The pre-design stage contains two different patterns that occur in close succession: recognition/ identification of the factors (43.8%) and orientation to research (8.2%).

Recognizing/Identifying the Factors. The excerpt given in Table 3 is an example of how participants identified the factors relating to the problem and shaped the solution. The excerpt comes from conversations in the early stage of the polymer design activity, in which the groups were given a scenario that states a company is looking for engineers to design a bouncy polymer. To create a bouncy polymer ball, the participants need to focus on the chemical properties of polymers and how to increase the elasticity of the polymer (i.e., amount of borax vs. polyvinyl acetate). With slow-motion video recording, the bounces of the balls are measured. The group whose ball has the highest bounce wins.

Before the excerpt, the first researcher, whose field is chemistry teacher education, introduces the design challenge. Teachers are asked to design a flexible polymer. The ball made from the polymer is supposed to bounce to a height of at least 30 centimeters.

Table 3. Excerpt for Recognizing/Identification the Factors: Polymer Activity (00:16:06-00:16:22)

Satır	Etkileşim	
1 TT2	sade<u>ce</u> üç malzeme [kullanıyoruz değil mi hocam]	We only use three components, don't we, teacher?
2 PT	[şeyi lazım bak ( )]	Its thing is needed. Look.
3 Res	evet	Yes.
4 PT	mesela [fiziksel olarakta yer]e temasının az olması	For example, it needs to have less physical contact with the ground
5 ET2	[sodyum borat tutkal]	Sodium, borate, glue.
6 PT	lazım eğer yere [çok] temas ederse:	If it contacts with the ground a lot…
7 ET3	[ney]	What?
8 PT	ge[ri] zıplaması o kadar azalır	… its rebound will decrease correspondingly.
9 ET3	[su]	Water.
10TT2	işte o <u>şey</u>liğiyle ilgili=	So, it is related to its thing…
11ET2	=ama o esnekliğiyle=	But it … to its flexibility.
12TT2	=[esnekliğiyle] ilgili birazda [sertliğiyle]	…related to its flexibility, and slightly to its rigidity.
13 PT	[esnekliğiyle] [sertliğiyle]	Its flexibility. Its rigidity
14TT2	o <u>da</u> hangisi belirleyecek ona bakmamız lazım	We will have to examine which one will determine it.

TT2: Technology Teacher2, PT: Physics Teacher, Res: Researcher, ET2: Elementary Teacher2

The excerpt starts with Tech Teacher 2 asking a tag question about the components of a polymer in the activity (line 1). This tag question can be categorized as a request for confirmation because Tech Teacher 2 displays awareness of the components of polymer in the activity by stressing the word "only" (sade<u>ce</u>). The situation is a reflection of the "position to know-personal" argument scheme and reflects the epistemic status of Tech Teacher 2, who shows knowledge by referring to the components. Researcher 2 confirms the ideas of Tech Teacher 2 (line 3), and Elementary Teacher 2 extends the information presented by Tech Teacher 2 and lists three components (line 5). After these interactions, Physics Teacher suggests his idea, which reflects the ideal properties of the polymer to be produced and his reasoning (lines 4, 6, 8). Then Tech Teacher 2 takes a turn and provides a demonstration of understanding, revealing the factors behind Physics Teacher's idea (lines 10, 12, 14). Overlaps in line 13 are evidence of this. Additionally, Tech Teacher 2 suggests an inquiry process (line 14). The information obtained at the end of this process will affect the chosen polymer making process. In summary, this excerpt shows how the participants identified the factors related to the problem and shaped its solution in the pre-design. It also demonstrates the "position to know-personal" scheme of Walton's argument schemes.

Orientation to Research. The excerpt given in Table 4 is an example of how the teachers oriented to the research, both clarifying the effects of the factors determined and exploring new ideas about possible designs. This excerpt comes from conversations during the early stage of the polymer activity; it occurred about one minute after conversations presented in Table 3.

Table 4. Excerpt for Orientation to Research: Polymer Activity (00:17:27-00:17:56)

Line	Mother language transcription	Idiomatic English translation
1 PT	[ama o bak] slime elde ediyor=	But look, s/he is getting slime.
2 ST	=slime gibi bir şey [elde ediyor]	S/he is getting something like slime
3 TT2	[ama slime ı]n	But the slime's…
4 PT	slime [çok yumuşak]	The slime is very soft.
5 TT2	[zıplama öze]lliği yok ki	… it has no bounce feature.
6 PT	zıplamıyor yani=	I mean, it doesn't bounce.
7 ST	=diyor ki bir parça aldığımı[zda]	/S/he says when we get a piece…
8 ET2	[sli]me ı biraz sertleştirip=	Harden the slime a bit.
9 ST	=akışkanı biraz sertleştirdiğinizde aldığınızda o	…when you harden its viscosity a bit, when you
10	parça .hh hafifçe bir zıplayacaktır (.) bu hafifçe otuz	take that piece, it will bounce slightly. I guess this
11	santim olmaz heralde	wouldn't be thirty centimeters.
12 TT2	((çık))	((tuts))
13 PT	yani slime yapmamamız lazım. Biraz daha böyle	So we shouldn't make a slime. We will increase
14	sertliğini arttıracağız o da ark- yapıştırıcıyla olur	the hardness a little bit more and that can be with gum.
15	(0.2)	
16 TT2	tutkalla	With glue.
17 PT	tutkalla	… with glue.
18 ET3	arkadaşlar bi on numara bir tane yapalım	Friends, let's do a number 10.
19 PT	tamam on numara[ya başlayalım]	Okay let's start number 10.
20 ET3	[ben (.) siz] araştırın	I… You research
21 PT	tamam on numara yap-	Okay, do number 10.

PT: Physics Teacher, ST: Science Teacher, TT2: Technology Teacher2, Res: Researcher, ET3: Elementary Teacher3

Science Teacher looks up how to make a number 10 polymer on the Internet and shares the information with the group members. This information—instructions on how to make slime—reflects the "position to know-research" argument scheme because Science Teacher tries to produce an argument based on his research information. Physics Teacher takes an overlapping turn and shows that he does not agree with the information by saying "but" and explaining his reasoning (lines 1 and 4). Similarly, Tech Teacher 2 does not like the information and explains why he does not, overlapping with Physics Teacher's turn (lines 3 and 5). After that, Physics Teacher repeats the turn of Tech Teacher 2, modifying for confirmation (line 6). Science Teacher uses indirect reported speech for background information (lines 7, 9, and 10) but he considers the reported information dubious and expresses his concern. After that, Tech Teacher 2 makes a tutting sound (line 12).

Physics Teacher concludes that making slime does not serve the purpose of the activity and offers a solution (lines 13 and 14). When he presents his idea, he says "with gum" (*yapıştırıcıyla*). However, polyvinyl acetate (glue) is used instead of gum in this activity. So, Tech Teacher 2 corrects him (line 16). The correction reflects the epistemic status of Tech Teacher 2, who is in a more knowledgeable position at that point in the discourse. In the interaction, it seems that the teachers do not decide or produce arguments on how exactly to make the number ten polymer until line 17. Because of this situation, Elementary Teacher 3 offers to make the adjusted number 10 polymer, and asks that the others research how the polymer is made (lines 18 and 20). In other words, Elementary Teacher 3 orients the group toward research to obtain the information. In this way, they can gather some information about polymers and put forward new ideas or arguments from "position to know-research."

In both of the excerpts, members of a heterogeneous group consisting of teachers with different backgrounds try to determine which factor plays a critical role in the design process and to try to consider why and how it affects the design in the pre-design process. In this way, the teachers determine the factors. If the teachers could not put forward proper or reasonable ideas or arguments, they turn to research.

Design Stage

Two different patterns emerged in the discourse of the design stage, namely, consensus on design ideas (6.9%) and disagreement on design ideas (30.1%).

Consensus on Design Ideas. The excerpt presented in Table 5 is an example of a situation in which the teachers reached a consensus on ideas relating to the design. This excerpt comes from the thermos design activity, in which the participants were supposed to design a thermos that could contain hot water and prevent heat transfer as much as possible over a 40-minute time interval. The designs' success was determined by the temperature difference of the hot water put into the thermos after 40 minutes.

Table 5. Excerpt for Consensus on Design Ideas: Design a Thermos (00:37:39-00:38:04)

Line	Mother language transcription	Idiomatic English translation
1 TT2	tek sorunumuz bunun kapak kısmını halletmek.	Our only problem is (how) to handle its lid.
2 ET2	onu nasıl açık bırakacağız?	How do we leave it open?
3 TT2	buraya birşey daha yapacağız	We will do one more thing here.
4	(0.9)	
5 ET2	normal kapak şey yapmaz değil mi	The normal lid doesn't do anything, does it?
6	bunu [açtık]tan sonra nasıl kapatacağız?=	How do we close it after opening it?
7 ET3	[benim]	My opinion is, well…
8 ET3	=fikrim şey	opinion is, well…
9 MT	tapa=	A stopper.
10 PT	=tıpa tıpa	Stopper…stopper…
11 ET3	tıpa=	Stopper.
12 MT	=tapa yapmalıyız	We have to make a stopper.
13 PT	tahta bir tıpa	a wooden stopper.
14 TT2	sonuçta içilecek ama içilecek diyor	Eventually it (the liquid) will be drunk, but it says to be drunk.
15 ET2	acaba benim evde var mı?	I wonder, do I have one at home?
16 MT	mantar mantar	Cork, cork.
17 PT	mantarlar var ya	Cork stoppers, you know…
18 TT2	mantıklı çok da mantıklı	That makes a lot of sense.
19 PT	plastik ya da	Plastic or…?
20 TT2	nerde var?	Where would you find it?
21 PT	bende var yukarıda	I have it, up there.
22 MT	var var yukarda var.	Yes, up there.
23 ET3	buna uygun mudur?	Is it suitable for this?
24 PT	evet	Yes.

TT2: Technology Teacher2, ET2: Elementary Teacher2, MT: Math Teacher, PT: Physics Teacher

The excerpt starts with a problem. Tech Teacher 2 defines the problem relative to the design (line 1). Elementary Teacher 2 clarifies the problem and expresses it as a question (line 2). Tech Teacher 2 offers a solution, but it is not clear (line 3). After that, Elementary Teacher 2 asks a tag question for confirmation (line 5). This confirmation states that the standard lid is not suitable for the designed thermos. Then Elementary Teacher 2 asks a wh-question (line 6) and Math Teacher offers a stopper as a design solution. After that, both Physics Teacher and Elementary Teacher 3 repeat this comment (lines 10 and 11). This situation shows us that both teachers accept the idea and agree with each other.

The next turns are related to the agreed-upon idea, which came from popular opinion. To sum up, if the teachers state similar ideas or claims about the design, they quickly reach a consensus and continue with new ideas or claims. They proceed with this situation until a disagreement arises or until the post-design process, where they implement their ideas or claims about the prototype.

Disagreements on Design Ideas. The teachers did not always agree with each other during the design process. An arising disagreement starts with the suggestion of different ideas (12.3%) by the teachers. The next phase can take place in one of three possible ways, namely, justification (8.2%), orientation to research (2.7%), or tending to pass directly into the post-design implementation process. After justification and/or orientation to the research, the teachers try to make a decision (6.9%) on the design.

Suggesting Different Ideas. The excerpt given in Table 6 is an example of a situation in which the teachers disagree while giving their ideas on the design. This excerpt comes from the DNA genetic code and message sending systems design activity. The activity consisted of two main parts. The teachers were supposed to design a message-sending algorithm using the four main DNA bases—adenine, thymine, guanine, and cytosine—in the first part. This could be considered a software design process. In the second part, the teachers developed a circuit system to send a message using the produced algorithm: a hardware design process. The teachers used initials for [a]denine, [t]hymine, [g]uanine, and [c]ytosine during the activity.

Table 6. Excerpt for Suggesting Different Ideas: DNA Genetic Code and Message Sending System Design Activity (0:36:18-0:36:36)

Line	Mother language transcription	Idiomatic English translation
1 TT2	tamam bu kolay [şimdi] ışık devresine	Okay, this is easy. Now, to the light circuit.
2 PT	[şimdi]	Now.
3 ET2	şimdi [kodlamaya geçiyoruz].	We are starting to code now
4 PT	[ışık devresinde ney]i neye bak	Look what there is in the light circuit.
5 ET2	kodlama yapacağız	We will code
6 PT	.hhh mesela a t ne olsun (.) a t var .hhh t a var (1) g c var=	For example, what about a, t? There are a, t. There are t, a. There are g, c.
7 TT2	=öyle mi o zor olur=	Really? That would be difficult.
8 PT	=tabi yok	Of course not.
9 TT2	sadece a harfini yapalım	Let's just make the letter a.

TT2: Technology Teacher2, PT: Physics Teacher, ET2: Elementary Teacher2

In the excerpt, the teachers have completed the previous process, in which they recognized and identified the factors that affect the design. They focus on a new situation, which is coding design. There are conversations about this situation in lines 1-5. In this situation, Physics Teacher expresses his ideas or thoughts on the coding (line 6 and 7). Thereupon, Tech Teacher 2 makes a negative assessment by displaying a claim of understanding (line 7). However, Physics Teacher does not accept this negative assessment (line 8). Then Tech Teacher 2 suggests his own idea. In this process, the teachers produce their arguments from the "position to know-personal" scheme. As a result, it is seen that the teachers are not in consensus as they suggest different ideas. Thus, to put it in Leitão (2000)'s terms, different arguments or counterarguments about the same issue emerged and were presented.

Justification. The excerpt given in Table 7 comes from the polymer activity. The excerpt shows when the teachers do not reach a consensus on a design idea, they try to justify their ideas to each other.

Table 7. Excerpt for Justification: Polymer Activity (01:06:02-01:07:08)

Line	Mother language transcription	Idiomatic English translation
1 PT	dört tane bağ yapmış (0.2) o zaman bun-bundan	It bonded four times. Then if there is one
2	bir tane olursa diğerinden dört tane olacak (.)	from this, there will be four of the other, so,
3	dolayısıyla şu CH o yani şunu arttırmam lazım	that C, H. I mean…I have to increase that.
4	(1)	
5 ST	bende tam tersini düşünüyorum	I think just the opposite.
6 ET3	ney ney	What? What?
7 ST	boraksı arttırmak lazım	We need to increase borax.
8 PT	yok	No.
9 Res2	siz neden boraks diyorsunuz?	Why do you say borax?
10 ST	çünkü boraks aradaki (.) şeyleri bağlıyor ya	Because borax bonds the things in between…
11 PT	ama za[ten borakslar bir ta]nesi iki tanesini	But since one borax bonds two things…
12 ST	[bağlayıcı kapsamında]	… considering it bonds.
13 PT	bağladığına göre yani bi boraksa iki tane şey lazım	… since the boraxes connect two of them, one borax needs two things.
14	(0.2)	
15 ST	tamam mesela boraksı arttırsan doymuşluğunu artırırsın	Okay, for example, if you increase borax, you increase the saturation.
16	(1.5)	
17 CT	boraks ı: bo- boraks ı: ne yapmaya çalışıyorsun?	Borax, borax. What are you trying to do?
18 ST	diyoruz ki onu daha mesela	What we're saying is that we still have to… For
19	[katılaştırmamız lazım slim]e gibi oldu ya	example, We have made it thicker because it was like slime.
20 PT	[şimdi hangisi katılaştırma]	Now which one? The thickener
21 PT	şurdaki bağ sayısını ne kadar çoğaltırsam	The more we increase the number of bonds
22	borakslar burada daha çok bağ yapacak (3) o	there, the more bonds the borax will make
23	zaman bence borakslar azaltmamız lazım (0.2)	here. Then I think we need to reduce the
24	boraksı biraz az diğerini biraz [daha fazl]a	borax. A little less borax, a little more of the other.
25 CT	[bu boraks]	This borax.
26 PT	daha sertleşir	It hardens into a solid.
27 ST	senin bir yorumun var mı? Bence	Do you have a comment? In my opinion,
28	[boraksı artırmamız lazım]	we need to increase borax.
29 CT	[boraksı azaltırsa nasıl b]ağlayacaksın sen ona?	If he reduces the borax, how will you bond to it?
30 ST	bende onu diyorum [boraks bağlıyor]	That's what I'm saying, too. Borax bonds.
31 PT	[tamamda zaten b]ir tane boraks	Okay, but it's just one borax; one boron bonds
32	ı: şu bir tane bor iki dört tane oksijeni bağlamış	four oxygens.
33 ST	((çık)) tamam suyu bağlı- su çözeltidir abi (.)	(tuts) Okay, water is the solution, brother.
34	suyu atacağız bak su hep dışarı verdi=	We will get rid of the water. Look, water is always discharged.
35 PT	hayır hayır	No, no.

PT: Physics Teacher, ET3: Elementary Teacher3, TT2: Technology Teacher2, ST: Science Teacher, CT: Chemistry Teacher, Res2: Researcher2, Before the conversation in the excerpt, Physics Teacher examines the reaction between borax and polyvinyl acetate. This examination reflects an orientation to research in the pre-design process. Physics Teacher describes the reaction and infers that he has to increase the amount of polyvinyl acetate (lines 1, 2, and 3) (It is more explicit in lines 22 and 23). This can be considered a reflection of argument based on consequences, because the inferences are about the possible consequences of an action. Science Teacher states disagreement (line 3). After that, Elementary Teacher 3 requests clarification; Science Teacher clearly expresses his claim in line 7. However, Physics Teacher opposes Science Teacher in line 8. Researcher 2 takes a turn and asks a referential question to Science Teacher to encourage justification (line 9). After this, both Science Teacher and Physics Teacher try to explain why their arguments must be true (lines 10-24). The teachers use different arguments, and they work to persuade each other. In other words, two counterarguments confront each other (Leitão, 2000).

Chemistry Teacher gets involved in the conversation in this process in line 17 and tries requesting information. While Science Teacher gives the information, Physics Teacher explains his justification and his argument (lines 20-26). Then, Science Teacher asks a yes/no question for any comment about the situation and states his claim in lines 27 and 28. Chemistry Teacher asks a referential question in line 29. The question serves both as a request for expanding on Physics Teacher's justification and as a disagreement. It also reflects the epistemic status of Chemistry Teacher—a more knowledgeable position. Science Teacher supports Chemistry Teacher's implicit claim in line 30. After that, Science Teacher and Physics Teacher restate their justifications. To sum up, when the teachers make their arguments, if there is a disagreement, they try to persuade and justify their own arguments.

Orientation to Research. Another pattern observed when there was a disagreement about ideas during the design process is orientation to research. The excerpt given in Table 8 is an example of this pattern. It mostly occurs when the teachers cannot persuade each other, or they lack persuasive arguments.

Table 8. Excerpt for Orientation to Research: Design a Thermos (00:23:38-00:24:19)

Line	Mother language transcription	Idiomatic English translation
1 ET3	.hh yalnız ben bir şey soracağım. Neden bütün	Just, I want to ask something.
2	termoslar silindir şeklinde o zaman eğer bu kötü bir fikirse .hhh	Why are all thermoses cylindrical then if this is a bad
3 PT	şimdi (0.3) ı: şu soru şuydu=	idea? Now, the question was that…
4 ET2	=taşıma=	carrying.
5 PT	= ı: [maksimum hacim min]imum yüzey alanı lazım	We need maximum volume, minimum surface area.
6 ET2	[kaplanılan alan mı]?	Is (it) the coated area?
7	(1)	
8 PT	ı: daire şeklinde olsa mı silindir şeklinde mi olsa	Will the surface area be larger if it
9	yüzey alanı büyük olur yoksa onun şey yapsam	is circular or cylindrical? Or if I
10	(0.7) altıgen yapsam mı yüzey alanı daha büyük olur.	make something else, like hexagonal, will it be larger then?
11	(0.2)	
12 MT	şimdi burda ( )	Now here…
13 PT	şöyle düşün	Think of it in this way…
14 ET2	daire şek-	Circle.
15	(1)	
16 PT	şöyle bir tane r yarıçap düşün tamam mı?.hh şunu	Think of one r radius like this,
17	daire mi yapsam (.) şu yüzey alanı büyük olur	okay? Would the surface area be
18	yoksa şöyle altıgen şeklinde mi yapsam	large if I made this a circle…or if I made it hexagonal like this?
19	(3)	
20 MT	hacim aynı kalacak	The volume will remain the same.

ET3: Elementary Teacher3, PT: Physics Teacher, MT: Math Teacher

Before the conversation in the excerpt, the group members tried to decide which shapes offer the maximum surface area for a container of the same size. Physics Teacher stated that the hexagonal structure is most suitable due to the fact that it would result in less heat loss from the surface. Most of the group members accepted this idea, but Elementary Teacher 3 was confused about it (see Table 9).

Table 9. Early Stage of the Excerpt Given Table 8: Design a Thermos (00:14:13-00:14:26)

Line	Mother language transcription	Idiomatic English translation
1 ET3	abi hacim (1.5) ı:: yani yüzey alanı olabildiğince dar olması lazım=	Bro, it's volume. So the surface area should be as narrow as possible.
2 PT	=işte altıgen en güzel örneği=	See, the hexagon is the best example.
3 TT2	=şeyi ilk[ini şeyi]	The first thing is…
4 ET3	[silindir]=	A cylinder…
5 PT	=yani maksimum hayır silindirin yüzey alanı	So the maximum, no. The surface area of
6	daha fazladır değil mi MT abi?	the cylinder is greater, isn't it, (Math Teacher)?

ET3: Elementary Teacher3, PT: Physics Teacher, TT2: Technology Teacher2

After nearly 10 minutes of discussion, Elementary Teacher 3 asks a referential question (line 1, Table 8). The question can be labeled as a disagreement position and a clarification request. It also reflects a counterclaim and points out the weakness of the argument produced. Physics Teacher tries to explain why most of the group members decided on the hexagon. However, he cannot provide any evidence or strong justification. He thus turns to research to gather evidence and decide which shape is most suitable for the design of a thermos. After the conversation in Table 8, the group tries to calculate which shape has the minimum surface area using evidence and justification. In other words, because of the occurrence of the counterclaim to the argument produced by Physics Teacher, they produce evidence and arguments from a "position to know-research" scheme. Consequently, it is seen that when there is no reasonable evidence, justifications, or reasons for the design claim put forward, if anyone opposes, they can orient to research to reveal reasonable evidence or justifications. After the justification or orientation to research, the participants make a decision related to the disagreement that had occurred in previous conversations about the design, based on evidence obtained through calculations or other information sources. A similar situation is presented as an example in Excerpt 8.

Decision-Making. The last pattern in the design process is decision-making. An example of this is seen in the excerpt given in Table 10 and comes from the design of a thermos activity.

Table 10. Excerpt for Decision-Making: Design a Thermos (00:30:52-00:31:06)

Line	Mother language transcription	Idiomatic English translation
1 MT	bizim değerler küçük olduğu için (1) şimdi büyüdüğü zaman=	because our values are small. Now, when they increase…
2 PT	=tabi büyüdüğü zaman=	Of course, when they increase…
3 MT	=ı::	err…
4 PT	çok fark eder.	it makes a lot of difference.
5 MT	çok fark eder.	it makes a lot of difference.
6 PT	ama sonuç şu=	But the result is that…
7 MT	=bir bir santim üzerinden düşündük	We thought based on one centimeter…
8 PT	yani altıgen şeklinde yapılması yüzey alanını küçültüyor	I mean, making it in the shape of a hexagon reduces the surface area.
9 MT	evet	Yes.
10 PT	yüzey alanını küçültmesi ısı kaybının azalması=	Reduced surface area equals reduced heat loss.
11 MT	=azalması demek	Equals reduced heat loss.
12 Res2	evet	Yes.

MT: Math Teacher, PT: Physics Teacher, Res2: Researcher2

The excerpt was intentionally selected due to the fact that it occurs nearly 7 minutes after the excerpt presented in Table 8. The participants were trying to calculate which shape had the smallest surface area. Just before the excerpt given in Table 10, Math Teacher and Physics Teacher calculated a small difference between the surface areas of cylinders and hexagonal cylinders in favor of the hexagon. After that, Math Teacher shares the information obtained in the process. He provides a reason for this situation and tries to explain what will happen when the values are increased (line 1, Table 10). In other words, he tries to promote his idea, produced as an argument, using consequences. Physics Teacher takes his turn and confirms the idea. Although the Math Teacher hesitates, he repeats the Physics Teacher for confirmation. Then, Physics Teacher clearly states the results of the calculation (line 8). A similar situation occurs in lines 10 and 11. Consequently they reach a consensus and make a decision about the design.

Due to time limitations and participants' reluctance to redesign, solid patterns could not be detected during the redesign process. It did not take place in a cohesive way during the course of the professional development. The redesign was realized through a short talk about what should have been done rather than a true redesign process. Besides, due to the fact that the teachers did not give permission to video-record the processes, we could not gather nonverbal cues to shed light on the post-design process. As a result, the results include mainly the pre-design and design stages.

The Existence of a Dominant Member

Dominant Member's Discourse

The excerpts presented above took place mainly in a consensus-based framework within the perspective of collaborative work. There were, however, different situations within the groups. Although most of the cases were collaborative efforts in the pre-design and design process, when a dominant character exists in the group, s/he decides on the design individually in some situations. In this case, the group members are not able to work collaboratively to recognize or identify the factors affecting the design or research the related phenomena, etc. Moreover, there is no consensus of ideas and disagreement on design. With the existence of a dominant character, although the STEM activity of the day is conducted by the group, the STEM professional development program context and the group dialogue are affected negatively.

To introduce this pattern, we must clarify the difference between a dominant character and highly active participants. Although the dominant characters in the current study—who were not all the same participant—had a negative impact on the activity process. Contrary to dominant member, some participants are highly active (e.g., Physics Teacher, Tech Teacher 2), engage in the process, and provide very positive contributions to the interactions. Those teachers tend to conduct argumentative and collaborative decision-making processes. Dominant characters, conversely, tend to work without input from their teammates. The following table presents an example of this issue.

Table 11. Excerpt for the Dominant Member's Discourse: Design a Thermos (00:18:48.20:19:51)

Line	Mother language transcription	Idiomatic English translation
1 CT	pa- pamuğu nerede kullanacağız (0.3) alimünyu[m folyo]	Where will we use cotton? Aluminum foil?
2 ET1	[sararız]	We wrap.
3 AT	pamukla işimiz yok	We will not use cotton.
4 BT	çevresini ı:	its surroundings…
5 ET1	saralım	Let's wrap
6 BT	sıcak tutmazlar mı	doesn't it keep warm?
7 CT	köpük yerine	instead of Styrofoam.
8 AT	köpüğü kullanacağız az önceki tabakalar vardıya üç dört tane burda	We'll use the Styrofoam. There were just three, four layers here.
	…13 lines omitted for space…	
22 ET1	bulaşık bezide var heralde	There is probably a dishcloth too.
23 TT1	işe yaramaz o	It is useless.
24	(1.8)	
25 CT	ama bi dikkat edelim hemen o acaba neden	But let's pay attention right away,
26	getirmiş (1) neden getirmiş ha elle tutması için soğuk hani şey tut-	why did she bring it? She brought it to, you know, handle. It is cold.
27 TT1	bizim [burada şey]	We…thing here…
28 CT	[zaten eğer] (.) eğer burası sıcak olursa dış	Besides if it's hot here, the outer
29	yüzey sıcak olursa zaten bir anlamı kalmamış evet	surface is hot, it didn't work… anyway, yes.
30 TT1	bende burda=	I also … here…
31 CT	=onun için	For it.
32 TT1	iki katman kullandı[k ya]	We used two layers, right?
33 CT	[orda] şey o plastik	That plastic, hold [it] by hand
34	[var ya elle tut]-	there.
35 TT1	[hah burda iki k]atman oluşturmamızın sebebi o	Ah, that's why we made it in two layers here. It will not lose heat
36	işte (0.7) buradan ısıyı vermeyecek buradan ısıyı almayacak amaç	from here, it will not take heat from here. That's the goal, anyway.
37	bu [zaten] yoksa yani mantık	I mean, otherwise, that's the logic of it.
38 CT	[aynen]	Exactly
39 CT	ısı alıp [yalıtımı olacak ısı alış ver]işi	Takes heat, there will be insulation, heat exchange.
40 TT1	[onu keseceğiz biz burdan]	We will inhibit it from here.
41 CT	olmayacak ısı alışverişi çarpı	The non-existent heat exchange, cross (that) out.
42 TT1	aynen öyle yani bakın eski termosların	Exactly. So, if the glass of the old
43	camı kırıldıysa adamlar şu mantıkta yapmış=	thermos was broken, the guys made it using that logic
44 CT	=ben hiç kırmadım=	I have never broken one.
45 TT1	=ben çok kırmışım abi=	I broke so many, bro.
46 CT	=neden?	Why?
47 TT1	düşüp kırılıyordu ondan	They fell and broke, that's why.
48 CT	hah hahhah	(laughing)

CT: Chemistry Teacher, ET1: Elementary Teacher1, AT: Art Teacher, BT: Biology Teacher, TT1: Technology Teacher1

The excerpt presented in Table 11 is an example of the discourse of a dominant character. The participants are trying to decide which materials they might need in the early stage of the activity. They produce ideas about the materials in lines 1-9. This process continues for a certain time and then Elementary Teacher 1 takes a turn and makes a comment about the materials brought in by the researchers, given in line 22. Tech Teacher 1, who acts as a dominant character, however, makes a negative assessment of the expressed material, a dishcloth (line 23). Despite the negative assessment, the Chemistry Teacher tries to re-focus the attention of the group on the material (lines 25 and 26) and express his own ideas (lines 28 and 29). Tech Teacher 1 retakes a turn and states what was done. While he began his comments using "I" in line 30, Tech Teacher 1 continues by saying "We used two layers" in line 32 and "we made" in line 35. He expresses his decisions and his design as if it were the decision or design of the group.

After that, other group members try to understand and orient themselves with his ideas. The prior knowledge and experiences expressed in lines 42, 43, 45, and 47 illustrate that the Tech Teacher 1 is the dominant character and how he makes his decisions. Additionally, they show that the arguments generated by him come from the "position to know-personal" scheme. It is important to note that the excerpt is taken from the very beginning of the activity process from 00:18:48 to 00:19:51; before that, the researcher introduced the activity for nearly 12 minutes. Additionally, there is no speech addressed by the Tech Teacher 1 in the intervening period for approximately 7 minutes. Consequently, as a result of this dominated process, counterarguments could be not produced or dismissed for the product design. The dominant character decides on the design, hindering group member contributions and skipping the pre-design and design process.

Argument Schemes

When the teachers worked collaboratively throughout the study, they used some of Walton's presumptive reasoning schemes, which addresses the second research question, which argumentation schemes are employed in different parts of the process. During data analysis, the researchers focused on main patterns and attempted to determine the schemes within them. By doing so, the researchers were able to provide insight into the nature of reflective decision-making processes of a group of teachers through the engineering design process of integrated STEM activities. The findings for the argument schemes used by teachers with different backgrounds in the STEM activity are summarized in Figure 3.

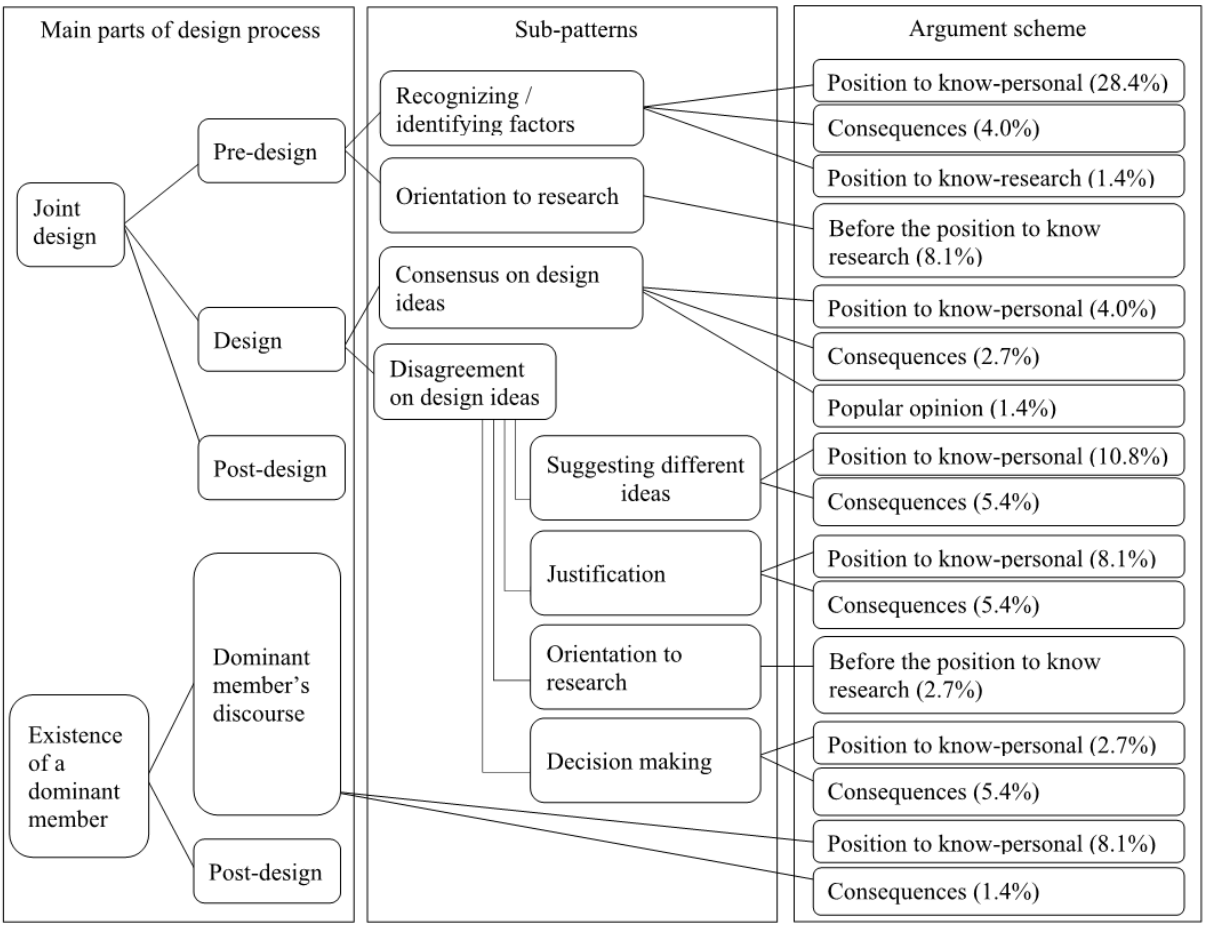

Figure 3. Synopsis of Results for Argument Schemes in the Design Process

The data in Figure 3 demonstrate that 74 argument schemes were identified out of the patterns of discourse during the integrated STEM activities. While labelling these schemes, their state of existence in each pattern was taken into consideration. Therefore, there may be more than one of the same schemes in a pattern. As the types of schemes in the pattern are related to each other, no separation is made.

Position to know-personal, consequences, and position to know-research schemes were detected most frequently in the patterns. The position to know-personal scheme appears to be predominant in almost every pattern. The consequences schemes (reflecting causal relationships) are used more frequently in the transition from the pre-design process to the design process. Therefore, it can be argued that there is a transition from source-based argument schemes to reasoning-based argument schemes. When the teachers lack the reasonable argumentation necessary for reflective decision-making, a position to know-research scheme occurs as a result; teachers get information by turning to different sources of information. Finally, the popular opinion schema was encountered in a single situation, in which everyone in the group expressed the same idea.

Discussion, Conclusion, and Implications

In this study, the nature of collaborative and reflective decision-making of a group of teachers for engineering design, and argumentation schemes that were employed in different parts of the process, were examined through discourse analysis in an integrated STEM professional development context. The different patterns of discourse relating to the design process and argumentation schemes in integrated STEM activities were revealed using line-by-line analysis. The patterns reported in data analysis were consistent across all five days of the study. This section discusses the results by considering both research questions together.

Regarding the nature of the process, the participants spent time on the two main parts of the process that were the pre-design and design stages. For each activity, the participants meticulously discussed the factors that would play important roles in the solid design, did research to find evidence to support their claims, and debated how to use those ideas for the design. For a better and richer understanding of the nature of the teachers' collective decision-making process, Figure 4 presenting a holistic conclusion for the nature of teachers' discourse of collaborative and reflective decision-making for engineering design study was formed.

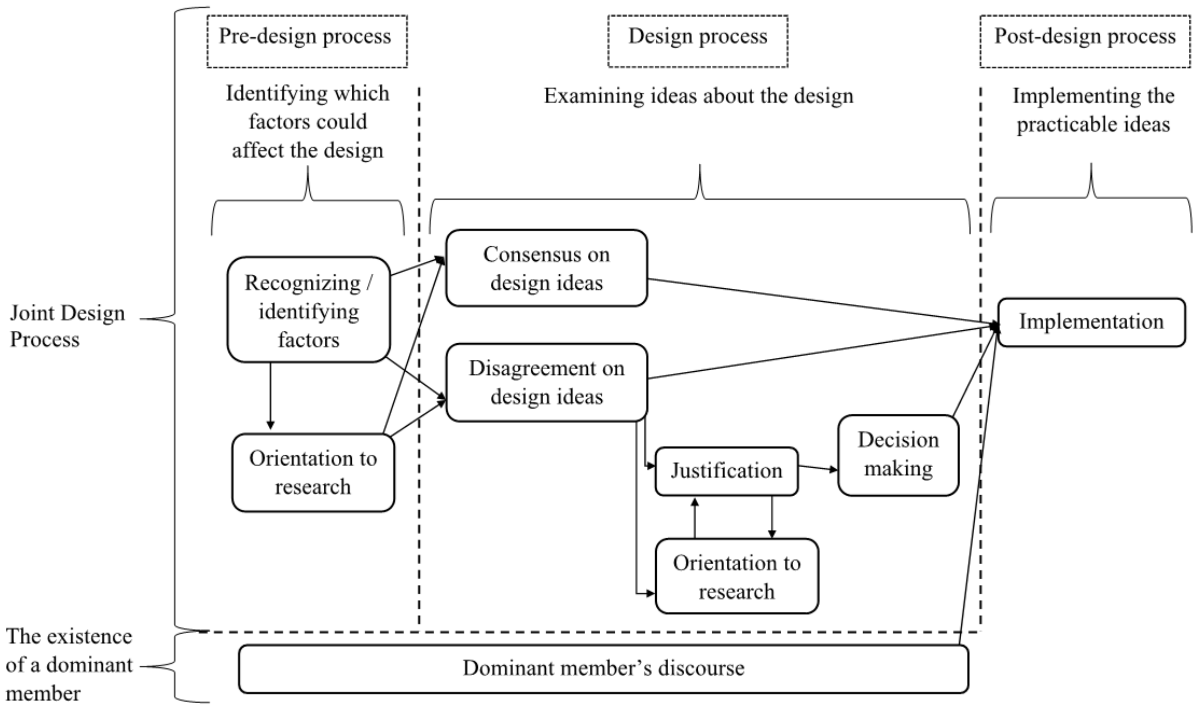

Figure 4. The Patterns and the Stages Detected in Teachers' Design Process of Integrated STEM Activities

Another important point regarding the nature of the collaborative and reflective decision making process of teachers throughout engineering design is that two types of patterns are detected. The first is the *joint design process,* based on argumentation carried out by teachers with different backgrounds while performing integrated STEM activities. The second is the *existence of a dominant member* within the group managing the activity process. The first situation appears in three stages, namely, pre-design, design, and post-design. The pre-design and the design process are close together, and in some cases, they are consecutive or overlapping. However, there are some differences in reflective decision-making processes in terms of discussing arguments and counterarguments. Some instances included a participant's domination over the group work throughout the design process. In this process, a dominant character dismissed counterarguments and tried to produce a product by his/her arguments and ideas alone. As a result, the group members did not experience reflective decision-making. Consequently, the results of the current study revealed that the patterns' flow and their interactional features are similar to the trajectories of participant interactions stated by Leitão (2000). Namely, teachers participating in collaborative STEM work experienced or demonstrated dismissal, local agreement, allowing for some exceptions or conditions, and/or withdrawal of initial view.

The Joint Design Process Based on Argumentation

When the teachers had a chance to go through a joint design process, two dominant patterns appeared in the pre-design stage (i.e., recognizing/identifying the factors and orientation to research). Recognizing/identifying factors from these patterns occurred in 43.8% of all detected patterns. This reveals that almost half of the patterns subject to analysis belonged to the pre-design, during which the teachers addressed the factors, variables, and essential points required to perform the activity. The "position to know-personal" and "consequences" schemes occur 28.4% and 4.0% of the time, respectively, when analyzed in terms of Walton's schemes (i.e., in the light of the second research question). This situation seems to show that when recognizing/identifying the factors' patterns, the teachers provide reasons, in some cases in the pre-design stage. The teachers tend to investigate when they encounter factors or events that cannot be justified or when they suspect there is a possible solution. In this case, the "orientation to research" pattern appears. ''Orientation to research'' pattern constitutes 8.2% of all the patterns. 8.1% of the all determined schemes is before Walton's position to know-research scheme in the talk in interaction. Information obtained through research was used in presumptive reasoning in the design process.

It is noteworthy that the teachers were directly knowledgeable in the first pattern (i.e., recognizing/identifying the factors); that is, the information source was themselves. In the second case (i.e., orientation to research), the source of information was the findings of the research conducted by the teachers. We argued that the discourse patterns observed were dependent on the nature of the integrated STEM activity, which requires knowledge from different STEM disciplines. Moreover, integrated STEM activities that necessitate content knowledge from different disciplines may result in changes in the participants' epistemic status from activity to activity and moment to moment throughout professional development. Epistemic status "involves the parties' joint recognition of their comparative access, knowledgeability, and rights relative to some domain of knowledge as a matter of more or less established fact" (Heritage, 2013, p. 558). In the current study, any inadequacy in the participant teachers' epistemic status or less knowledgeable positions resulted in changes in the argumentation schemes used. Hence, based on the results, we argued that when the participants know the factors necessary for the design, their arguments come from the position to know-personal scheme; when they have less information, they orient to research and produce arguments from the position to know-research scheme. These situations can be interpreted as the teachers tending to reveal a valid and reliable idea that sheds light on the activity process or design. Because there is an expectation for teachers to be knowledgeable or to become knowledgeable through research on topics related to the issue at hand, they are expected to put forward an idea supporting their claim (Mebane, 2020).

Although the line between the pre-design and the design stages is blurry, the patterns observed in those stages are clear and distinct in our study. During the design stage, the existence or lack of consensus shaped the discourse. If there is a consensus (6.9% of all patterns), the teachers interacted among themselves to consider different ideas suggested for the design. This situation continues until the post-design process begins or a disagreement arises. Regarding disagreement in the group, Kim et al. (2014) reported that different groups handled it differently. One group listed the pros and cons of different ideas and tried to compromise; this did not force any member to change ideas. The other group, on the other hand, could not integrate dissimilar ideas, which resulted in a lack of consensus on the solution. In this study, disagreements were mainly handled through justification of ideas and by turning to research. Although consensus might be reached after persuading other members or providing more evidence from research, agreement may not be reached when the arguers' claims and evidence are seen as bias (Macagno & Konstantinidou, 2013).

The level of controversy about the issue and the availability of the evidence determine the likelihood of reaching a consensus (Kim et al., 2014). If a topic is controversial and supporting evidence is not available, arguers tend not to hear the others' evidence. Instead, they stick to their ideas, resulting in unsuccessful persuasion (Kim et al., 2014). In the current study, when no consensus emerged, teachers had initially stated their ideas (12.3% of total scenarios). When the teachers express their thoughts, they contribute to the interaction with the knowledge they already have and with causal statements in agreement or disagreement about the design ideas. The interaction was proceeded by teachers, by justifying their thoughts and trying to carry out the design process.

In some cases, although the teachers had not yet reached any consensus, they bypassed the agreement and decision-making interactions and tended to move directly into implementation. Regarding this issue, Whitworth and Wheeler (2017) and Aydin-Günbatar (2018) reported that participants tend to skip the research step of the engineering design process and switch to the design step without any scientific or mathematical background knowledge to form a base for a solid design. We observed that tendency as well. It seems that designing something might motivate the participants more than arguing over factors, materials, or conditions.

According to the data analysis, teachers performed justifications only 8.2% of the time. When the teachers justified their ideas, they employed the position to know (10.8%) and consequences (5.4%) schemes. In cases where the teachers were not able to put a reasonable argument forward, they orient to research (2.7%). These situations generally seem to occur when the justification for persuading the other participants is insufficient, or justification cannot be provided. Then, the teachers carry out the necessary research and reach a consensus—or they decide on a design based on the data and evidence they obtained. This occurred 6.9% of the time in the data set. The use of justifications among our participants reveals two findings. First, individuals need to evaluate scientific claims or arguments critically during the decision-making process (Kolstø et al., 2006). Second, an absence of a solid argument for a successful design may direct people toward researching.

The Existence of a Dominant Character

Regarding the nature of a group of teachers' collaborative and reflective decision-making, results showed that the existence of a dominant character in the group is one of the essential factors shaping the activity and process. If there is one in the group, this dominant character limits collaboration and presents his/her ideas as if they were the group's ideas. Yet another important finding of the current study was that the dominant character is not the same participant for all activities. Rather, different dominant characters appeared for different design activities. In other words, it was not a personality trait. While one participant may appear as a dominant character in an activity related to his or her core competency, the same person conducts interactions in the usual, collaborative process in another design activity. Furthermore, when the dominant character is not included in the discourse or when s/he moves away from the group, the other members carry out the usual conversation and refer to the structure of the activity sheet. For this reason, the existence of the dominant character is shown in the discrete structure in the model specified in Figure 4.

The emergence of a dominant character is treated as a manifestation of the teacher seeing him/herself as both social and epistemic authority, just like in usual classroom interactions. In the classroom, a teacher generally manages the flow of conversation, evaluates ideas, and so on (Berland & Hammer, 2012). Considering the interactions that occur within this pattern, the dominant character generally utilizes the position to know-personal (8.1%) and consequences (1.4%) presumptive reasoning schemes. Ignorance in listening to others' points and evaluating the quality of the evidence are signs of the participant teachers' weak collaboration and argumentation skills. This requires the attention of teacher educators.

Practical and Research Implications

Based on the results, it can be said that professional development programs that allow teachers with different background to work together are useful for teachers to fully grasp the nature of the integrated STEM approach. By working with colleagues from other disciplines, they can argue over different ideas and decisions to provide a better solution, learn how to cooperate with colleagues, and see why cooperation is necessary. Therefore, in addition to providing professional development to only one group of teachers (e.g., science teachers), teacher educators should also design integrated STEM professional development activities inviting teachers with different backgrounds (i.e., from science, math, technology, art). Those teachers with diverse knowledge from different fields can easily act as a source of information and come up with ideas. Additionally, those teachers can experience what the integration of disciplines means for a better design solution to a real-world problem.

It is also important for teachers to collaborate with peers from the same institution, learn through professional development programs with colleagues, and obtain the necessary support for developing integrated STEM teaching knowledge and skills, as this makes them feel that they have the support that they need (Stohlmann, Moore, & Roehrig, 2012). This is one reason why it is important for researchers to work with teachers from the same center. When they have experienced integrated STEM activities together, they will more likely collaborate in future integrated STEM activities. In light of the points revealed, teachers working in the same center or schools should try to implement STEM activities together. For example, the "DNA Genetic Code and Message Sending System Design" activity is a good example for that implementation. In the activity, a biology teacher can start by providing the challenge and then a math teacher can take a leading role when learners calculate the combination of different messages sent (i.e., the phenotype of the person described). Such collaboratively implemented activities are more in line with the nature of integrated STEM education. One of the starting points of the integrated STEM approach is improving learners' collaborative skills.

As in the case of teacher presented in this study, students may also dominate the group work and make others passively follow and agree with their decisions. To help teachers handle with the dominant students, integrated STEM professional development programs should also support teachers how to handle those types of students in class. To address the problem, collaborative group work strategies can be taught to teachers. To be more specific, for example, Bianchini (1997) suggests the use of strategies for collective group work, namely, multiple abilities treatment, i.e., "attempts to widen students' conception of what it means to be smart," (p. 1041) and assigning competence, i.e., "more individualized means of equalizing participation among students" (p. 1041).

Future research should examine how different collaborative strategies influence group discourse as this may provide useful insights into how to develop collaborative skills through integrated STEM activities. In addition, we think that shedding light on teachers' use of argumentation practices is critical to teacher educators' ability to provide first-hand experience to teachers who are supposed to practice integrated STEM lessons. With this type of professional development program experience, teachers can see how group argumentative discourse is important for solving real-world problems, how small group members interact with each other, and how difficult it is to incorporate different disciplines' knowledge into better design solutions.

In light of the experience that the teachers gained in this integrated STEM professional development program, we believe that the participants are now equipped with a clearer picture of what integrated STEM education is and how argumentation and reflective decision-making processes are integrated into STEM education. Furthermore, the results add to the literature an idea about the nature of teachers' collaborative and reflective decision-making process throughout engineering design and their use of argumentation schemes. Our results have the potential to inform the literature about how group members argue and make reflective decisions about design problems. Future research in this area could clarify when people use different argumentation schemes (e.g., orientation to research)and the types of replies seen in an argument (e.g., dismissal or allowing for some exceptions or conditions).

Studying with only 11 teachers, providing only a 20-hour professional development program, and having only audio recordings so that only verbal data could be collected (i.e., no visual data are available for facial expressions) limited this study in terms of breadth and generalizability. Additionally, having two large groups—five or six teachers in each—may have discouraged some teachers from participating in the discourse. Moreover, due to the lack of a redesign stage, the researchers could not provide discourse analysis or offer any pattern for that stage of the activities.

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References

Akaygun, S., & Aslan-Tutak, F. (2016). STEM images revealing stem conceptions of pre-service chemistry and mathematics teachers. *International Journal of Education in Mathematics, Science and Technology*, *4*(1), 56-71. doi:10.18404/ijemst.44833

Antink-Meyer, A., & Brown, R. A. (2019). Nature of engineering knowledge. *Science & Education, 28*(3), 539-559. doi:10.1007/s11191-019-00038-0

Asghar, A., Ellington, R., Rice, E., Johnson, F., & Prime, G. M. (2012). Supporting STEM education in secondary science contexts. *Interdisciplinary Journal of Problem-Based Learning*, *6*(2), 85-125. doi:10.7771/1541-5015.1349

Aslan-Tutak, F., Akaygun, S., & Tezsezen, S. (2017). Collaboratively learning to teach STEM: Change in participating pre-service teachers' awareness of STEM. *Hacettepe University Journal of Education*, *32*(4), 794-816. doi:10.16986/HUJE.2017027115

Aydin-Günbatar, S. (2018). Designing a process to prevent apple's browning: A STEM activity. *Journal of Inquiry Based Activities, 8*(2), 99-110.

Basista, B., & Mathews, S. (2002). Integrated science and mathematics professional development programs. *School Science and Mathematics*, *102*(7), 359-370. doi:10.1111/j.1949-8594.2002.tb18219.x

Berland, L. K., & Hammer, D. (2012). Framing for scientific argumentation. *Journal of Research in Science Teaching*, *49*(1), 68-94. doi:10.1002/tea.20446

Bianchini, J. A. (1997). Where knowledge construction, equity, and context intersect: Student learning of science in small groups. *Journal of Research in Science Teaching*, *34*(10), 1039-1065.

Bryan, L. A., Moore, T. J., Johnson, C. C., & Roehrig, G. H. (2015). Integrated STEM education. In C. C. Johnson, E. E. Peters-Burton, & T. J. Moore (Eds.), *STEM road map: A framework for integrated STEM education* (pp. 23-37). New York: Routledge.

Capobianco, B. M., DeLisi, J., & Radloff, J. (2018). Characterizing elementary teachers' enactment of high-leverage practices through engineering design-based science instruction. *Science Education*, *102*(2), 342-376. doi:10.1002/sce.21325

Chen, Y. C., & Qiao, X. (2020). Using students' epistemic uncertainty as a pedagogical resource to develop knowledge in argumentation. *International Journal of Science Education*, *42*(13), 2145-2180. doi:10.1080/09500693.2020.1813349

Couso, D., & Simarro, C. (2020). STEM education through the epistemological lens: Unveiling the challenge of STEM transdisciplinarity. In C. C. Johnson, M. J. Mohr-Schroeder, T. J. Moore, & L. D. English (Eds.), *Handbook of research on STEM education* (pp. 17-28). New York: Routledge.

Creswell, J. W (2007). *Qualitative inquiry and research design: Choosing among five approaches* (2nd ed.). Thousand Oaks, CA: Sage.

Crismond, D. P., & Adams, R. S. (2012). The informed design teaching & learning matrix. *Journal of Engineering Education*, 101(4), 738-797. doi:10.1002/j.2168-9830.2012.tb01127.x

Cunningham, C. M., & Kelly, G. J. (2017). Epistemic practices of engineering for education. *Science Education*, *101*(3), 486-505. doi:10.1002/sce.21271

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, *38*(3), 181-199. doi:10.3102/0013189x08331140

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, *84*(3), 287-312.

Duschl, R. (2007). Quality argumentation and epistemic criteria. In S. Erduran & M. P. Jiménez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (pp. 159-175). New York: Springer.

Dym, C., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education, 94*(1), 103-120. doi:10.1002/j.2168-9830.2005.tb00832.x

Erduran, S., & Jiménez-Aleixandre, M. P. (2008). *Argumentation in science education. Perspectives from classroom-Based Research*. New York: Springer.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's Argument Pattern for studying science discourse. *Science Education*, *88*(6), 915-933. doi:10.1002/sce.20012

European Commission. (2014). EU Skills Panorama -STEM skills analytical highlight. Retrieved from https://skillspanorama.cedefop.europa.eu/sites/default/files/EUSP_AH_STEM_0.pdf

Herder, A., Berenst, J., Glopper, K., & Koole, T. (2020). Sharing knowledge with peers: Epistemic displays in collaborative writing of primary school children. *Learning, Culture and Social Interaction*, *24*(2020), 100378. doi:10.1016/j.lcsi.2020.100378

Heritage, J. (2013). Action formation and its epistemic (and other) backgrounds. *Discourse Studies*, *15*(5), 551-578. doi:10.1177/1461445613501449

Jefferson, G. (2004). Glossary of transcript symbols with an introduction. In G. H. Lerner (Ed.), *Conversation analysis: Studies from the first generation* (pp. 13-34). Amsterdam: John Benjamins Publishing Company.

Jiménez-Aleixandre, M. P., & Erduran, S. (2007). Argumentation in science education: An overview. In S. Erduran & M. P. Jiménez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (pp. 3-28). New York: Springer.

Jiménez-Aleixandre, M.-P., & Pereiro-Munoz, C. (2002). Knowledge producers or knowledge consumers? Argumentation and decision making about environmental management. *International Journal of Science Education*, *24*(11), 1171-1190. doi:10.1080/09500690210134857

Johnstone, B. (2018). *Discourse analysis* (3rd ed.). New York: John Wiley & Sons.

Jordan, M. E., & McDaniel Jr, R. R. (2014). Managing uncertainty during collaborative problem solving in elementary school teams: The role of peer influence in robotics engineering activity. *Journal of the Learning Sciences, 23*(4), 490-536.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, *3*(1), 1-11. doi:10.1186/s40594-016-0046-z

Kim, M., Anthony, R., & Blades, D. (2014). Decision making through dialogue: A case study of analyzing preservice teachers' argumentation on socioscientific issues. *Research in Science Education*, *44*(6), 903-926. doi:10.1007/s11165-014-9407-0

Kolstø, S. D., Bungum, B., Arnesen, E., Isnes, A., Kristensen, T., Mathiassen, K., … Ulvik, M. (2006). Science students' critical examination of scientific information related to socioscientific issues. *Science Education*, *90*(4), 632-655. doi:10.1002/sce.20133

Kortland, K. (1996). An STS case study about students' decision making on the waste issue. *Science Education*, *80*(6), 673-689.

Lantolf, J. P. (2000). Introducing sociocultural theory. In J. P. Lantolf (Ed), *Sociocultural theory and second language learning* (pp. 1-26). Oxford: Oxford University Press.

Leitão, S. (2000). The potential of argument in knowledge building. *Human Development*, *43*(6), 332-360. doi:10.1159/000022695

Macagno, F., & Konstantinidou, A. (2013). What students' arguments can tell us: Using argumentation schemes in science education. *Argumentation, 27*(3), 225-243. doi:10.1007/s10503-012-9284-5

Martín-Páez, T., Aguilera, D., Perales-Palacios, F. J., & Vílchez-González, J. M. (2019). What are we talking about when we talk about STEM education? A review of literature. *Science Education, 103*(4), 799-822. doi.10.1002/sce.21522

Mathis, C. A., Siverling, E. A., Glancy, A. W., & Moore, T. J. (2017). Teachers' incorporation of argumentation to support engineering learning in STEM integration curricula. *Journal of Pre-College Engineering Education Research*, *7*(1), 76-89. doi:10.7771/2157-9288.1163

Mebane, W. (2020). *Confidence in arguments in dialogues for practical reasoning*. OSSA 12: Evidence, Persuasion & Diversity, University of Windsor, Kanada.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis an expanded sourcebook* (2nd ed.). Thousand Oaks, CA: Sage.

Miller, G., & Fox, K. J. (2004). Building bridges: The possibility of analytic dialogue between ethnography, conversation analysis and Foucault. In D. Silverman (Ed.), *Qualitative research: Theory, method and practice* (pp. 35-55). Thousand Oaks, CA: Sage.

Ministry of National Education. (2018a). *Computer science course curriculum (course 1-2).* Ankara: Ministry of National Education.

Ministry of National Education. (2018b). *Information technologies and software curriculum (secondary school 5th and 6th grades).* Ankara: Ministry of National Education.

Ministry of National Education. (2018c). *Science course curriculum (primary and secondary school 3, 4, 5, 6, 7, and 8th grades).* Ankara: Ministry of National Education.

Ministry of National Education. (2018d). *Virtual art course curriculum (9th, 10th, 11th, and 12th grades).* Ankara: Ministry of National Education.

Ministry of National Education. (2018e). *Mathematics curriculum (primary and secondary school grades 1, 2, 3, 4, 5, 6, 7, and 8).* Ankara: Ministry of National Education.

Ministry of National Education. (2018f). *Secondary education physics course curriculum (9th, 10th, 11th, and 12th grades).* Ankara: Ministry of National Education.

Ministry of National Education. (2018g). *Secondary education chemistry course curriculum (9th, 10th, 11th, and 12th grades).* Ankara: Ministry of National Education.

Ministry of National Education. (2018h). *Secondary education mathematics course curriculum (9th, 10th, 11th, and 12th grades).* Ankara: Ministry of National Education.

Ministry of National Education. (2018i). *Technology and design course curriculum (secondary school 7th and 8th grades).* Ankara: Ministry of National Education.

Moore, T. J., Johnston, A. C., & Glancy, A. W. (2020). STEM integration: A synthesis of conceptual frameworks and definitions. In C. C. Johnson, M. J. Mohr-Schroeder, T. J. Moore, & L. D. English (Eds.), *Handbook of research on STEM education* (pp. 49-76). New York: Routledge.

Moore, T. J., Stohlmann, M. S., Wang, H. H., Tank, K. M., Glancy, A. W., & Roehrig, G. H. (2014). Implementation and integration of engineering in K-12 STEM education. In S. Purzer, J. Strobel, & M. Cardella (Eds.), *Engineering in precollege settings: Synthesizing research, policy and practices* (pp. 34-51). Indiana: Purdue University Press.

Moore, T. J., Tank, K. M., Glancy, A. W., & Kersten, J. A. (2015). NGSS and the landscape of engineering in K-12 state science standards. *Journal of Research in Science Teaching*, *52*(3), 296-318. doi:10.1002/tea.21199

National Association of Colleges and Employers. (2016). Job outlook 2016: Attributes employers want to see on new college graduates' resumes. Retrieved from https://www.goodcall.com/news/nace-job-outlook-2016-what-employers-want-tosee-on-your-resume-03807

National Research Council. (2012). *A framework for K12 science education: Practices, cross cutting concepts, and core ideas*. Washington: National Academies Press.

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Washington: The National Academies Press.

Nussbaum, E. M. (2011). Argumentation, dialogue theory, and probability modeling: Alternative frameworks for argumentation research in education. *Educational Psychologist*, *46*(2), 84-106. doi:10.1080/00461520.2011.558816

Owen, D. (2015). Collaborative decision making. *Decision Analysis, 12*(1), 29-45. doi:10.1287/deca.2014.0307

Patton, M. Q. (2002). *Qualitative evaluation and research methods* (3rd ed.). Thousand Oaks, CA: Sage.

Peräkylä, A. (2004). Reliability and validity in research based on naturally occurring social interaction. In D. Silverman (Ed.), *Qualitative research: Theory, method and practice* (pp. 283-304). Thousand Oaks, CA: Sage.

Pinnell, M., Rowley, J., Preiss, S., Blust, R. P., Beach, R., & Franco, S. (2013). Bridging the gap between engineering design and PK-12 curriculum development through the use the STEM education quality framework. *Journal of STEM Education*, *14*(4), 28-34. Retrieved from https://ecommons.udayton.edu/mee_fac_pub/193

Pomerantz, A., & Fehr, B. (2011). Conversation analysis: An approach to the analysis of social interaction. In T. A. V. Dijk (Ed.), *Discourse studies: A multidisciplinary introduction* (pp. 165-190). Thousand Oaks, CA: Sage.

Purzer, S. (2011). The relationship between team discourse, self-efficacy, and individual achievement: A sequential mixed-methods study. *Journal of Engineering Education*, *100*(4), 655-679. doi:10.1002/j.2168-9830.2011.tb00031.x

Rieke, R. D., Sillars, M. O., & Peterson, T. R. (2013). *Argumentation and critical decision making*. London: Pearson.

Rinke, C. R., Gladstone-Brown, W., Kinlaw, C. R., & Cappiello, J. (2016). Characterizing STEM teacher education: Affordances and constraints of explicit STEM preparation for elementary teachers. *School Science and Mathematics*, *116*(6), 300-309. doi:10.1111/ssm.12185

Roehrig, G. H., Moore, T. J., Wang, H.-H., & Park, M. S. (2012). Is adding the E enough? Investigating the impact of K-12 engineering standards on the implementation of STEM integration. *School Science and Mathematics*, *112*(1), 31-44. doi:10.1111/j.1949-8594.2011.00112.x

Rusk, F., & Rønning, W. (2020). Group work as an arena for learning in STEM education: Negotiations of epistemic relationships. *Education Inquiry*, *11*(1), 36-53. doi:10.1080/20004508.2019.1638194

Ryu, M., Mentzer, N., & Knobloch, N. (2019). Preservice teachers' experiences of STEM integration: Challenges and implications for integrated STEM teacher preparation. *International Journal of Technology and Design Education*, *29*(3), 493-512. doi:10.1007/s10798-018-9440-9

Sadler, T. D., & Zeidler, D. L. (2005). Patterns of informal reasoning in the context of socioscientific decision making. *Journal of Research in Science Teaching*, *42*(1), 112-138. doi:10.1002/tea.20042

Silverman, D. (2004). Introducing qualitative research. In D. Silverman (Ed.), *Qualitative research: Theory, method and practice* (pp. 1-8). Thousand Oaks, CA: Sage.

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education*, *28*(2-3), 235-260. doi:10.1080/09500690500336957

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research*, *2*(1), 28-34. doi:10.5703/1288284314653

Şardağ, M., & Kaya, G. (2021, October). *Genetic code analysis and encrypted communication: A multidisciplinary approach in STEM education.* 3rd International Conference on Science, Mathematics, Entrepreneurship and Technology Education, Bursa.

van Eemeren, F. H., & Grootendorst, R. (2004). *A systematic theory of argumentation: The pragma-dialectical approach*. Cambridge: Cambridge University Press.

Walton, D. (2006). *Fundamentals of critical argumentation*. Cambridge: Cambridge University Press.

Walton, D., Reed, C., & Macagno, F. (2008). *Argumentation schemes*. Cambridge: Cambridge University Press.

Wang, H.-H., Charoenmuang, M., Knobloch, N. A., & Tormoehlen, R. L. (2020). Defining interdisciplinary collaboration based on high school teachers' beliefs and practices of STEM integration using a complex designed system. *International Journal of STEM Education*, *7*(1), 1-17. doi:10.1186/s40594-019-0201-4

Wendell, K. B., Wright, C. G., & Paugh, P. (2017). Reflective decision-making in elementary students' engineering design. *Journal of Engineering Education*, *106*(3), 356-397. doi:10.1002/jee.20173

Wheeler, L. B., Whitworth, B. A., & Gonczi, A. L. (2014). Engineering design challenge: Building a voltaic cell in the high school chemistry classroom. *The Science Teacher*, *81*(9), 30-36.

Whitworth, B. A., & Wheeler, L. B. (2017). Is it engineering or not? To bring engineering tasks into the classroom, know what qualifies—and what doesn't. *The Science Teacher*, *84*(5), 25-29.

Wieselmann, J. R., Dare, E. A., Ring-Whalen, E. A., & Roehrig, G. H. (2020). "I just do what the boys tell me": Exploring small group student interactions in an integrated STEM unit. *Journal of Research in Science Teaching*, *57*(1), 112-144. doi:10.1002/tea.21587

Wright, C., Wendell, K. B., & Paugh, P. P. (2018). "Just put it together to make no commotion:" Re-imagining urban elementary students' participation in engineering design practices. *International Journal of Education in Mathematics, Science and Technology*, *6*(3), 285-301. doi:10.18404/ijemst.428192

Appendix. *Activities and Their Learning Outcomes*

Activity	**Learning outcomes**
Vacuum Cleaner Design	Science *F.8.7.3.2. Designs a model based on the conversion of electrical energy into heat, light, or motion energy (Ministry of National Education [MoNE], 2018c, p. 54).* Engineering and Technology *TT.7.D.1.3. Prepares a design plan.* *TT.7.D.1.4. Creates a model or prototype of the design* *TT.7.D.1.5. Evaluates the design according to the determined criteria (MoNE, 2018i, p. 18).* *TT.8.C.3.4. Designs a product using the engineering design process (MoNE, 2018i, p. 22).* Mathematics *M. 8.4.1.2 Displays data as a column, circle, or line graph and makes appropriate conversions between these representations (MoNE, 2018e, p. 76).* Virtual Arts *12.3.6.3. Makes unique one-dimensional designs for industrial products (MoNE, 2018d, p. 25).*
Water purification design	Chemistry *9.3.2.1. b. Examples of strong interactions include ionic, covalent, and metallic bond; Examples of weak interactions include hydrogen bonding and van der Waals forces (MoNE, 2018g, p. 17).* *9.5.1.3. Explains the hardness and softness properties of water (MoNE, 2018g, p. 20)* *11.3.3.1. Establishes a relationship between the colligative properties and concentrations of solutions* *c. Brief information about water treatment with reverse osmosis method is given (MoNE, 2018g, p. 30)* Engineering and Technology *TT.7.D.1.3. Prepares a design plan.* *TT.7.D.1.4. Creates a model or prototype of the design* *TT.7.D.1.5. Evaluates the design according to the determined criteria (MoNE, 2018i, p. 18).* *TT.8.C.3.4. Designs a product using the engineering design process (MoNE, 2018i, p. 22).* Virtual Arts *12.3.6.3. Makes unique one-dimensional designs for industrial products (MoNE, 2018d, p. 25).*

Thermos design	Science-Physics *F.6.4.3.1. Classifies materials in terms of heat conduction.* *F.6.4.3.2. Determines the selection criteria of thermal insulation materials used in buildings (MoNE, 2018c, p. 33).* *9.5.4.1. Explains the ways of energy transmission with examples.* *9.5.4.3. Designs insulation for living spaces to save energy (MoNE, 2018f, p. 20).* Engineering and Technology *TT.7.D.1.3. Prepares a design plan.* *TT.7.D.1.4. Creates a model or prototype of the design* *TT.7.D.1.5. Evaluates the design according to the determined criteria (MoNE, 2018i, p. 18).* *TT.8.C.3.4. Designs a product using the engineering design process (MoNE, 2018i, p. 22).* Mathematics *10.6.1.1. Creates the length, area, and volume connections of right prisms and right pyramids (MoNE, 2018h, p. 31).* *11.6.1.1. Performs operations by creating area and volume connections of sphere, right circular cylinder, and right circular cone (MoNE, 2018h, p. 36).* Virtual Arts *12.3.6.3. Makes unique one-dimensional designs for industrial products (MoNE, 2018d, p. 25).*
Polymer design	Chemistry *9.3.2.1. b. Examples of strong interactions include ionic, covalent, and metallic bond; Examples of weak interactions include hydrogen bonding and van der Waals forces (MoNE, 2018g, p. 17).* *10.1.4.1. Makes calculations by associating the concepts of mass, number of moles, number of molecules, number of atoms as well as volume under normal conditions for gases.* *a. Emphasis is placed on the limiting component calculations (MoNE, 2018g, p. 22).* *10.4.1.2. Gives examples of usage areas of common polymers.* *a. -mer, monomer and polymer concepts are emphasized explaining the phenomenon of polymerization* *b. The main usage areas of rubber, polyethylene (PE), polyethylene terephthalate (PET), kevlar, polyvinyl chloride (PVC), polytetrafluor ethene (TEFLON) and polystyrene (PS) are mentioned without going into the structural details (MoNE, 2018g, p. 26).* Engineering and Technology *TT.7.D.1.3. Prepares a design plan.* *TT.7.D.1.4. Creates a model or prototype of the design*

	TT.7.D.1.5. Evaluates the design according to the determined criteria (MoNE, 2018i, p. 18). *TT.8.C.3.4. Designs a product using the engineering design process (MoNE, 2018i, p. 22).* Mathematics *9.3.5. Applications related to equations and inequalities* *9.3.5.1. Solves problems using ratio and proportion concepts (MoNE, 2018h, p. 21).*
DNA Genetic Code and Message Sending System Design	Science *F.7.2.1.1.c. The relationship between DNA, gene and chromosome concepts is mentioned (MoNE, 2018c, p. 40).* *F.7.7.1.1. Draws a circuit diagram consisting of series and parallel light bulbs (MoNE, 2018c, p. 46).* Engineering and Technology *BT.6.5.1.5. Develops an algorithm for solving the problem.* *BT.6.5.1.6. Tests the solution of an algorithm.* *BT.6.5.1.7. Examines different algorithms and chooses the fastest and most accurate solution (MoNE, 2018b, p. 18).* *TT.7.D.1.3. Prepares a design plan.* *TT.7.D.1.4. Creates a model or prototype of the design* *TT.7.D.1.5. Evaluates the design according to the determined criteria (MoNE, 2018i, p. 18).* *TT.8.C.3.4. Designs a product using the engineering design process (MoNE, 2018i, p. 22).* *1.2.3.3. Designs different algorithms to solve the given problem.* *Pseudocode is used to create algorithms (MoNE, 2018a, p. 18).* Mathematics *10.1.1.2. Calculates how many different ways r arrays (permutations) can be created with n kinds of objects (MoNE, 2018h, p. 26).*