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Students' Interactions During Laboratory Group Activity in a Science Museum

Neta Shaby[1] · Orit Ben-Zvi Assaraf[2] · Nicole Pillemer Koch[2]

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Abstract

There are relatively few studies examining cooperative learning during laboratory activities in a science museum. This study aims to explore such activities to better understand the nature of cooperative learning, if any, in that setting. The participants in this study were 60 fourth-grade students who visited a science museum lab as part of a school field trip. The students, divided into 12 groups, were videotaped and audio-recorded during group work consisting of balancing a scale. Our inductive data analysis of the observations revealed that although each group's interactions were distinctive, common themes emerged. Moreover, even though the group work required cooperative learning, students did not engage in such. Students mostly instructed each other on how to operate the scale, with no scientific explanations. As the students did not know how to work together in order to solve the task, frustration abounded. This research adds to the body of knowledge about lab activities in science museum and offer practical implication to design more effective activities in these settings. Careful pedagogy and thoughtful facilitation can contribute to the students' learning outcomes; therefore, educators should consider the following: ensuring students have sufficient prior knowledge, having the museum educator play the role of a mediator, taking steps to reduce the level of student frustration, and planning additional activities that promote the learning outcomes of the activity.

Keywords Cooperative learning · Informal learning · Laboratory activity · Science museums

✉ Neta Shaby
N.Shaby@soton.ac.uk

Orit Ben-Zvi Assaraf
ntorit@bgu.ac.il

[1] Southampton Education School, University of Southampton, Building 32, Highfield Campus, Southampton SO17 1BJ, UK

[2] Program of Science and Technology Education, Ben-Gurion University of the Negev, P.O.B. 653, 84105 Beer-Sheva, Israel

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Introduction

The call for more active elements in science education has highlighted the role of lab work in and outside of the science classrooms (Itzek-Greulich et al., 2015). However, lab work at school is often restricted due to lack of infrastructure. Therefore, visiting labs in informal environments outside of school not only promotes cognitive, affective, and psychomotor learning and increases interest in science, it also offers students the opportunity to explore new topics in a well-equipped learning environment where hands-on activities and experiments can be conducted easily by the students themselves (Tal, 2012). Informal environments, such as Science Museums, usually offer hands-on lab work in small groups, a form of interaction that is often addressed as collaborative or cooperative learning.

Despite the inherent potential of cooperative learning, there has been very little research into its effectiveness in school laboratory classes in general (Raviv et al., 2019), and in science museum lab work in particular. This study aims to broaden the scope and explore the lab activities in a science museum, to better understand the nature of the cooperative learning, if any, in that setting. This insight could become a significant addition to the literature on school visits to science museums and help make the museum experience more meaningful for school students, as well as contributing to the body of knowledge about cooperative learning and group work.

Laboratory Activities in Science Museums

Laboratory activities in the science classroom have been considered essential to science teaching in learning. Hofstein and Lunetta (2004) defined science laboratory activities as "learning experiences in which students interact with materials and/or with models to observe and understand the natural world" (p. 31). The fact the students are actively engaged with (i.e. interacting and observing) an artifact is a consequential matter in science education (Hofstein & Lunetta, 2004; Lee et al., 2020; Raviv et al., 2019).

Recent studies examining science laboratory activities have focused on formal education—namely, school and university students (Abrahams & Millar, 2008; Hofstein & Lunetta, 2004; Lee et al., 2020). However, it is evident that schools cannot provide full science-learning experiences on their own; they must have support from other educational centers and informal science environments (National Research Council [NRC], 2009). Science museums are such settings that can support schools by offering hands-on science experiences, one of which is the science laboratory. It is important to distinguish between laboratory activities that take place in a formal setting, and activities that occur in an informal environment such as a science museum. Each environment has different goals and impact on students (Itzek-Greulich et al., 2017). In a sense, schools may lag behind informal learning environments in their ability to inspire and develop students' interest in science (Feinstein et al., 2013). Furthermore, while laboratory activities in the school setting prove to be more effective in improving learning achievement, laboratory activities at an out-of-school setting are more effective in improving motivational gains (Itzek-Greulich et al., 2017).

Although there is abundant research on school visits to a science museum, little is known about students' experiences during laboratory activities in those settings. Some of the studies done on laboratories in science museums have demonstrated that laboratories with hands-on activities can change visitors' conceptions of gravity, being ideal environments for constructivist, inquiry-based learning (Lelliott, 2014). Nativ Ronen and Tal (2019) presented a study regarding a visit that included laboratory activities at university-based science youth centers. Findings revealed that the students described scientific process, provided accurate examples, and expressed strong positive feeling about the natural world. These findings underscore the importance of informal environments and laboratory activities in science education. Similarly, Tsybulsky et al. (2018) found that a carefully designed outreach program in which high school students worked collaboratively within university labs had a positive effect on students' understanding of nature of science and on their attitudes towards science. More recently, Tal and Dallashe (2021) focused on high school students who visited a medical simulation-based hands-on learning environment in a science center. The students visiting the simulations center acknowledged the hands-on, sensory-motor activities; the collaborative learning that includes not only hands-on activities but also discussions and mutual decision-making; relevance to everyday life; and enhanced curiosity and interest.

Collaborative and Cooperative Learning

Science lab activities include various objectives such as promoting scientific skills and cognitive abilities, understanding of concepts and the nature of science, and promoting positive attitudes towards science, which includes collaboration and collaborative group exploration (Shulman & Tamir, 1973). Reviewing the literature on collaborative and cooperative learning (that also includes group work and problem-based learning) reveals inconsistencies, disagreements, and even contradicting definitions of the pedagogies. As stated in the review "Boundary Crossings: Cooperative Learning, Collaborative Learning, and Problem-Based Learning" by Davidson and Major (2014): "Unfortunately, the terminology associated with group-learning approaches has become so entangled that it is difficult to distinguish between them, and there are unclear and even muddled messages in the literature" (p. 8). In this work, we use both collaborative and cooperative learning, however, not interchangeably. From the numerous definitions, emerging from research in schools in general, science classrooms, and science laboratory activities, the most suitable definition related to the context of this research states: "Cooperative learning, which is a type of collaborative learning in which students must work together to achieve goals and rewards which apply to the group as a whole, rather than to single individuals" (Micari & Pazos, 2021, p. 127). In the abovementioned review, Davidson and Major (2014) mention that both collaborative and cooperative learning include "A common task suitable for group work, small-group interaction focused on the learning activity, individual accountability and responsibility and interdependence in working together" (p. 29). They also add that distinctive to cooperative learning is "mutually helpful behavior among students as they strive together to accomplish the learning task" (ibid). As per those definitions, we see cooperative learning as part collaborative learning, with the distinction of working together towards a specific task. Hence, students might work generally collaboratively on a given task and cooperatively towards the goal. As stated before, some scholars view those differently, and some even in the opposite way (see Baker, 2015 for example). Despite the different views of scholars, all agree that the basis of this group work is interactions between students. We view interactions similarly to Jordan and Henderson's (1995), which describe interaction as "human activities, such as talk, nonverbal interaction, and the use of artifacts and technologies, identifying routine practices and problems and the resources for their solution" (p. 39). Drawing on this notion and the socio-cultural approach, following others work, we identify four main components of interactions: cognitive, physical, social, and effective (Shaby et al., 2018). The cooperative group work in the science museum's lab contains all those components. Moving beyond the definitions, research on collaborative and cooperative learning outlines the benefit of this pedagogy (note: in what follows, we use the term collaborative or cooperative as used by the authors of each publication). Grounded in constructivist learning theory, collaborative learning allows students to interact, a behavior that is expected to promote cognitive development (Vygotsky, 1980). Drawing on this notion, Slavin (1996) claims that children in similar ages are likely to operate within the same "Zone of Proximal Development," hence modeling collaborative behaviors and promoting individual growth. According to Hoek and Seegers (2005), collaborative learning in small groups may have a strong potential to contribute to learning. They claim that for co-construction of knowledge to take place, students should be actively engaged in reasoning, trying to achieve mutual understanding, and building on each other's contributions. Nevertheless, students need to be actively involved in collaborative problem solving in order for it to be effective (Hoek & Seegers, 2005). Furthermore, some studies regarding collaborative learning underscore the students' difficulty in solving conflicts and their lack of collaborative skills. Students struggle to collaborate as they may not have experience in how to manage a collaborative task (Le Janssen & Wubbels, 2018; Mello, 1993). In psychology, cooperative learning is rooted in social interdependence, where the outcomes of individuals are affected by other group members' actions (Johnson & Johnson, 1978). In that form of participation, students are mutually dependent upon their cooperative work; the learning environment offers the students equal opportunities for mutual cooperation regarding the learning tasks and encourages them to communicate; every member of the group is responsible for contributing to the group work and is committed to the group learning process; and the learning environment is structured in a manner that facilitates the abovementioned requirements (Raviv et al., 2019).

As the students visiting the museum lab were expected to jointly solve a particular task, we have approached this investigation as a study of a cooperative learning activity. This kind of activity can create "promotive interaction" (Johnson & Johnson, 2009, p. 366), which is an interaction characterized by individuals working to promote the success of other members of the group. Yet, Galton et al. (2009), who examined the academic performance of cooperative group work of students engaged in a problem-solving task, maintain that social interaction tends to dominate cooperative learning as opposed to emphasizing cognitive outcomes.

Although laboratory work is prominent in science and therefore should be inherent to science teaching and learning, there are relatively few empirical studies examining the school laboratory learning approach in general, and the effectiveness of cooperative learning, in particular (Raviv et al., 2019). Since research points to the significance of cooperative learning in the classroom, and the fact that it is used extensively in science museums lab activities, it is important to explore the way science museums use this environment to promote effective learning. In this study, we take a closer look at small-group cooperative work in a science museum lab activity and examine the interactions around a scale-balancing activity. This insight could become a significant addition to the literature on school visits to science museums, while broadening the scope of research on lab activities in informal settings and obtaining a better understanding of the nature of cooperative learning, if any, in that setting.

Method

Research Participants and Setting

This is a naturalistic study, exploring an activity designed by the science museum as it naturally unfolded. This is part of a larger study taking place at Carasso Science Park, an interactive science museum located in the city of Be'er Sheva, in southern Israel. Most of the museum visitors are school students participating in fieldtrips. The participants of this study included 60 fourth-grade students, visiting the science museum as part of a school fieldtrip. The students were from four schools, one class from each school, all from the same city where the science museum is located (for further details on participants, see previous publications, Shaby et al., 2018, 2019, 2020). The fieldtrip consisted of four activities, 30–40 min each: a laboratory activity, visit to two exhibition halls, and the science garden. In this study, we focus only on one lab activity, "Cranes, Pulleys and Scales." The laboratory room contained four round tables, each designed for 4–6 participants, allowing up to 24 students to participate at a time. As each class entered the laboratory, the students were free to choose where and with whom to sit, thereby dividing themselves into groups, with a total number of 12 groups for all participants (some classes had less students to begin with). The lab activity consisted of three parts: introduction (10 min), group work (20 min), and summary (10 min).

During the introduction, the museum educator (ME) presented the topic of the activity (i.e. Cranes, Pulleys and Scales) using a PowerPoint presentation, and this introduction was identical in all activities. The museum educator explained the Law of the Lever: The further we apply a force from the fulcrum, the less force we need in order to lift a given weight (i.e. pulling a weight further from the fulcrum will be easier). Next, the ME presented a scale (Fig. 1) and pointed out its various parts (left and right arms, fulcrum, hooks, and weights, see Fig. 1).

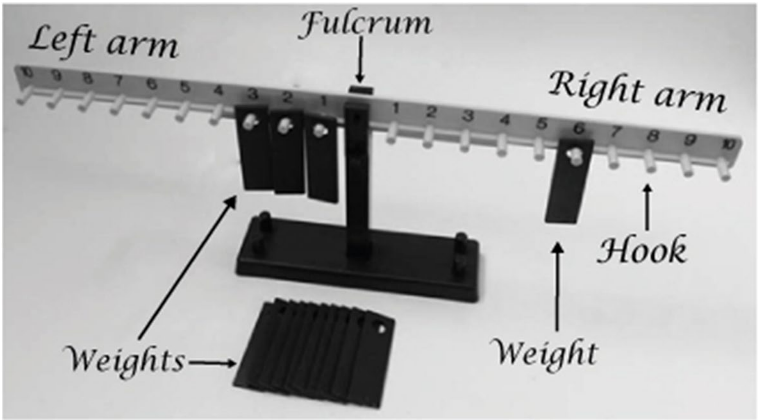

Fig. 1 Scale used during group work

Group Work with the Scale

Each group was given a scale that they needed to balance (a term used by the ME in the introduction). The task was to place a certain number of identical weights on the right arm and then balance the scale by placing weights on the left arm, but not in the same spot(s) as on the right arm. Figure 1 shows an example where one weight that is placed at position #6 on the right arm (=6) and one weight each at positions #1, #2, and #3 on the left arm (1+2+3=6) will balance the scale. The students were shown one example (such as the above), then four elements of the task were written on the whiteboard for the students to solve. Students were given instruction on where to place weight on the right arm, after following those instructions, they need to balance the scale by placing weight on the left arm. Those were the elements of the task that were written on the whiteboard for the students to follow: (1) place one weight at positions #2 on the right arm, (2) place two weights at positions #2 on the right arm, (3) place one weight at positions #2 and one weight at positions #4 on the right arm, and (4) place three weights at positions #4 on the right arm. Balance the scale by placing weights on the left arm. Try as many ways to balance the scale as possible.

While the students were working together on solving the tasks, ME approached each group (either randomly or in response to students), observing their work, making comments, and offering guidance. This form of instruction was very minor and inconsistent between groups; more importantly, it had no effect on the way students continue working, therefore was not included in the analysis.

Data Collection

The data for this study were collected through video-recorded observations. We used two hand-held video cameras for each class, with each camera capturing half of the students (i.e. simultaneous video recording of two groups sitting around two tables).

In addition, each group had an audio recorder on the table. Recording the activity offered the researchers a chance to repeatedly review and observe the activity in each group, enabling the researchers to notice and focus on many different interactions occurring simultaneously. This research was approved by the Israel Ministry of Education ethical board, and all parents have signed consent forms for their children to participate in all aspects of the research.

Data Analysis

We only analyzed the activities of the 12 groups working with the scales. The video recordings of the group work were transcribed, and all audio and visual data (e.g. speech, activity, and gestures) were documented in writing. The separate audio recordings supplemented the video when needed. During this stage, we randomly assigned numerical codes for each student and group, with the letter *S* denoting a student and letter *G* denoting a group. Thus, for example, S8G2 refers to student 8, from group 2. Additionally, all students were assigned pseudonymous.

We used an inductive data analysis approach (Lincoln & Guba, 1985) to describe the interactions. During the analysis, three researchers used the transcripts and the original videos to describe the interactions. The analysis process was conducted at both macro and micro levels: The macro level revealed emerging categories from all types of interactions from all groups, while the micro level described the nature of the interaction of *each group* separately.

At the macro level, we used thematic analysis to discover emerging themes (or categories) and performed microanalyses during the micro level of analysis. To illustrate the findings, we created a visual and graphic scheme for each group (see Fig. 2).

The visual scheme represents the way the students sat in the group, who spoke to whom, and how often. The arrows represent speech by each student (S#) to another student or to the group (represented by G#). The visual scheme makes it easier to perceive the dynamics of the group. For example, Fig. 2 represents the interaction between the students in group G6. We can see that S25 addresses S29 a great many (20) times (compared to the group itself and other groups as well), while S29

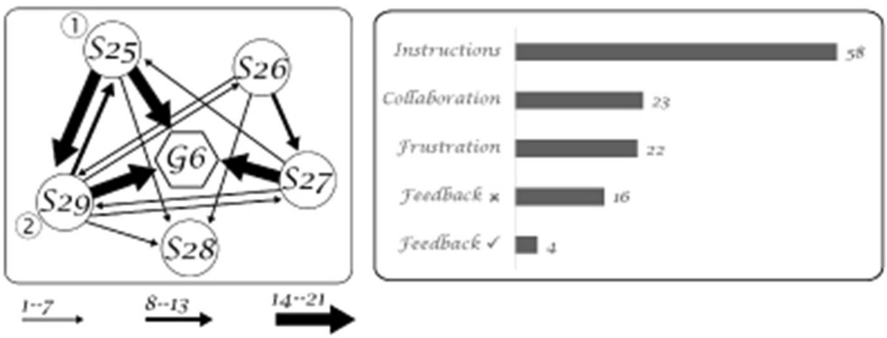

Fig. 2 Visual and graphic scheme for Group 6 (G6)

speaks to S25 only 9 times. Some students, such as S28, do not interact verbally at all throughout the activity. Arrows pointing at G6 are utterances that were directed to the whole group and not to a specific person. The smaller circles next to some of the students represent private speech (i.e. the utterances the students addressed to themselves); for example, two of S29's utterances were directed at herself.

The graphic scheme further unpacks the common themes within the group, presenting the following categories: instruction, collaboration, frustration, and negative or positive feedback (see further explanations in the "Findings" section and Appendix 1). In G6 for example, we see that verbal instruction was the most common in this group, with 58 utterances. Collaboration and social frustration were similar with 23 and 22 utterances, respectively. This type of analysis represents what the students were talking about, and not only whom they were talking to. The two schemes complement each other by addressing the specific themes and the dynamics of the group in an attempt to examine the interactions within the group (see Appendix 2).

During the process of analysis, significant attention was paid to the credibility of the study. To ensure credibility, the audio from video recordings was transcribed in detail. To address transferability, we have provided a rich description of the setting of the activity. The analysis was done by three researchers (authors) in an iterative manner that included rethinking and evaluating the significance of the utterances, actions, and categories. We checked for inter-coder reliability while describing the categories and discussing various utterances.

Findings

Overall, we observed 12 groups during a 20-min activity with a scale in a science museum lab. The data analysis revealed that the interactions among peers during the activity in the laboratory took place in the physical, social, emotional, and cognitive domains. As dictated by the learning activity, most of those interactions took place within the physical (i.e. around the scale) and social (i.e. in the group) domains.

Physical interactions included physical operation of the scale, such as placing weights on it and pointing at the scale. Social interactions included verbal instructions, wherein the students interacted with their peers regarding the given task, for example, instructing each other where to place the weights and giving feedback (negative or positive) regarding their operation of the scale (i.e. "no, this is the wrong spot for the weight"). In the emotional (or affective) domain, students exhibited excitement (usually when successful in balancing the scale) or frustration, either with the task or with their peers (i.e. unsatisfied with the group cooperation). The cognitive domain produced few interactions, including the students giving intuitive scientific explanations such as, "This is heavier"; or when students mirrored the ME's terminology, such as, "Now it's balanced." As those examples show, we cannot actually separate the domains in which the interactions occurred — peer instruction concerned the physical operation of the scale; frustration was expressed about peers' actions; often, an explanation about balancing the scale was followed by the action of placing a weight on it.

Although the groups participating in the study employed interactions (i.e. verbal, actions, or gesturing) within the four domains, each group had its own nature of engagement and communication. When examining the different interaction characteristics of the groups, we noticed that none of the groups was similar. Every group was unique, and the distribution of the various types of interactions was different in each group. Our analysis revealed several types of group dynamics, including talkative, frustrated, and non-communicative. In what follows, we provide examples of 5 groups during cooperative group work. For each group, we present a visual and graphic scheme. The visual scheme shows who the group members were addressing, who the most verbal and dominant students were, or who the quiet or passive students were. Moreover, the visual scheme helps to examine the role the students took on during the activity. Although each group's interactions were unique, there are common themes found among all groups (instruction, collaboration, frustration, and negative or positive feedback, see Appendix 1), as demonstrated by the graphic scheme. Additionally, a visual and graphic scheme for each of the twelve groups can be viewed in Appendix 2.

The Talkative Group

Group G6 consisted of five girls: Sarah, Emily, Lenor, Daniela, and Michelle. This group was very talkative and active (except Daniela, S28). Group G6 was characterized by a high number of overall utterances (compared to all 12 groups). The 58 utterances in the verbal instruction category (see Fig. 2) indicate the group members were talking and interacting about the task and were engaged with the scale during the activity. The visual representation (Fig. 2) indicates that Michelle (S29), Lenor (S27), and Sarah (S25) were the most dominant group members. Although Sarah (S25) was the group member with the greatest number of utterances (43 utterances), she addressed only Michelle or the whole group. Michelle (S29) was a dominant participant as well; she produced 41 utterances, of which 12 were verbal instructions, making her the group member providing the most verbal instructions. Unlike Sarah, Michelle related to the entire group and most of the group members addressed her, making her the group leader.

The fact that the group demonstrated positive feedback and collaboration suggests that this group was working together in a positive, cooperative manner. Although the task itself was of the cooperative kind, where the students needed to work towards a specific solution to a problem, they needed to work collaboratively. Therefore, we determined that collaboration was manifested by talking about taking turns and working in a manner that enabled all the group members to take part. The members of G6 were highly communicative, and the interaction revolved around teamwork, collaboration, and cooperation. For example, during a discussion between Michelle and the group regarding taking turns, Michelle explained the system of taking turns, and how all the group members should participate in the activity. Michelle: "Emily (S26) was first, and then Sarah (S25), and then me, and then you." Her group members listened to her and worked in the order she suggested.

This was uncommon in other groups, where the students worked individually and did not collaborate, as is the case in groups G3, G7, and G10 (see Appendix 2). Most groups found it hard to collaborate and cooperate. In many groups, collaboration was not demonstrated, suggesting that some groups were not able to function as a team and solve the tasks together.

The Frustrated Group

The five students of G4 (Fig. 3), two boys and three girls (Tom, Jonathan, Rona, Laura, and Jenny), expressed frustration through 33 utterances, being the group with the greatest number of utterances in this category.

In some groups, not all the group members had a chance to participate, resulting in frustration and disappointment. Looking at the visual representation of G4, it might seem that Tom (S15) was the dominant participant in the group, but the fact was that 13 of his utterances were addressed to the group (i.e. not to a specific participant), and consisted of social frustration: “You are not listening to me!” or “I told you [to do it] like this! Listen up for a minute.” Such remarks indicate that Tom was not active in solving the tasks. Jenny (S19), on the other hand, was actively engaged in interaction and conversation with all the group members. Sixteen of her utterances were verbal instructions regarding how to operate the scale, while 11 of her utterances were demonstrations of social frustration. The frustration was mainly a result of not participating in the activity. When students gave a verbal instruction that was not implemented, they felt frustrated and excluded as in the case of Johnathan (S16) when he suggested a solution but was ignored by Jenny (S19):

Student	Talk	Gesture/action
Jonathan (S16)	Place here one [weight], and here one [weight]	Points at the scale
Jenny (S19)	No	

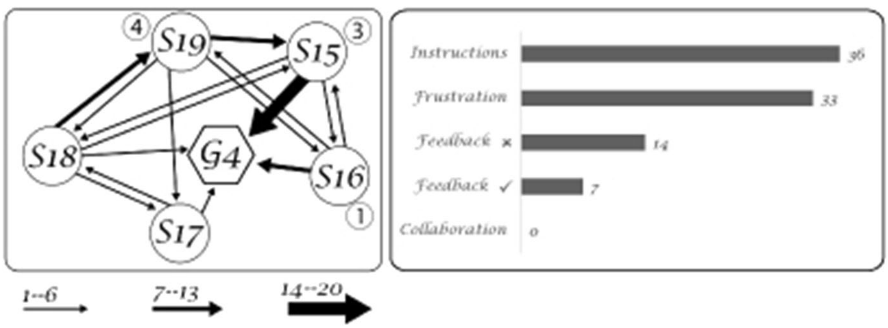

Fig. 3 Group G4—visual and graphic schemes of the interactions

Student	Talk	Gesture/action
Jonathan (S16)		Places a weight on the scale
Jenny (S19)	No	Removes the weight Jonathan placed
Jonathan (S16)	It's easy, but you're not listening to me	

This sample interaction reveals the demonstration of social frustration that occurred in G4 throughout the activity. Jonathan (S16) gave the group verbal instructions many times during the activity, but his suggestions were dismissed or ignored time after time. Moreover, he hardly got a chance to place weights on the scale. As a result, the frustrated Jonathan reacts, saying that the task was easy but "you're not listening to me." In this case, the verbal instructions of some of the students were not implemented, causing them to feel excluded and thus, frustrated. This form of participation also prevented the group from solving the tasks, which created even greater frustration. Under such circumstances, the students did not get along with one another, which resulted in lack of collaboration, cooperation, and frustration. In other cases, students did not even communicate with each other, as seen in the examples below.

The Non-communicative Groups

Although the social setting of the activity called for *social* cooperation, it is evident that the nature of the task did not really require teamwork. In many groups, students sat around the table with the scale in the center but did not interact with each other. In some groups, the students worked individually or in smaller groups within the group at the table but did not relate to other group members. For example, in group G2 (four boys, see Fig. 4), Eli (S8) interacted mostly with Danny (S7), speaking only once to another group member, Avi (S9), to give him negative feedback. Many times, the members of this group did not communicate at all, leading to simultaneously placing the weights unevenly on the scale.

G3 (five students) is another example of a non-communicative group where the students mostly worked individually, interacting very little with one another.

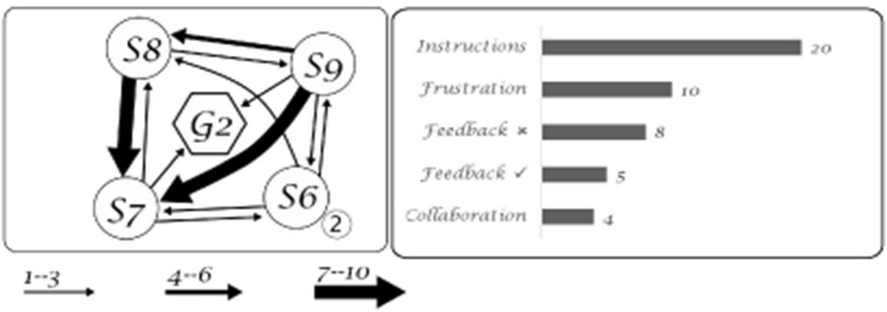

Fig. 4 Group G2—visual and graphic schemes of the interactions

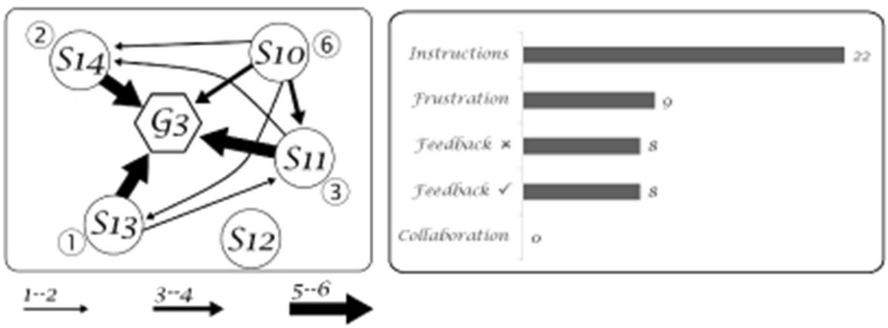

Fig. 5 Group G3—visual and graphic schemes of the interactions

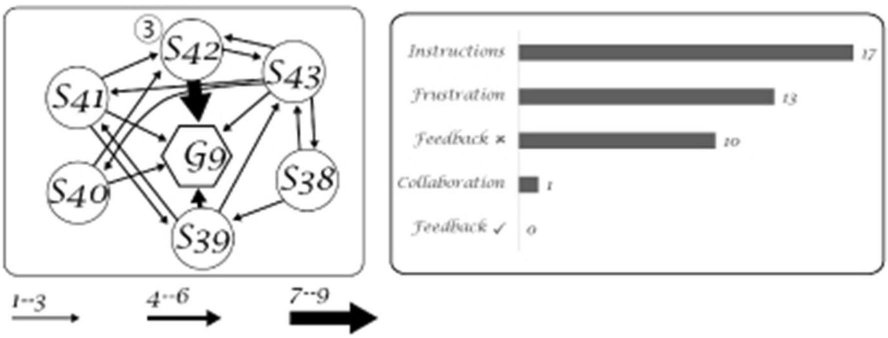

Fig. 6 Group G9—visual and graphic schemes of the interactions

For example, in G3, Gil (S11) addressed another group member only once, when he gave Gal (S14) a verbal instruction: "One, two, three, four… place here one [weight] (points at the scale) and… one two…" Other than this utterance, all of Gil's interactions were addressed to the group and not to a specific member. Gal (S14) only addressed the group as a whole, giving verbal instructions and positive and negative feedback. Shani (S12) is an example of a student who did not interact at all. Shani did not engage in the activity, nor did she address any of her group members or interact with the scale. None of the group members interacted with her, either. Notice that the only two students who spoke to each other were Yotam (S10) and Yael (S13): as is evident in Fig. 5, they are the only members of G3 with arrows pointing to and from each other, indicating they were the only two students who interacted directly with each other. Figure 5 reveals that most of the interactions in G3 were directed towards the whole group, rather than to a specific group member.

In comparison, six students in G9, Anat, Maya, Tal, Dudu, Tomer, and Roni (Fig. 6), directed their talk to one or two specific group members, creating sub-groups within the group.

In G9, Tal (S40) only addressed Tomer (S42); Tomer (S42) only addressed Roni (S43); and both of them addressed the whole group as well. Anat (S38) interacted only with Maya (S39) and Roni (S43), who were sitting next to her, while Dudu (S41) only spoke to Maya (S39) and Tomer (S42). Once again, students clearly referred to other group members without getting any response (as indicated by an arrow in one direction), as in the case of Tal (S40) and Tomer (S42), or Anat (S38) and Maya (S39), which not all arrows pointing from them have a reciprocate arrow from the same student in the opposite direction.

Although it may appear in some groups that students were active and interacted with each other, it was evident that this could not be considered group work, as the interaction did not reflect collaboration or cooperation.

To conclude, the findings reveal that each group engaged in a different form of collaborative and cooperative group work. Although each group's interactions were distinctive, nevertheless, common themes emerged. Moreover, even though the group work required cooperative learning, students did not engage in such. Students mostly instructed each other on how to operate the scale, without providing scientific explanations, resulting in minimal cognitive interactions. As the students did not know how to work together in order to solve the task, frustration abounded.

Discussion

This study aimed to explore cooperative learning during group work as part of a science museum laboratory visit. There are pedagogical challenges in integrating informal education in school visits to a science museum (Shaby et al., 2019, 2020). Most school visits are stand-alone events, with students visiting the museum perhaps once a year for a few hours, which makes the learning process hard to assess (Rennie & Johnston, 2004). Learning is a process that requires time for reflection and link new information with old, to reconstruct mental models in order to reassemble information, and to experience new ways of understanding (Rennie & Johnston, 2004). Furthermore, many informal education environments do not offer any preparation or follow-up work for the teacher to carry out at school, leading to doubtful connections to the students' prior knowledge or to the school curriculum (Nativ Ronen & Tal, 2019).

As demonstrated by the findings, the balancing scale activity did not promote cooperative learning. Lack of prior knowledge and pedagogy might be among the factors inhibiting cooperative learning in this case. The students in this research did not learn about balancing scales at school. More importantly, they were not prepared for such group work as was employed at the science museum. Studies regarding cooperative learning underscore students' lack of collaborative skills, emphasizing that students struggle to collaborate because they may not have experience in how to manage a cooperative task (Lee et al., 2020; Mello, 1993). Johnson and Johnson (1978) claim that students that are not socially unskilled in cooperative learning cannot be successful in it, unless trained in the interpersonal and small group skills needed to perform cooperation tasks and be motivated to use those skills. Training students beforehand on how to work together should not be taken for granted, as demonstrated in Hoek and Seegers' (2005) study, showing that at the start of the school year students mainly focused on finding answers when engaging in collaborative tasks. However, during the school year, when collaborative tasks were introduced with explicit instructions about how to work together and the students were trained to do so, the students showed development towards more productive patterns in their collaborative interactions.

The task (i.e. balancing the scale) designed by the museum staff might have seemed appropriate for promoting cooperative learning, but our findings show that the problem (the task) could be solved without any form of cooperation. As demonstrated by the findings, individuals in the group could simply place various weights on the scale, arriving at the correct solution by means of trial and error. Tasks that are designed to have a correct answer restrict collaboration and exchange of information or explanations that can promote problem solving, whereas open-ended tasks encourage higher levels of collaboration (Cohen, 1994; Shachar & Sharan, 1994). Therefore, designing a task that truly supports cooperative learning is crucial (Hoek & Seegers, 2005), as well as defining cooperative learning as one of the learning outcomes addressed by the ME (Abrahams & Millar, 2008). Moreover, although other studies in school settings suggest that overall achievement of cooperative learning may be high, this is not necessarily the case regarding each individual in the group. Heterogeneity in the group may lead to irrelevant work, or even to a situation where certain students are passive to the point of sitting and doing nothing (Raviv et al., 2019).

Lack of prior knowledge both with the content of the task and precious experience with cooperative learning along with the pedagogy of the activity resulted with minimal cooperation while engaging with the task. Another notable finding is the *absence* of cognitive interactions in the observed interactions.

As students were trying to solve the task simply by placing weights on the scale, they did not provide any scientific explanations for their actions, nor did they attempt to obtain any scientific information from other members in the group. These findings, or better yet, lack of findings, are consistent with others' work exploring outreach and informal science programs (Garner & Eilks, 2015). Research on outreach and informal educational programs shows increased motivation towards science learning and the development of a scientific identity (Millar et al., 2019) rather than cognitive outcomes. This is not to say that group activities in informal environments cannot promote cognitive outcomes. Affective outcomes and learning at a museum can be cognitively significant, but this requires appropriate preparation at school and well-planned activities (Sturm & Bogner, 2010). As the cognitive load during a museum visit is higher than at school because the environment is different, hence, the novelty is greater (Itzek-Greulich et al., 2015).

Implications

As this study demonstrates, the main impediment to the students' cooperative learning was the task (e.g. pedagogy). This raises a question regarding what ME can do to better design the environment to support cooperative learning. The importance of pedagogical design of a task was highlighted by Abrahams and Millar (2008), which stated that educators must acknowledge the fact that "doing" things with objects will not lead to the students' learning ideas or concepts unless provided with more scaffolding. Abrahams and Millar (2008) also mention that "The fundamental purpose of practical work in school science is to help students make links between the real world of objects, materials and events, and the abstract world of thought and ideas" (p. 4); however, those links must be introduced by the educator to the students.

Careful pedagogy and thoughtful facilitation can contribute to the students' learning outcomes. The following factors may contribute to this end: ensuring students have sufficient prior knowledge, having the ME play the role of a mediator, taking steps to reduce the level of student frustration by simplifying the task, and planning additional "aiding" activities that promote cooperation.

Prior knowledge is an essential element in the construction of new knowledge. The designed environment and activity must take the students' prior knowledge into consideration (Falk & Dierking, 2016). If this knowledge is insufficient, preparatory activities need to take place to ensure that the students have sufficient knowledge on which to build. These preparatory activities can be carried out either at school, prior to the museum visit, or at the museum itself, before the specific activities. We would like to note that there is a limit to what can be achieved in one standalone 45-min visit. Therefore, preparation prior to the visit is vital. Teachers should decrease cognitive novelty (Itzek-Greulich et al., 2015) as well as prepare the students for that kind of cooperative group work.

In order to foster learning, the group activity must be well-planned, adapted to the level of the students, and the instructor's guidance has to be particularly helpful to the students' learning process (Law, 2011). According to Law (2011), the role of the instructor (in our case, ME) is to provide scaffolding in the form of leading questions, as well as to guide the students and encourage them to find solutions through discussion and cooperative work. The ME must operate as a mediator, leading the specific students in the process of solving the task and guiding them with regard to their scientific reasoning, providing ongoing human mediation during the task. The ME must provide the required scaffolding and encourage collaboration and teamwork among all the group members. It might be worth introducing this activity to the accompanying teachers prior to the visit, asking them to act as additional mediators in this activity.

In addition, the pedagogy of the activity can benefit from simplifying to reduce frustration and promote cooperation. To achieve the first, the activity can be modified by introducing each element of the task at a time, in increasing level of difficulty, and not presenting all of the elements together (as it was, by writing four individual task elements on the white board). By doing so, students can try the first element and be given the solution before moving on to a "harder" element of the task. Another way to simplify this particular task is to place weights on one side of the scale *in advance*, so students will only need to balance it by placing weight on the other side. Advancing cooperative work might pose a greater challenge, particularly if students are not accustomed to this way of learning. However, the ME might ask students to try to place a weight by turn and explain to the group why the scale was balanced, or not. The following student will take that explanation into consideration before placing their weight. Another way would be to assign roles to each student (Bruffee, 1995): student who is in charge of physically placing the weight, student in charge of deciding where to place it, student in equity making sure everyone got their turn, and student in charge of summarizing the success or failure of each particular placement. This might feel forced to start but will direct the students into a more productive way of working together.

Limitations and Further Research

This research offers new insights into laboratory cooperative activities in science museums. As integrating informal venue as science museums in the formal curriculum is becoming more prominent, it is important to explore the range of advantages and disadvantages these settings can offer.

This research explored only four schools in one city in one science museum, further studies with bigger sample size are in need, along with diverse populations.

As prior knowledge and pedagogical design shown to inhibit cooperative learning in this case, an intervention plan considering those aspects might shed light on those elements, providing more concrete implications (such as suggested above). In addition, the ME instruction before the given task was out of the scope of this research (as explained in the methods), other research might consider including this in the analysis.

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Declarations

Competing Interests The authors declare no competing interests.

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