ORIGINAL ARTICLE

Grade-7 Students' Negotiation during the Engineering Design Processes Regarding the Status of Their Argumentation Training

Sayıner Tug,[1] Bahadır Namdar[2]

1 *Ministry of National Education, Izmir, Turkey*
2 *Ege University, Izmir, Turkey*

***Abstract**: This study aimed to investigate grade-7 students' negotiation during the engineering design process regarding the students' status of argumentation training. The participants were 33 students studying at a public urban middle school in Turkey. They worked in small groups on four engineering design tasks about electricity and light. Data were collected through small group audio recordings, student worksheets, and the observation. The data were analyzed by using content analysis. The results indicated that negotiation patterns were similar across all groups. However, differences were found between the group that received argumentation training and the one that did not receive in terms of proposing ideas for material design, using justifications when in agreement with others, counter proposing and acquiring information for better planning and altering the design, and critiquing for design advantages and disadvantages.*

Science Insights Education Frontiers 2024; 22(1):3513-3528
DOI: 10.15354/sief.24.or578

How to Cite: Tug, S., & Namdar, B. (2024). Grade-7 students' negotiation during the engineering design processes regarding the status of their argumentation training. Science Insights Education Frontiers, 22(1):3513-3528.

Keywords: *Argumentation, Engineering design process, Negotiation, Science Education*

About the Author: *Sayıner Tug, Ministry of National Education, Izmir, Turkey. E-mail: sayiner2561@gmail.com.*

Bahadır Namdar, Ege University, Department of Mathematics and Science Education, Izmir, Turkey. E-mail: bahadir.namdar@ege.edu.tr.

Correspondence to: *Sayıner Tug at Ministry of National Education of Turkey.*

Conflict of Interests: *None*

Introduction

RECENT curriculum reforms highlight the need for engaging students in science and engineering practices (Ministry of National Education, 2018; National Research Council [NRC], 2012). Both scientists and engineers utilize argumentation in their daily work. While scientists use argumentation to evaluate and explain natural phenomena, engineers use it to find the best design solution (NRC, 2012). Argumentation provides an opportunity for reaching a consensus over design solutions by enabling negotiation in the engineering design process (EDP). Negotiation is broadly defined as the collaborative decision-making process of more than one party (Pruitt, 1981). Since they facilitate information exchange and exploration of different perspectives by using multidisciplinary perspectives, negotiation processes can lead to the creation of new designs (Jin & Geslin, 2009).

Engineering design tasks usually occur in teams (Sheppard et al., 2006). These tasks require team members to engage in discourse and construct, share, negotiate, and critique ideas for the best design solution (Brereton et al., 1996; Crismond & Adams, 2012; Mentzer et al., 2015). However, group products might negatively reflect students' argumentation qualities and discourse problems (Chi & Menekse, 2015; Dillenbourg & Hong, 2008). Furthermore, verbal interactions such as questions, conflict, and reasoning in group work affect individual and group success (Menekse et al., 2019). Collaboration during EDP does not always guarantee a good design, so different supports should be in place to structure students' design process (Hertel et al., 2017). Argumentation-based negotiation in engineering has been proposed to address issues related to cooperation and co-construction (Jin & Geslin, 2009). Therefore, engineering design is affected by the speech acts enacted during negotiation processes. Speech acts give designers a space to exchange ideas and information, get exposed to distinct perspectives, and identify opportunities for improving the design. Therefore, argumentation-based negotiation as a verbal process is essential to successful decision-making (Jin & Geslin, 2009).

Studies show that students' prior knowledge and argumentation skills influence their decision-making. In engineering design, recent research indicates that argumentation scaffolds can increase, for example, preservice teachers' use of scientific concepts (Urueña et al., 2017) and their evidence-based reasoning, and thus, decision making on engineering design tasks (Rebello et al., 2019). However, fewer empirical studies exist on the negotiation process in engineering design discourse (Guzey & Aranda, 2017). Our research addresses this gap in the literature by investigating the effect of students' argumentation training on students' argumentation-based negotiation during EDP. Analyzing the influence of argumentation training on negotiation processes within EDP and evaluating students' strengths and weaknesses in these processes will provide valuable insights for optimizing the structure of EDP. This, in turn, will guide the implementation of necessary measures to enhance students' engineering design skills. (Jin & Geslin, 2009). In this context, we examined the argumentation-based negotiation of seventh graders. The research question guiding the study was: "*How do grade-7 students use argumentation-based negotiation in engineering design processes regarding their status of argumentation training?*"

Engineering Design Process (EDP)

During a design process, students are expected to decide on design components, select, plan, draw a prototype, and create arguments based on evidence in steps such as product promotion. Engineering design involves processes in which decisions are jointly made. Therefore, EDP requires designers to engage in argumentation to negotiate possible solutions to the given problems (NRC, 2012). "However, understanding how students engage in argument from evidence within K-12 engineering settings has not been studied extensively" (Siverling et al., 2019, p459).

Students engage in discourse and argumentation in design processes. They negotiate and justify the design for a productive and effective solution. Azevedo et al. (2015) found that students' discourse in engineering design involved description and explanation practices, while argumentation episodes occurred less frequently. Guzey and Aranda (2017) found that design discourse unfolds uniquely in small groups, influencing students' decision-making in engineering design. In small group discussions, students tend to focus more on the financial aspects of their designs rather than the scientific aspects. Additionally, the instructors play a role in shaping the argumentation processes during these discussions. In another study, Wendell et al. (2017) found that articulating multiple solutions, evaluating pros and cons, intentionally selecting a solution, retelling the performance of a solution, analyzing a solution according to evidence, and purposefully choosing improvements as reflective decision-making elements of elementary students in EDP. More specifically, argument-driven engineering is proposed for developing students' engineering experience in an argumentation context. A model that allows these design tasks to be completed in a few weeks is suggested. The EDP comprises eight stages: introducing the problem, concept generation, concept selection, design argumentation, design testing, evaluation argumentation, report development, and reflection and discussion (Chu et al., 2019).

Argumentation-Based Negotiation in the Context of Engineering Design Process

Depending on the design task's complexity, designers can engage in different collaborations (Engeström, 2014; Leont'ev, 1978). Subtasks are examined to perform the interactions between designers in mutual collaboration. In this context, a designer's design decisions may influence the group's decisions. Argumentation-based negotiation has been proposed for collaborative design in engineering to understand joint decision-making processes (Jin & Geslin, 2009). The original framework interlinks both the designers and engineering systems. Jin and Geslin argue, "For multidisciplinary collaborative design problems, negotiation is a way for multiple designers to exchange information, acquire knowledge of other designers' perspectives and intents, and identify new opportunities. Therefore, design negotiation has the potential to create new opportunities and new designs (Jin & Geslin, 2009, p127)." They suggest that negotiation helps designers resolve conflicts cooperatively, co-construct an understanding of the task, and discuss alternative design solutions. Based on the argumentation-based approach, argumentation-based engineering negotiation focuses on moving beyond simply accepting and rejecting the proposal; instead deals with how individuals argue about their positions, understandings, and goals about the design task. Their model suggested speech acts, negotiation stages, and strategic actions.

Drawing on the Toulmin (2003) argument model, Jin and Geslin (2009) mentioned nine negotiation states in their developed model, all leading to claims, data and warrants. Besides, the model includes speech acts and strategic actions. In strategic actions, the action of 'quit' differs from negotiation patterns. This act was not used in the current study as students' regular participation was ensured. We adopted these negotiation states to identify how students' design involved negotiation based on their argumentation training. In the current study, this three-stage framework in the argumentation processes has been merged into a single structure called negotiation patterns to make it easily applicable in the middle school context. **Table 1** shows the negotiation patterns and their explanation.

Method

In this exploratory case study (Stake, 1995), the participants were 33 students from two grade-7 classes studying in a public-school in Northeast Turkey. The case study approach allowed us to explore groups' EDP more in-depth. In addition, the convenience sampling method was used in student selection. A total of 17 students were in the group that did not receive argumentation training, and 16 were in the group that received argumentation training. The reason for selecting grade-7 students was that physics subjects such as the "Light-matter Interaction and Electric Circuits" unit in the curriculum are suitable for STEM activities enriched with argumentation (Bağ & Çalık, 2017).

Table 1. Negotiation Patterns and Their Explanation.

Proposing	The student proposes an idea for their design solution, design process, and design product
In Disagreement	The student disagrees with a proposed idea
In Agreement	The student agrees with a proposed idea
Acquiring Info	The student asks questions to comprehend any information regarding the engineering design.
Defending	The student defends an idea by providing—further justification.
Critiquing	The student proposes counterclaims and evaluates the provided arguments.
Counter proposing	The student proposes counterclaims when encountered with a claim.
Evaluating	The student weighs the appropriateness and validity of the claims, planning, design solutions, and processes.
Compromise	The student compromises their claims when they accept the proposed claims for the design.
Explaining	The students elaborate on their ideas and claims put forward during the design.

Procedures

The study was conducted in the spring semester of the 2018-2019 academic year. First, a three-hour argumentation training was given to one of the groups based on Toulmin's argumentation model. Subsequently, both groups participated in four STEM activities, each lasting 16 hours (40 minutes per session).

In the first session of the training, the claim, evidence, reasoning, and rebuttal model was used to introduce argumentation (McNeill & Krajcik, 2007). In addition, the features that would make a good argument were discussed with the students. In the second session, an activity including argumentation components was carried out for students to create verbal and written statements containing argument components. The third and last session completed the process by evaluating and discussing the students' arguments during the activity. Argumentation training lasted 3 hours (40 mins each). Although the students had prior experience in engineering design, none had previous experience regarding argumentation in either group. The students worked in groups of 4-5 to complete the tasks. A total of 4 engineering design tasks on the absorption of light, reflection of light, and electric current subjects were designed. Based on the 7th-grade objectives and subject matter, students worked on solar ovens, telescopes, camping lighting systems, and battery construction design tasks.

The researchers, in compliance with EDP, prepared worksheets. The students utilized these worksheets as the primary course material. Content in each worksheet channeled the students to the stages of EDP. All activities were led by the first author, a science teacher of the participants with bachelor's degrees in civil engineering and science education.

Data Collection

First, audio recordings of the groups for EDP processes were used as the primary data source in the study. Each group's negotiations were audio recorded in each class as verbal data. High-quality audio recorders were placed on each groups' tables during the activities. Second, the worksheets completed by the students during the activities were also collected. Third, the first author acted as a percipient observer (Creswell, 2013). The observation notes kept by the first author each day were used as a secondary data source for data triangulation.

Data Analysis

Each audio recording was transcribed verbatim by the first author. Conversations that were irrelevant to the task were excluded from the transcription. The content was analyzed descriptively based on argumentation-based negotiation patterns. The purpose of descriptive analysis is to present the findings to the reader in an organized and interpreted way (Yıldırım & Şimşek, 2006). First, we read the transcripts thoroughly. Then, we identified the turns. A turn constituted a timeframe when a student started presenting an idea and completed it. We coded each turn based on the negotiation patterns for each group. Then, the percentage of negotiation patterns among all turns were calculated. The contents of the observation notes were examined to better understand the students' negotiation patterns and used to support the data in the audio recordings when necessary. Similarly, the observation notes were analyzed descriptively according to the negotiation patterns.

Validity and Reliability

Expert opinions on the designed activities were sought from three science teachers, two of whom held master's degrees in science education. Additionally, two faculty members, possessing doctoral degrees in science education, provided their expertise in evaluating the activities. The content analysis of the audio recordings was done by both researchers independently for one group in each activity. The interrater reliability was calculated (Miles & Huberman, 1994) for four design activities. The reliability score for solar oven activity data was .92, for telescope activity data was .86, for camping light activity data was .94, and for battery construction activity data was .88; all indicating a high level of agreement. The researchers met twice to work on the disputes regarding the tapes, and all the conflicts were resolved through peer debriefing. The rest of the coding was completed by the first author.

Table 2. Negotiation Patterns in Groups that Received Argumentation Instruction.

	Group1		Group2		Group3		Group4	
	f	%	f	%	f	%	f	%
Proposing	109	30	70	32	80	31	97	29
Defense	15	4	2	1	0	0	0	0
Evaluating	50	14	4	2	22	8	22	7
In agreement	29	8	23	10	16	6	16	5
In disagreement	4	1	3	1	0	0	0	0
Critiquing	13	4	31	14	17	7	25	7
Counter proposing	11	3	8	4	9	3	10	3
Acquiring info	78	21	32	14	51	20	64	19
Opposing	7	2	2	1	0	0	1	0
Compromise	5	1	0	0	0	0	1	0
Explaining	48	13	47	21	65	25	99	30

Table 3. Negotiation Patterns in Groups that did not Receive Argumentation Instruction.

	Group5		Group6		Group7		Group8	
	f	%	f	%	f	%	f	%
Proposing	119	37	141	39	95	40	141	38
Defense	16	5	2	1	0	0	0	0
Evaluating	17	5	1	0	5	2	9	2
In agreement	31	10	16	4	5	2	15	4
In disagreement	11	3	0	0	0	0	0	0
Critiquing	17	5	21	6	15	6	26	7
Counter proposing	9	3	10	3	2	1	9	2
Acquiring info	33	10	98	27	38	16	84	23
Opposing	0	0	0	0	0	0	0	0
Compromise	0	0	1	0	0	0	3	1
Explaining	73	22	70	19	78	33	84	23

Findings

Negotiation Patterns in Groups

Negotiation patterns were identified in both groups to understand the discourse during EDP (**Table 2**). Eleven codes based on the literature were used to determine the negotiation patterns. The use of negotiation patterns was similar across groups. For example, the most used negotiation pattern was proposing for all groups, followed by acquiring information. This pattern was expected as students' design processes mostly use proposing ideas and acquiring information regarding design choices.

However, close examination of the qualitative data, including audio recordings and the researcher's observation notes, revealed different purposes for using negotiation patterns during the EDP. Across all eight small groups, six negotiation patterns were used: proposing, in agreement, critiquing, counter proposing, acquiring information, and explaining. Except proposing, groups receiving argumentation training used the remaining negotiation patterns for different purposes. We chose Group 1 and Group 5 to illustrate the differences and similarities of the negotiation regarding EDP, as these groups used the highest number of negotiation patterns in total (**Table 3**).

Proposing Ideas for Negotiating Material Design

Upon close examination of audio recordings, it was observed that students in both groups predominantly generated ideas during the research phase for potential design solutions and in the planning stages. For instance, in Group 1, during the planning of the camping light equipment, students put forward ideas to enhance the design by taking into account scientific data related to lenses and the optimal reflection of light.

S2: We will fix the torch here. Then, we need something to reflect the light.

S3: Convex mirror?

S2: Does light not reflect when it hits a convex mirror? Uhm, we tie a mirror to a tree.

S3: Torch already reflects the light; it has a convex mirror. It does not only reflect light where you point to it. It reflects everywhere.

S4: So it reflects it, right?

S1: Yes, so we use convex.

Overall, both groups proposed ideas across five stages of the engineering design. The students were proposing ideas for ensuring a better design. It was also evident from the researchers' notes that the group that did not receive argumentation training used the proposing state more. "In general, it was seen that the students in the group who did not receive argumentation training took more time to decide on which material to use." (Observation notes). The students tended to propose ideas instead of justifying and negotiating the design ideas.

In Agreement Followed by a Justification for a Design Solution

When the students in Group 1 agreed on a proposed idea, they tended to follow their agreement with a justification across all engineering design stages. Out of 28 in-agreement states, 24 of them followed by justification and data. As an illustration, students in Group 1 engaged in negotiations regarding the decision to use concave lenses. During these discussions, scientific information was utilized by students to support and agree with their peers.

S1: I think this is good. We have aluminum foil and cardboard containers. We assemble them and put concave lenses to the sides.

S2: Yes, correct…, in terms of data, concave lenses collect light, so it heats things. Perfect.

The students in Group 5 mostly used this negotiation pattern to approve their friends' design choices or support the claim put forward during the planning and construction of the design. However, no justification for why they support the design choice or plan is provided. Out of 31 turns taken for this negotiation pattern, only four times they followed with a justification.

S2: I'm taking this lens out and putting this one in, OK?

S3: Yes, sure. It is better this way.

Overall, the students' negotiation in the agreement was expected in the group that received argumentation instruction because the first author spotlighted the importance of justifying claims during negotiation.

Counter proposing and Acquiring Information for Better Planning vs. Changing the Design

The students in Group 1 used counter proposing and acquiring information more frequently while planning their design. Out of 11 turns during counter proposing, eight turns occurred during the planning stage. Justifications also followed these turns. For example, in telescope design activity, Group 1 negotiated which lens they should use. This occurred before they interacted with physical materials. During these turns, students were also acquiring information about their planning regarding the design.

S2: To better see the sky, [we should use] the things that reflect light, I mean convex mirror and concave lens.

S1: No, we should use convex lenses, not concave….
S2: If we use concave, it collects the light in one area; if it reflects, we see bigger and more apparent.

However, in Group 5, all six turns occurred during the design stage. It was also evident from the researcher's notes that the students in this group spent less time planning. "The students in this group did not spend time discussing how they would construct their telescope. Instead, they immediately interacted with the materials available, and during their negotiation, they tend to manipulate the materials physically" (Researcher's notes, Group 5, Activity 2). The excerpt below shows how students in this group negotiated for the changes in their design.

S3: We need lenses. I get it.

S4: Let's use these magnifiers as well.

S1: This is a concave lens, and let's cut this [cupboard]

S2: Lenses here. I put them to the back, which goes here and the other.

S1: It asks, please explain why you chose the design and why you eliminated the other… We chose this design….

S2: We chose this one because we can see other items more clearly.

S3: Well, can we say that the lenses make it look closer so that we see clearly?

It was evident from the excerpt that the students' counter-proposing and acquiring information occurred after they already chose the better design and finished the construction of their design. The student's reasoning, on the other hand, was not complete. This situation was also evident from the researcher's notes "It was observed that the students in the group that received argumentation training spent more time on the planning stage while students in the other group skipped the planning stage quickly and spent more time on the design process." (Researcher's notes, Group 5, Activity 2)

Critiquing for Design Advantages and Disadvantages

Group 5 did not justify the reasons for the advantages and disadvantages of their design decision. For example, this group did not explicitly discuss the advantages and disadvantages of their solar oven design.

S1: What could be the disadvantage of this [design]

S2: I do not see anything

S3: What could it be?

S1: It won't cook everywhere.

However, Group 1 elaborated on their design by justifying the construction and planning of it. The justification of the disadvantages leads to the modification of their design. This could lead to better design solutions. The excerpt below illustrates how Group 1 changed its design based on negotiation process.

S1: We can put a solar panel here on top.

S2: Can we?

S1: We have two disadvantages here. One is the inappropriate use of the lenses, and the other is the lack of an actual solar panel.

S3: What can we do to cook in a shorter time?

S1: Do we increase the number of lenses?

S3: An egg cooks at 90-100 degrees. Ours is only 30.

S1: I think our system is not good enough.

S2: OK, let's increase the lenses to collect more light to increase the oven's temperature.

The researcher also noted a similar observation regarding the discussion on the advantages and disadvantages of the design. "Students in Group 1 did a better job discussing the advantages. They engaged in argumentation, and their design progressed due to critiquing the design advantages and disadvantages" (Observation Notes, Group 1). On the other hand, although Group 5 stated the disadvantages and advantages, they did not elaborate on how this could strengthen their design.

Discussion and Implications

Student conversations, essential for accessing students' decision-making processes during a given design challenge, have been scarcely studied in science classrooms. As students engage in evidence-based reasoning during engineering design (Aranda et al., 2020), this study explored the negotiation patterns of grade-7 students regarding their argumentation training. The findings illustrated that all groups similarly used negotiation patterns. However, differences were found between the group that received argumentation and the one that did not.

Our findings highlight that students' negotiation patterns showed similar patterns among groups regardless of their argumentation training. A similar result was obtained in a study by Guzey and Aranda (2017), where they compared small group discourse patterns during an engineering design task. They found that although the students' discourse patterns showed similarities in terms of discourse patterns, they differed in the number of turns and the complexity of discourse patterns (Guzey & Aranda, 2017). In addition, they found that the groups could not causally elaborate on their design. Our results are consistent with the previous research regarding the similarities in the number of negotiation patterns. However, the result of the current study further showed that causal elaboration could be enhanced by giving direct argumentation instruction so that the students can elaborate on their proposed ideas by providing justifications.

A previous study also indicated that the high-performing group, in terms of argumentation, discussed proposed ideas more than the low-performing group before accepting or rejecting a proposed idea (Sampson & Clark, 2009). Our findings indicate that direct argumentation training has the potential to assist students in providing more extensive justifications for their claims, even when they are in agreement with their peers. This implies that regardless of students' initial argumentation performance, dedicated argumentation training can effectively support them in articulating and defending their design solutions and ideas.

The planning stage creates a space for students to explore ideas and co-create a shared understanding (McDermott, 1978). "Outcomes from initial brainstorming activities are thus important for understanding and improving design choices, decisions, and constraints" (Lutz et al., 2022, p2). However, rather than discussing the possible design solutions, novice learners tend to test the tangible properties of their design (Wendell & Lee, 2010). To overcome such design challenges, researchers, for example, suggest giving written support (McFadden & Roehrig, 2019). Our findings additionally suggest that argumentation training may contribute to students employing counter-proposing strategies and acquiring information to enhance the planning phase. This implies that, with the aid of argumentation training, students may develop skills to navigate challenges and gather relevant information for more effective planning in the design process.

Decision-making through negotiation and consensus has been identified as one of the core components of engineering design (Wendell et al., 2017). It requires students to critique design ideas and solutions. During this stage, students evaluate the advantages and disadvantages of the design components, processes, and solutions. This process requires students to engage in evidence-based reasoning. Argumentation engages students in reasoning processes in which students weigh advantages and disadvantages, pros and cons related to a given problem. Argumentation might be externalized by high-quality reasoning processes (Sadler & Zeidler, 2005). Therefore, argumentation as a core component of EDP should be incorporated into engineering design contexts to enrich the design process through students' reasoning.

In this study, the frequency of counterclaims was low across all groups. The results were similar to Seppanen (2022), who found that university students that did not receive argumentation training also had low levels of counterclaims in their arguments. Hence it becomes critical to engage students in situations where they could discuss alternative design ideas through high-quality argumentation. Verbal scaffolds can be provided to enrich such a learning environment so that the students can negotiate the design alternatives. Future studies can focus on the argumentation scaffolds provided by the teachers and their influence on EDP.

Previous research indicates that instructors' discourse patterns influence students' scientific reasoning and justifications when working in small groups to solve a design challenge (Guzey & Aranda, 2017). However, our study only focused on students' negotiation without considering the teachers' influence on design negotiation and argumentation. Therefore, future research can focus on the effect of different teachers' discourse moves and argumentation on students' engineering design decisions. Furthermore, the current study did not elaborate on the students' consensus and design. Therefore, future studies might focus on the impact of such negotiation patterns on students' engineering design products.

Conclusion

This study investigated grade-7 students' negotiation during EDP regarding the students' status of argumentation training. It addresses the gap in the literature by providing evidence from negotiation processes during four different design tasks. While both groups exhibited similar negotiation patterns, those with argumentation training justified their design solutions, enhance their planning for a design solution, critique for design advantages and disadvantages. Incorporating argumentation instruction enhances the engineering design process.

References

Aranda, M. L., Lie, R., & Guzey, S. S. (2020). Productive thinking in middle school science students' design conversations in a design‐based engineering challenge. *International Journal of Technology and Design Education*, 30:67-81. DOI: https://doi.org/10.1007/s10798-019-09498-5

Azevedo, F. S., Martalock, P. L., & Keser, T. (2015). The discourse of design-based science classroom activities. *Cultural Studies of Science Education*, 10(2):285-315. DOI: https://doi:10.1007/s11422-013-9540-5

Bağ, H., & Çalık, M. (2017). A thematic review of argumentation studies at the K-8 level. *Education and Science*, 42(190):281-303. DOI: https://doi.org/10.15390/EB.2017.6845

Brereton, M., Cannon, D., Mabogunje, A., & Leifer, L. (1996). Collaborations in design teams. In N. Cross, H. Christiaans, & K. Dorst (Eds.), Analysing Design Activity). John Wiley & Sons. pp. 319-341.

Chi, M. T. H., & Menekse, M. (2015). Dialogue patterns that promote learning. In L. B. Resnick, C. Asterhan, & S. N. Clarke (Eds.), Socializing intelligence through talk and dialogue. AERA. pp. 263-274.

Chu, L., Sampson, V., & Hunter, T. L. (2019). Argument-driven engineering in middle school science: An exploratory study of changes in engineering identity over an academic year. *Journal of Pre-College Engineering Education Research*, 9(2):6. DOI: https://doi.org/10.7771/2157-9288.1249

Creswell, J. W. (2013). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (4th ed.). Sage. ISBN: ISBN: 1071817949

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

Dillenbourg, P., & Hong, F. (2008). The mechanics of CSCL macro scripts. *International Journal of Computer-Supported Collaborative Learning*, 3(1):5-23. https://doi.org/10.1007/s11412-007-9033-1

Engeström, Y. (2014). Learning by Expanding: An Activity-Theoretical Approach to Developmental Research. Cambridge University Press. DOI: https://doi.org/10.1017/CBO9781139814744

Guzey, S., & Aranda, M. (2017). Student participation in engineering practices and discourse: An exploratory case study. *Journal of Engineering Education*, 106(4):585-606. DOI: https://doi.org/10.1002/jee.20176

Hertel, J. D., Cunningham, C. M., & Kelly, G. J. (2017). The roles of engineering notebooks in shaping elementary engineering student discourse and practice. *International Journal of Science Education*, 39(9):1194-1217. DOI: https://doi.org/10.1080/09500693.2017.1317864

Jin, Y., & Geslin, M. (2009). Argumentation-based negotiation for collaborative engineering design. *International Journal of Collaborative Engineering*, 1(1/2):125-151. DOI: https://doi.org/10.1504/ijce.2009.027443

Leont'ev, A. (1978). Activity, Consciousness and Personality. Prentice-Hall. ISBN: 9780130035332

Lutz, B. D., Chiem, A. T., & Bethel, C. (2022). Using discourse analysis to investigate conversations during engineering brainstorming activities. Paper presented at the American Society for Engineering Education, 1-10. Minneapolis, MN, August 23.

McDermott, D. (1978). *Planning and acting. Cognitive Science*, 2:71-109. DOI: https://doi.org/10.1207/s15516709cog0202_1

McFadden, J., & Roehrig, G. (2019). Engineering design in the elementary science classroom: supporting student discourse during an engineering design challenge. *International Journal of Technology and Design Education*, 29(2):231-262. https://doi.org/10.1007/s10798-018-9444-5

McNeill, K. L., & Krajcik, J. (2007). Middle school students' use of appropriate and inappropriate evidence in writing scientific explanations. In M. C. Lovett & P. Shah (Eds.), Thinking with data: The Proceedings of the 33rd Carnegie Symposium on Cognition. Erlbaum. pp. 233-265.

Menekse, M., Purzer, S., & Heo, D. (2019). An investigation of verbal episodes that relate to individual and team performance in engineering student teams. *International Journal of STEM Education*, 6(7):1-13. DOI: https://doi.org/10.1186/s40594-019-0160-9

Mentzer, N., Becker, K., & Sutton, M. (2015). Engineering design thinking: High school students' performance and knowledge. *Journal of Engineering Education*, 104(4):417-432. DOI: https://doi.org/10.1002/jee.20105

Ministry of National Education. (2018). Fen bilimleri dersi öğretim programı (İlkokul ve Ortaokul 3,4,5,6,7 ve 8. sınıflar) [Science course instruction program (Elementary and middle school, 3,4,5,6,7,8 grades]. Talim Terbiye Kurulu Başkanlığı.

National Research Council. (2012). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Committee on Conceptual Framework for the New K-12 Science Education Standards. The National Academies Press.

Pruitt, D. G. (1981). Negotiation Behaviour. Academic Press. eBook ISBN:

9781483266206

Rebello, C. M., Urueña, Y. B. P., Magana, A. J., Deleon, A. M., & Dasgupta, C. (2019). Scaffolding evidence-based reasoning in a technology supported engineering design activity. Paper presented at The 13th Conference of the European Science Education Research Association (ESERA), Bologna, Italy. August 26-30.

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: https://doi.org/10.1002/tea.20042

Sampson, V., & Clark, D. B. (2009). A comparison of the collaborative scientific argumentation practices of two high and two low performing groups. *Research in Science Education*, 41(1):63-97. DOI: https://doi.org/10.1007/s11165-009-9146-9

Seppanen, M. (2022). The quality of argumentation and metacognitive reflection in engineering co-design. *European Journal of Engineering Education*. 48(1):75-90. DOI: https://doi.org/10.1080/03043797.2022.2054314

Sheppard, S., Colby, A., Macatangay, K., & Sullivan, W. (2006). What is engineering practice? *International Journal of Engineering Education*, 22(3):429-438.

Siverling, E. A., Suazo-Flores, E., Mathis, C. A., & Moore, T. J. (2019). Students' use of STEM content in design justifications during engineering design-based STEM integration. *School Science and Mathematics*, 119(8):457-474. DOI: https://doi.org/10.1111/ssm.12373

Stake, R. (1995). The Art of Case Study Research. Sage. ISBN: 080395767X.

Toulmin, S. (2003). The Uses of Argument. Cambridge University Press. ISBN: 0-521-82748-5.

Urueña, Y. B. P., Rebello, C. M., Dasgupta, C., Magana, A. J., & Rebello, N. S. (2017). Impact of argumentation scaffolds in contrasting designs tasks on elementary preservice teachers' use of science ideas in engineering design. *Physics Education Research Conference. Cincinnati*, OH. July 26-27. DOI: https://doi.org/10.1119/perc.2017.pr.071

Wendell, K. B., & Lee, H. S. (2010). Elementary students' learning of materials science practices through instruction based on engineering design tasks. *Journal of Science Education and Technology*, 19(6): 580-601. DOI: https://10.1007/s10956-010-9225-8

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: https://doi.org/10.1002/jee.20173

Yıldırım, A., & Şimşek, H. (2006). Sosyal bilimlerde nitel araştırma yöntemleri [Qualitative research methods in social sciences] (6th ed.). Seçkin Yayıncılık. ISBN: 9789753472487.

Received: January 16, 2024
Revised: January 22, 2024
Accepted: February 02, 2024