# MOSAIC Protocol: Analyzing Small Group Work to Gain Insights into Collaboration Support for Middle School STEM Classrooms

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**Abstract:** Collaborative learning is widely viewed as a tool for promoting educational equity and developing 21st-century skills. To support the improved facilitation of collaborative learning, this study applies the MOSAIC video analysis protocol to analyze student collaboration in small groups across 618 moments of support. The MOSAIC protocol provides insights into the types of support received, classroom conditions, and actions preceding and following support. Our analysis revealed a predominance of task-related support, with collaboration-focused support being notably less frequent. Activity design played a crucial role in accounting for the type of support provided.

## Introduction

Collaborative learning equips students with critical skills necessary for workforce preparation, including communication, social aptitude (Bower & Richards, 2006), and shared objectives (Johnson & Johnson, 2009) while also promoting equitable learning opportunities (Werner et al., 2004). However, students frequently encounter challenges managing their learning during small-group activities (Molenaar et al., 2010), and grouping students does not guarantee productive collaboration (Barron, 2003). Thus, a crucial need exists for targeted support to foster collaboration and improve collaborative learning experiences.

While there is a wealth of research on supporting individual learning (van de Pol et al., 2019; Webb & Palincsar, 1996), scaffolding the collaborative aspects of small-group work in Computer-Supported Collaborative Learning (CSCL) environments is less extensive, highlighting potential areas for further exploration. Artificial intelligence (AI) holds promise for enhancing online collaborative learning environments with features like task guidance and question-answering (Chen et al., 2019), though its application in physical settings is still emerging. For AI agents to be effectively integrated into face-to-face collaborative learning, a deeper understanding of current teacher support strategies in CSCL classrooms and the assistance needed is essential. Our study delves into *support moments* during small-group activities to understand the types of support received across different tasks in a collaborative unit and what student activity may have prompted it.

## Theoretical framework

Collaborative learning takes place when two or more students work to build a shared understanding and construct new knowledge together (Dillenbourg, 1999), through engagement in activities designed to mirror real-world complexities, leverage students' prior experiences, and foster a richer understanding by facilitating peer interaction (Bransford, 1999). Supporting students in their Zone of Proximal Development (Vygotsky, 1978) can enhance collaborative efforts by helping students accomplish together what they could not do alone.

We incorporate the Collaborative Problem Solving (CPS) framework (Graesser, 2019) to dissect the multifaceted nature of collaborative action in educational settings. CPS, involving small student groups tackling problems collectively, highlights skills such as establishing common ground, negotiation, coordination (Barron, 2003; Barron & Roschelle, 2009), knowledge building (Suthers et al., 2010), and effective communication, which are considered essential for collaboration. Further, we integrate CSCL principles, envisioning the AI as a dynamic, intelligent partner in the learning process. This perspective redefines the role of AI from a technological tool to an active collaborator in the learning environment, working synergistically with students and teachers.

### MOSAIC framework

We used the MOSAIC framework (Dey et al., 2024) to analyze specific instances of support within classroom interactions, focusing on *support moments* as the primary unit of analysis. A *support moment* starts when individuals outside the group (e.g., teachers, students from other groups, etc.) provide guidance or instructions to group members, and it concludes when they leave. The MOSAIC protocol (Table 1) examines details of the support moment and students' activity one minute before and after the support moment. Thirteen types of support are identified during the support moment, with three specifics to collaboration: collaborating with others, including group members, and building group consensus. These categories are not mutually exclusive, allowing a single moment to capture multiple types of support.

**Table 1**
*Summary of the MOSAIC Coding Protocol for Analyzing Support Moments*

| **General Information of the Support Moment** | |
|---|---|
| • Lesson in the Unit (1, 2, 3, 4)<br>• Sensor (environmental sensor, sound sensor, soil sensor, all sensors)<br>• Who Provides the Support? (teacher, peer, researcher)<br>• Who Initiates the Support? (teacher, students, peer, researcher)<br>• Who the Support is Addressed to? (whole class, a small group, a student) | |
| **Analyzing Student Behavior Before and After Support Moment** | |
| • Students on task | • Students share information |
| • Students off task | • Students ask questions |
| • Students get stuck | • Students offer ideas |
| • Students express a need for direction | • Students build on other's ideas |
| • Students talk about collaboration | • Socializing |
| **Type of Support During the Support Moment** | |
| • Validation | • Higher academic goal |
| • Strategy for problem solving | • "Get back to work" directive |
| • Getting the right answer | • Off-task support |
| • Collaboration | • Asks questions of the group |
| • Direction about the assignment | • Group asks questions |

To develop an AI agent to support small-group collaboration, we seek to answer the following questions:

1. What types of support are provided to students during small group activities in a computer science (CS) based collaborative unit?
2. How does the collaboration support vary based on classroom conditions, such as the activity design, the provider, the initiator, whether the support was solicited, and student activity in the minute before the support moment?

## Methods

### Participants and context

This study was conducted within research-practice partnerships between the NSF Institute for Student-AI Teaming and two school districts in rural and suburban areas of the Western United States. Data collection included video recordings from four teachers across 17 classrooms of 7th and 8th graders, for a total of 302 consenting students. Students participated in these activities in small groups of 2 to 4 members, with teachers circulating to provide support.

The instructional context is the Sensor Immersion unit, an inquiry-based CS curriculum (Gendreau Chakarov et al., 2019) that strongly emphasizes collaborative skills through three kinds of small-group activities:

1. *Card-Sort (Lesson 1):* Students engage in discussions to identify and understand the characteristics of effective explanatory science models.
2. *Program and Wiring (Lessons 2, 3, and 4):* Students work with physical sensor systems (environmental, sound, and soil sensors) for the chosen project.
3. *Jigsaw (Lesson 4):* Each student becomes an expert in one of three sensors and then shares their expertise within a small group of three, promoting an exchange of knowledge.

### Data analysis

We used the MOSAIC coding protocol to identify and examine 618 support moments from 205 videos, totaling approximately 21 hours of small group work. We used Krippendorff's Alpha for reliability, chosen for its flexibility in evaluating various metrics and multi-observer data (Hayes & Krippendorff, 2007). The average Krippendorf's alpha is 0.44, indicating moderate agreement due to the infrequent items in the dataset. The lead author performed expert coding, re-evaluating, and reaching consensus on rare items to improve reliability.

We used logistic regression to investigate the effects of activity type, type of support, and preceding actions on whether groups received collaboration support (1) or not (0), focusing on six categorical variables:

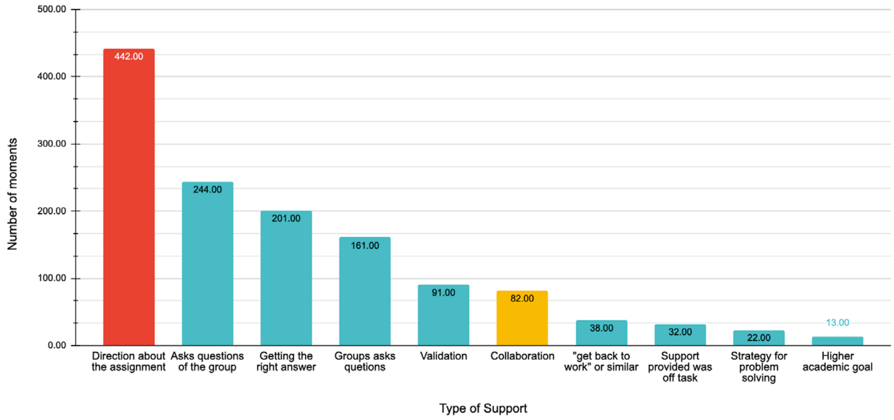
lesson activity, sensor type, support provider, initiator, recipient, and student activity before support. We incrementally built models, including only significant categorical variables adjusted by Sidak correction for conservatism.

## Results

To address our first research question, we analyzed the types of support provided during small group activities (Figure 1). The most frequent support type was *Direction about the assignment*, accounting for approximately 71.5% of the total support. This finding contrasts with the typical expectations for a high-structure classroom, where students usually require less process support (Mäkitalo-Siegl et al., 2011).

*Collaboration* support was found only 82 times, representing about 13% of all support moments and less than one-fifth as frequent as *Direction about the assignment* support. Given the curriculum's collaborative emphasis, this finding prompts consideration of whether teachers should provide greater collaboration in the classroom or if the result reflects a greater student need for task-related support. We also noticed that when the teacher *Asks questions of the group* or the *Group asks questions* of the teacher, the support types mirrored the overall support distribution, indicating that the act of asking and answering questions did not significantly alter the received support.

**Figure 1**
*Frequency of Each Type of Support (n = 618 moments of support)*




We initially performed a regression model with six covariates to address our second research question. While model fit improved with the addition of covariates and both who initiated and who was addressed by the support had some significant covariation, the most significant results were related to lesson activity. This remained significant even when accounting for other covariates, revealing an association between activity design and collaboration support. Post-hoc tests showed that none of the coefficients showed statistically significant differences when compared to covariates within the same category other than the reference group (i.e., Lesson 2). Analysis of the odds ratios presented in Table 2 showed that collaborative support was significantly more likely (odds ratio 2.31, $p<0.01$) when students worked on the Lesson 4 jigsaw than when they programmed in Lesson 2. Lesson 2 was significantly less likely (odds ratio 0.12, $p<0.001$) to have collaboration support than other lessons.

**Table 2**
*Results from Logistic Regression to Explore the Impact of Lesson Activity on Collaboration Support*

| | Categorical Variable 1: Lesson Activity | | | | |
|---|---|---|---|---|---|
| Covariate | L1 Card sort | L2 Programming | L3 Programming | L4 Jigsaw | L4 Programming |
| Model 1 | 1.44<br>(-0.56) | **0.12*****<br>**(-11.57)** | 0.45<br>(-1.45) | **2.31****<br>**(-2.77)** | 0.50<br>(-0.94) |
| pseudo $R^2 = 0.04$; $chi^2 = 0.01$; $p = 0.01$ | | | | | |
| Exponentiated coefficients present odds ratios; z statistics in parentheses. * p<0.05, ** p<0.01, *** p<0.001. | | | | | |

## Discussion

This research highlights a significant reliance on support focusing on task direction, even in classrooms that implement a curriculum emphasizing collaboration. Considering that procedural support is closely tied to specific curricula, there is a promising opportunity for AI interventions or AI partners to alleviate the burden of routine support tasks from teachers. This, in turn, would allow teachers to dedicate more effort to providing higher-level assistance, such as facilitating problem-solving and enhancing collaboration among students.

The MOSAIC protocol helped us identify *lesson activity* as the most significant covariate related to collaboration support. Students received more collaboration support during the jigsaw activity in lesson 4 than during the first programming and wiring task in lesson 2. The complexity of the jigsaw activity, requiring contributions from all team members, likely necessitated increased support for effective collaboration. This activity also provided a structure that assisted teachers in facilitating collaboration, thus fostering positive student interdependence (Johnson & Johnson, 2009). Surprisingly, the regression model revealed that lesson 2 saw students receiving less collaboration support, despite this being their first encounter with a complex form of collaboration (pair programming). This discrepancy may be attributed to the task's complexity; the introductory nature of the programming and wiring tasks might not have sufficiently challenged students to engage their collaborative skills.

Our study has highlighted several focal points and tensions in the quest to better support teachers and students in a collaborative learning environment. Even though our analysis had a rich data set of 618 support moments, our study's focus on a singular curriculum unit within middle school classrooms may limit the generalizability of our findings. Future research should aim to extend this analysis to other curricula and contexts, as well as refine and extend our regression model to encompass post-support activity to understand collaborative support dynamics better. Such insights are vital for developing AI agents that effectively support collaborative learning experiences.

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