Learning Engagement in Elementary Science Collaborative Classrooms: Current Status and Influencing Factors

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Abstract: Learning engagement is an important indicator for evaluating students' learning outcomes and classroom quality, and it plays a critical role in improving the quality of elementary science teaching and fostering students' scientific literacy. Based on engagement theory and the characteristics of science education, this study developed an analytical framework for learning engagement in elementary science collaborative classrooms. Eight classroom videos were analyzed using NVivo. The results show that students demonstrated relatively high levels of behavioral engagement, while deeper learning behaviors were less evident. Social engagement supported basic collaboration, but emotional interaction and peer support were limited. In terms of cognitive engagement, students were active in expressing ideas, whereas higher-level cognitive processes remained insufficient. Emotional engagement was mainly characterized by positive and neutral states. Further analysis indicates that classroom organization and task design, teacher guidance and feedback, and the quality of group collaboration are key factors influencing learning engagement in elementary science collaborative classrooms.

Keywords: Learning Engagement; Elementary Science Education; Collaborative Learning; NVivo

1. Introduction

The primary goal of elementary science education is to develop students' scientific literacy. Classroom learning activities serve as a key context in which students understand scientific concepts, develop scientific thinking, and engage in scientific practices. With the ongoing curriculum reform, inquiry-oriented collaborative learning has become an essential instructional approach. Through working with peers to solve problems, collaborative learning supports the development of students' problem-solving abilities and higher-order thinking skills [1].

The effectiveness of collaborative learning is closely related to students' learning engagement [2]. Collaborative learning engagement refers to a shared psychological state in which group members are active, effortful, and positively involved in joint tasks. As an important indicator of students' participation in learning processes, learning engagement has been widely used to evaluate classroom quality and learning outcomes [3]. In collaborative settings, engagement is not only reflected in individual participation, but also in the quality of interaction and cooperation among group members, making it a valuable lens for understanding collaborative learning [4].

However, both prior studies and classroom practices suggest that students' engagement in elementary science collaborative classrooms remains limited in several ways. Existing research has mainly focused on individual dimensions such as behavioral, cognitive, and emotional engagement, while paying less attention to social interaction in collaborative contexts. In science education, although inquiry and practice are emphasized, empirical studies that systematically examine the structure and dynamic features of learning engagement in classroom settings are still insufficient. In particular, there is a need to better understand how students' engagement can be described from a multidimensional perspective and how it is manifested in authentic elementary science classrooms.

To address this gap, this study draws on collaborative learning engagement theory and the characteristics of science education to develop an analytical framework for learning engagement in elementary science collaborative classrooms. It aims to examine students' engagement patterns and explore the factors that influence them, providing both theoretical insights and empirical evidence for improving classroom practice.

2. The Multidimensional Nature of Learning Engagement

The concept of learning engagement was first proposed by Fredricks and colleagues, who categorized it into three dimensions: behavioral, cognitive, and emotional engagement [5]. This framework highlights the extent to which learners participate in and invest effort in the learning process. As research in this area has progressed, the understanding of learning engagement has expanded beyond individual participation to include more complex and context-dependent forms.

In collaborative learning settings, engagement is no longer limited to individual involvement but reflects a broader range of participation within group activities. Kearsley and Schneiderman's theory of collaborative learning engagement emphasizes that meaningful engagement can be fostered through group interaction, creative tasks, and the production of shared outcomes in authentic contexts [6]. Building on this perspective, Sinha and colleagues further extended the concept by identifying behavioral, cognitive, social, and conceptual outcome dimensions of engagement, highlighting the interaction between individual thinking and group-level collaboration [7].

Drawing on these perspectives, this study defines learning engagement in elementary science collaborative classrooms as a multidimensional state of participation that emerges during group-based learning activities. It includes four key dimensions: behavioral, cognitive, social, and emotional engagement. Behavioral engagement refers to students' level of participation in collaborative tasks. Cognitive engagement reflects the depth of their involvement in knowledge construction and problem solving. Social engagement involves the interactions and supportive behaviors among group members. Emotional engagement captures students' feelings and affective responses during the learning process.

3. A Practice-Oriented Context for Learning Engagement in Science

The Next Generation Science Standards (NGSS), developed through a collaboration of multiple states in the United States, provide a framework for K–12 science education that includes three core dimensions: science and engineering practices, disciplinary core ideas, and crosscutting concepts [8]. Among these, the dimension of science and engineering practices emphasizes students' active involvement in scientific inquiry and engineering design, aiming to develop their scientific thinking and problem-solving abilities.

Elementary science classrooms share a similar emphasis on hands-on inquiry and collaborative learning. Students engage in experiments, problem solving, and group work to build their understanding of scientific concepts and practices. This alignment highlights the relevance of practice-oriented learning environments in shaping how students participate in classroom activities. Within such contexts, students' learning engagement is often reflected through observable actions. Activities such as conducting experiments, recording observations, and presenting results provide visible indicators of behavioral participation. At the same time, discussions and explanations around problem solving offer opportunities to examine students' cognitive and social engagement.

From this perspective, the practice-oriented approach emphasized by NGSS offers an important contextual foundation for this study. Building on a multidimensional framework of learning engagement, this research situates students' participation within the specific practices of elementary science classrooms, allowing for a more contextualized analysis of engagement across different stages of learning activities.

4. Participants and Methods

4.1 Participants

This study adopted a purposive sampling approach, considering curriculum topics and core concepts in science. Eight elementary science experimental lesson videos were selected from the "National Smart Education Platform for Primary and Secondary Schools" in China. The selected lessons cover a range of core scientific concepts, as shown in Table 1.

Table 1. Overview of Selected Lessons

No.	Core Scientific Concept	Lesson Topic
L1	Structure and properties of matter	Exploring whether common materials sink or float in water

L2	Changes of matter and chemical reactions	Making soda
L3	Motion and interactions of matter	Measuring force using a spring scale
L4	Energy transformation and conservation	Electricity and magnetism
L5	Levels of organization in living systems	Observing the human respiratory system
L6	Earth in the universe	Simulating Earth's revolution
L7	Earth systems	Observing soil
L8	Engineering design and application of matter	Measuring time using water

4.2 Research Procedure and Methods

Drawing on collaborative learning analysis models developed by previous studies [911], this study developed an analytical framework for learning engagement in elementary science collaborative classrooms. The model was adapted to fit the characteristics of experimental science lessons and includes four dimensions: behavioral, cognitive, social, and emotional engagement. The detailed framework is presented in Table 2.

Table 2. Analytical Framework for Learning Engagement in Elementary Science Collaborative Classrooms

Dimension	Sub-dimension	Indicators
Behavioral Engagement (B)	Experiment operation (B1)	Rigor and accuracy in conducting experiments
	Observation and recording (B2)	Completeness and organization of data recording
	Problem solving (B3)	Engagement in discussing problems and applying scientific methods to explore solutions
	Reporting results (B4)	Clarity and organization in presenting results
Cognitive Engagement (C)	Question posing (C1)	Frequency of raising innovative or critical questions
	Expressing ideas (C2)	Use of prior scientific knowledge; proposing solutions with reasoning; explaining and analyzing problems; drawing conclusions; responding to others' ideas
	Reflection and revision (C3)	Instances of reflection and self-correction
	Metacognition (C4)	Self-monitoring and adjustment of learning strategies during experiments
Social Engagement (S)	Active listening (S1)	Behaviors such as maintaining eye contact, nodding, and leaning forward during interactions
	Team collaboration (S2)	Balance in role distribution and participation within the group
	Encouraging participation (S3)	Instances of inviting and responding to peers' ideas
	Social-emotional support (S4)	Use of inclusive language; supportive and encouraging behaviors; willingness to help peers
Emotional Engagement (E)	Positive (E1)	Expressions of interest, excitement, and curiosity
	Confusion (E2)	Expressions of doubt or uncertainty
	Negative (E3)	Signs of disengagement or negative emotions
	Neutral (E4)	Lack of clear emotional expression during interaction

Based on this coding scheme, a second researcher independently coded the same lesson using NVivo 14. The inter-coder agreement reached 85 percent, indicating a high level of reliability.

This study selected eight elementary science experimental lessons as the research context to explore two key questions: What are the current patterns of students' learning engagement in elementary science collaborative classrooms, and what are the main factors influencing such engagement? Using NVivo as a qualitative analysis tool, classroom videos were systematically examined to identify the characteristics and limitations of learning engagement across different dimensions. Based on this analysis, the study further explored the key factors that shape students' engagement in collaborative learning settings.

5. Learning Engagement in Elementary Science Collaborative Settings

5.1 Behavioral Engagement

Within the dimension of behavioral engagement, clear differences can be observed across sub-dimensions (see Figure 1). Students showed relatively high levels of participation in experiment operation (B1) and result presentation (B4), which were present in most of the lessons. This suggests that students were generally active during hands-on activities and presentation stages.

In contrast, observation and recording (B2) occurred less frequently. This may indicate that students have limited ability in systematically recording data and organizing information during experiments. It also reflects a possible lack of emphasis on recording practices and process-oriented expression in classroom instruction, as well as insufficient familiarity with recording methods. Problem solving (B3) showed the lowest level of engagement among all sub-dimensions. Students demonstrated limited involvement in exploring solutions independently, including proposing ideas, adjusting strategies, and sustaining the problem-solving process. Classroom activities tended to focus more on following procedures and presenting results rather than engaging in extended inquiry.

Overall, while students demonstrated a high level of participation in behavioral terms, deeper forms of engagement related to inquiry and problem solving remain underdeveloped.

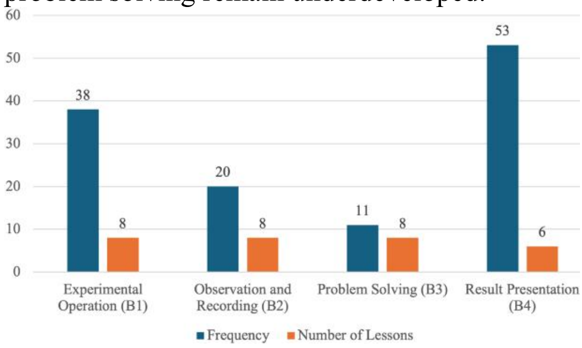

Figure 1. Frequency and Number of Lessons for Behavioral Engagement Sub-Dimensions

5.2 Cognitive Engagement

Cognitive engagement shows a clear imbalance across sub-dimensions (see Figure 2). Students demonstrated relatively high levels of participation in expressing ideas (C2). They were generally active in presenting results and viewpoints, often drawing on prior knowledge to propose solutions and explain or summarize problems during group discussions. In contrast, other sub-dimensions of cognitive engagement were much less evident. Reflection and revision (C3) and metacognition (C4) remained limited. Although a small number of students showed the ability to reflect on experimental results and make adjustments, such behaviors were not widespread. Overall, students rarely engaged in sustained reflection on their learning strategies or thinking processes, and they seldom monitored or adjusted their approaches during experiments. This pattern may be partly related to insufficient instructional guidance.

Question posting (C1) was also rarely observed. Students seldom initiated questions during classroom activities. This may be influenced by the classroom context. On the one hand, the lessons analyzed were open demonstration classes, where maintaining order was emphasized, potentially limiting students' willingness to ask questions. On the other hand, the level of openness and complexity in experimental tasks may not have been sufficient to stimulate students' curiosity and encourage inquiry.

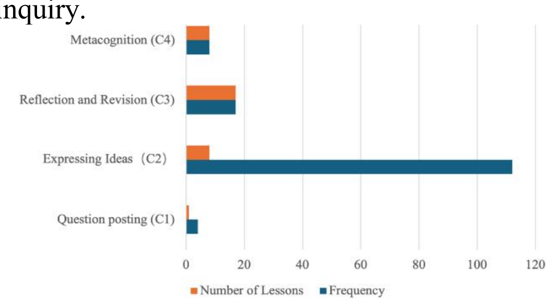

Figure 2. F Frequency and Number of Lessons for Engagement Sub-Dimensions

5.3 Social Engagement

Within the dimension of social engagement, students' participation was mainly concentrated on listening and task-oriented collaboration (see Figure 3). Active listening (S1) and team collaboration (S2) showed relatively high levels of engagement, indicating that students were generally able to communicate and coordinate with peers to complete experimental tasks. In contrast, encouraging participation (S3) and providing social-emotional support (S4) were less evident. Most students tended to focus on completing assigned tasks, with limited initiative in inviting others' input or responding to peers' ideas. This suggests that interaction within groups remained largely task-oriented, with relatively little emotional exchange. Supportive and inclusive language was also infrequent. These patterns may be related to several factors. Classroom tasks often emphasize procedural completion over interpersonal interaction, which may limit opportunities for emotional engagement. In addition, limited familiarity among group members, a lack of collaborative experience, and time constraints in classroom settings may also contribute to the relatively low level of social-emotional interaction.

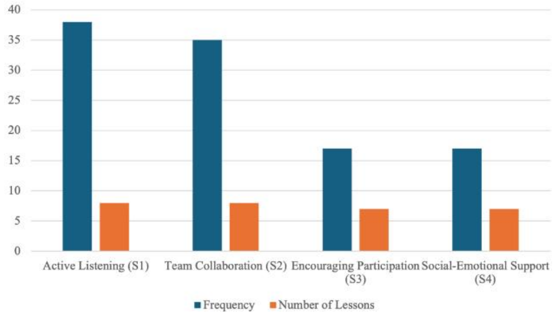

Figure 3. Frequency and Number of Lessons for Social Engagement Sub-Dimensions

5.4 Emotional Engagement

Emotional engagement plays an important role throughout the collaborative learning process, as it influences students' motivation and depth of participation. Overall, emotional engagement was characterized mainly by neutral (E4) and positive (E1) states (see Figure 4). Students often showed interest and enthusiasm during experimental activities, with positive emotions frequently observed. However, in task-oriented and time-limited collaborative settings, emotional expression tended to decrease. Neutral emotional states accounted for a relatively large proportion, suggesting that students were more focused on task completion than on expressing feelings. This pattern may indicate that some students were only minimally engaged at an emotional level, highlighting the need for timely emotional support and encouragement from teachers to sustain motivation. Feelings of confusion (E2) were most commonly observed during problem-solving and observation stages, indicating that some students experienced uncertainty when dealing with complex tasks or unclear role distribution. Negative emotions (E3) were relatively rare, suggesting that most students maintained a generally positive attitude toward the classroom environment.

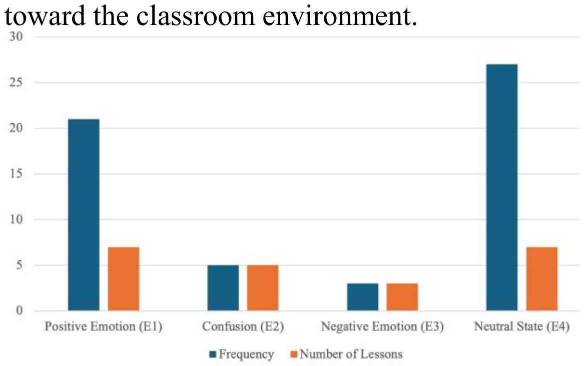

Figure 4. Frequency and Number of Lessons for Emotional Engagement Sub-dimensions

6. Factors Influencing Learning Engagement in Elementary Science Collaborative Settings

6.1 Instructional Design and Task Structuring

Instructional design plays a key role in shaping students' learning engagement. Effective learning activities are typically supported by clear goals, well-structured tasks, and appropriately challenging learning situations. In the lessons analyzed in this study, structured instructional design helped sustain students' behavioral participation and supported basic cognitive engagement, while also contributing to a certain level of social and emotional involvement within groups.

Clear task structures were particularly important for maintaining behavioral engagement. In Lesson L1, the teacher provided detailed experimental procedures and refined task steps, allowing students to follow a structured process and remain consistently involved in group activities. While such design ensured continuous participation, it also tended to orient students toward task completion rather than deeper exploration.

Task structuring also influenced cognitive engagement. In Lesson L6, the teacher broke down a complex phenomenon into stages such as model construction, data recording, and scientific reasoning. This provided students with a scaffolded pathway to engage in more advanced thinking. However, although such structuring supported the progression of tasks, students' engagement in reflection and metacognitive regulation remained limited.

The design of challenging tasks further affected students' social and emotional engagement. In some lessons, students were required to collaborate to complete relatively complex tasks, which encouraged coordination and basic interaction within groups. For example, in Lesson L8, students were asked to design a practical solution by adjusting water flow to measure time. The open-ended nature of the task stimulated curiosity and interest, and students showed a sense of accomplishment upon completing the activity.

Despite these positive effects, such instructional designs mainly supported participation centered on task completion. Interaction among students remained largely functional, with limited emotional exchange and relatively few supportive or encouraging behaviors.

6.2 Teacher Guidance and Feedback

Teacher guidance and feedback play an important role in shaping students' learning engagement across multiple dimensions. Targeted cognitive guidance and open-ended questioning can support deeper learning and higher-order thinking. In Lesson L3, students showed relatively strong metacognitive engagement, which was closely related to the teacher's interactive feedback. By evaluating students' experimental results from multiple perspectives, the teacher prompted them to reflect on key aspects such as variable control, thereby encouraging deeper cognitive involvement. When guidance is insufficient or task expectations are unclear, students' participation may become unfocused. In some lessons, vague task instructions led to off-task discussions and reduced engagement during experimental activities. This suggests that effective guidance is necessary not only for maintaining participation, but also for directing it toward meaningful learning goals.

Process-oriented feedback also helps regulate students' behavioral and social engagement. In Lesson L8, when uneven task distribution reduced group interaction, the teacher used guiding questions to prompt students to reconsider their roles and redistribute tasks. This helped restore participation and supported basic collaboration within the group. However, such feedback mainly focused on task completion and had limited impact on promoting deeper interaction or discussion.

In terms of emotional engagement, teachers' supportive feedback can help students cope with frustration and sustain motivation. In Lesson L2, when students felt discouraged due to unclear experimental results, the teacher explained the conditions of the reaction and encouraged them to adjust variables. This support enabled students to persist and experience a sense of accomplishment. Nevertheless, emotional feedback in most cases remained reactive, addressing immediate difficulties rather than providing consistent encouragement throughout the learning process.

6.3 Group Collaboration

The level of collaboration within student groups shows a clear association with overall learning engagement. In lessons where social engagement was relatively high, students also tended to demonstrate higher levels of engagement across behavioral, cognitive, and emotional dimensions (see Table 3). For example, in Lessons L2 and L6, group members maintained ongoing communication and coordinated their efforts through task distribution, which supported sustained participation throughout the activities. In these cases, students engaged in active discussion and established a basic sense of trust, allowing them to work more effectively as a group. Clear role allocation helped involve each member in the task, while supportive language and peer encouragement reduced uncertainty during experimental processes. As a result, students were able to complete problem-solving tasks and experimental procedures more efficiently. By contrast, in groups with limited interaction, participation tended to be more passive. Students often focused on completing assigned tasks with minimal communication, and emotional exchange was relatively limited. This lack of interaction and support may reduce students' motivation and weaken their overall engagement. These findings suggest that group collaboration is not only reflected in task coordination, but also in the quality of interaction and the presence of peer support, both of which can influence students' engagement in collaborative learning.

Table 3. Frequency of Social Engagement and Total Learning Engagement Across Lessons

No.	Lesson Topic	Frequency of Social Engagement	Total Learning Engagement
L1	Exploring whether common materials sink or float in water	8	44
L2	Making soda	24	75
L3	Measuring force using a spring scale	13	52
L4	Electricity and magnetism	6	43
L5	Observing the human respiratory system	15	51
L6	Simulating Earth's revolution	19	75
L7	Observing soil	11	43
L8	Measuring time using water	11	43

7. Conclusion

This study developed an analytical framework for learning engagement in elementary science collaborative learning contexts and conducted a qualitative analysis of students' participation across behavioral, cognitive, social, and emotional dimensions. The findings reveal clear structural differences in engagement. Behavioral engagement was relatively strong, mainly reflected in experiment operation and result presentation. Cognitive engagement was dominated by idea expression, while deeper processes such as reflection, revision, and question generation were less evident. Social interaction generally supported task completion, but emotional exchange and supportive interaction remained limited. Emotional engagement was relatively stable, yet the overall level of emotional involvement was not high. Overall, classroom participation tended to be task-oriented, with limited depth in both cognitive and emotional engagement. Further analysis suggests that behavioral engagement is closely related to the clarity of task design. Teacher guidance and feedback can regulate students' cognitive and collaborative processes, although such support is often focused on task completion. High-quality social interaction within groups can indirectly enhance both cognitive and emotional engagement, while positive emotional experiences can help sustain students' participation in classroom activities.

This study has several limitations. The sample size is relatively small and mainly consists of demonstration lessons. In addition, the study relies primarily on qualitative analysis, and the relationships among variables have not been fully examined. Future research could expand the sample scope and incorporate quantitative methods and instructional interventions to further explore the mechanisms of learning engagement and ways to improve it.

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