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Fostering Students' Dialogic Engagement with the Use of Visual Learning Analytics as a Teaching Assistant Tool in Primary School Classrooms

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Abstract: Using visual discourse tools can be a valuable approach for teachers to foster academically productive talk in the classroom. However, teachers often pay considerable attention to highly engaged students and fail to create sufficient opportunities for less engaged students to participate in classroom dialogue. This study seeks to enhance learning by incorporating social network analysis to elucidate students' levels of engagement in classroom discourse. Over a three-week period, this study analyzed both overall and individual student's dialogic engagement in the classroom. The results demonstrate that as teachers purposefully lead class dialogue and limit their own speech, students gradually speak more. Additionally, those who initially speak less are given more opportunities to engage in classroom dialogue. These results emphasize the significance of using visualization tools to assist teachers in orchestrating and optimizing classroom dialogue.

Keywords: Visual learning analytics, dialogue visualization, dialogic engagement, social network analysis, primary school classroom

1. Introduction

Classrooms are dynamic social and physical environments where teaching and learning occur through interactions between teachers and students. To facilitate effective learning, teachers must organize and manipulate environmental structures, instructional activities, and classroom resources to guide students' attention and learning, thus allowing students to acquire a wide range of knowledge and skills. However, teachers often encounter considerable challenges when attempting to ensure that students are engaged in learning and discussion in the classroom (Saunders-Stewart et al., 2012). Despite the availability of various support tools in research (e.g., visualization-based scaffolding), few are used in practice, and there is a lack of sufficient strategies to aid teachers in optimizing their teaching approaches (Echeverria et al., 2019; Urhahne et al., 2009). This phenomenon is particularly pronounced in primary school classrooms where students' learning performance is highly dependent on practices that place high demands on teachers (Wolery & Hemmeter, 2011). More empirical evidence is needed to explore how to support talk-based instruction in primary school classrooms and enable students to engage in learning more effectively (Mavrikis et al., 2019; Urhahne et al., 2009).

Visual learning analytics is a combination of learning analytics and visualization techniques that represent learning and teaching information. This approach goes beyond simply summarizing and visualizing data and presents the classroom learning process in a form that is easy for users to understand (Hsiao & Lin, 2017). These visual approaches can also function as teaching assistant tools. For example, Chen (2020) developed the classroom discourse analyzer (CDA) to aid teachers in reflecting on classroom dialogue and improving classroom teaching practices. They found that visualization-based scaffolding enhanced teachers' self-efficacy in orchestrating effective classroom dialogue and significantly impacted classroom teaching behaviors (Chen et al., 2020). While this visual

tool had a positive impact on middle and high school classrooms, its effectiveness in elementary schools, where children are more likely to be distracted and disengaged (Downer et al., 2007), requires further investigation. Furthermore, besides focusing on students who are more proficient in the classroom, these analytical methods must also be extended to focus on marginal learners and the participation of the entire class. Therefore, this study attempts to introduce social network analysis to further support classroom teaching and investigate its impact on students' engagement in classroom dialogue. The research questions are as follows:

RQ1: What are the influences of discourse-based visual tools on the overall dialogic engagement in the classroom?

RQ2: What are the influences of discourse-based visual tools on individual students' dialogic engagement in the classroom?

RQ3: Do students exhibit significant improvements in their learning performance when discourse-based visual tools are incorporated into classroom learning?

2. Literature Review

2.1 Talk-Based Instruction

Talk-based instruction is beneficial for student learning and skill development, particularly for elementary school students with less learning experience who require more dialogue guidance from teachers to participate in the classroom. According to the "two-thirds rule" uncovered by Flanders (1964), verbal communication dominates classroom practice and its quality is crucial to what and how students learn during lesson time (Khong et al., 2017). Therefore, it is critical for teachers to consciously guide students' awareness of their behaviors and discourse.

Michaels and O'Connor (2015) put forward a form of talk referred to as academically productive talk (APT), which holds several talk moves that encourage teachers to give students more space to (1) share or clarify their initial ideas (e.g., "Can you say more about it?"), (2) listen carefully to one another (e.g., "Do you repeat his idea in your word?"), (3) deepen their reasoning (e.g., "Why do you think that?"), and (4) think together (e.g., "Do you add on to his idea? Why?") (Michaels & O'Connor, 2015; O'Connor & Michaels, 2019). APT prompts teachers to encourage students to elaborate, reason, argue, and share thoughts to aid students' learning. It creates an atmosphere of equal teacher-student dialogue, which helps students to generate new ideas in collaboration, thus deepening their own understanding and communication skills. Studies have shown positive relationships between productive dialogue and students' academic achievements in mathematics (Chen et al., 2020), English (Vetter et al., 2021), and reading (Barak & Lefstein, 2021).

2.2 Discourse Visualization Tool

Discourse visualization is a technical scaffolding used in the talk-based classroom that employs visual learning analytics to provide a more structured way for teachers to make sense of dialogue information. This approach is widely used in the learning environment to increase students' collaborative discourse engagement (Celepkolu et al., 2022) and foster diverse students' science learning (Ryoo & Bedell, 2019). The Classroom Discourse Analyzer (CDA) is this kind of discourse visualization platform (Chen, 2020), as shown in Figure 1. The CDA comprises dynamic, interactive statistical graphs that represent talk moves between teachers and students (Chen, 2020; Chen & Chan, 2022) and social network analysis that models classroom interaction (Mameli et al., 2015; Wolf et al., 2022).

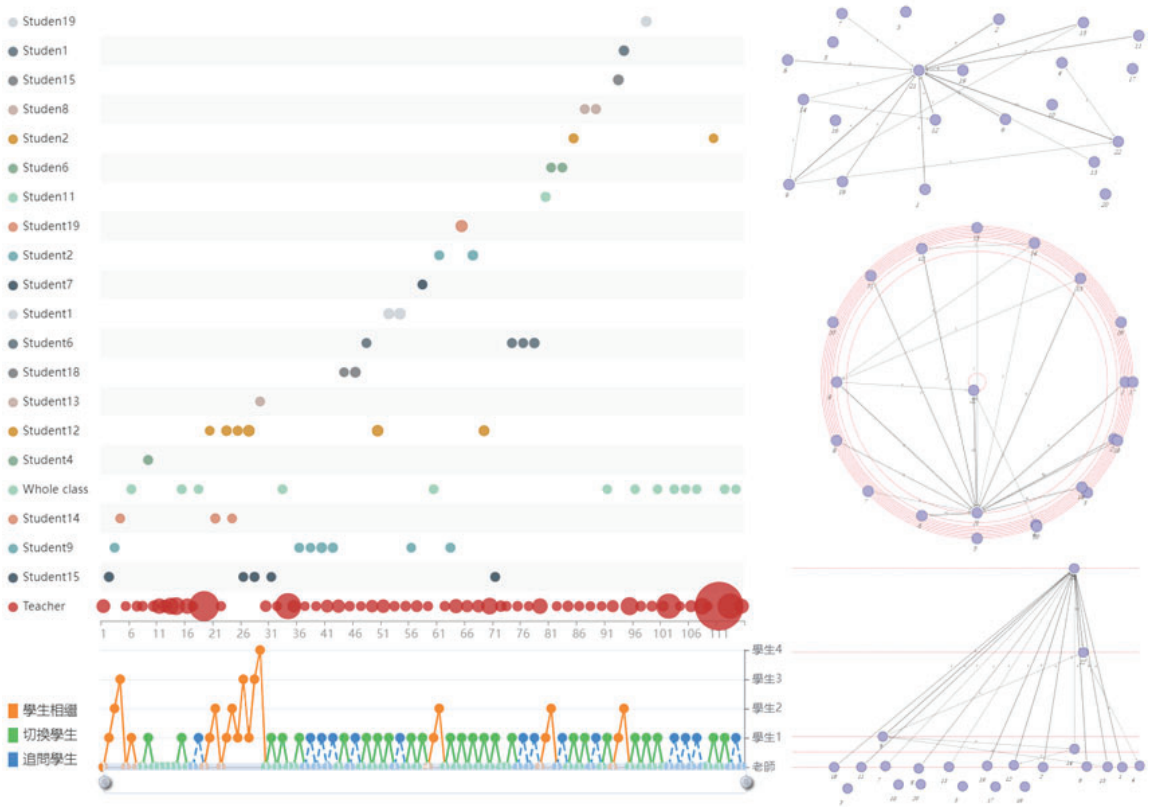


Figure 1. The Classroom Discourse Analyzer's (CDA) Visualization of the Whole-class Talk in a 35-min Lesson.

Dynamic interactive statistical graphs use bubbles, tables, and statistics to show classroom discourse information, as shown on the left side of Figure 1. This information includes the number of words, turns, and student-teacher talk patterns (Chen, 2020). Each bubble in the graph represents a participant's talk, and the size of the bubble corresponds to the number of the participant's words spoken. The picture in the lower left corner of Figure 1 illustrates turn-taking among participants and represents the number of student-student and teacher-student talks in the real classroom setting.

Social network analysis identifies overall discursive interaction and individual contribution in regular classroom activities, as shown on the right side of Figure 1. In these analyses, ties indicate the quantity of network participants, and relationships show the amount of messages sent and received by each network member (Bokhove, 2016). Network density is a global metric that represents the total number of possible ties and the overall tightness of the network. Generally, the higher the frequency of interaction, the higher the density of the network. The nodal degree involves in-degree ties (the quantity of messages received from others) and out-degree ties (the quantity of messages sent to others) (Mameli et al., 2015). The degree of centrality measures the relevance of a network participant's amount of dialogues taking place in a classroom (Bokhove, 2016).

2.3 Dialogic Engagement

Learner engagement refers to whether and how students respond to the learning environment, which correlates with academic performance, persistence, and satisfaction (Bergdahl, 2022; Yang et al., 2022). Dialogic engagement is a critical component of classroom engagement that indicates whether learners actively participate in classroom instruction and exchange ideas with peers or teachers. Analyzing discourse could contribute to understanding students' classroom engagement. Therefore, this study views student-student and student-teacher dialogue as an indicator to reveal classroom engagement.

Social network analysis is widely used to explore classroom interaction. For example, Bokhove (2016) proposed dynamic social network analysis (SNA) to model classroom

interaction through video and transcript data, representing the changes in overall interaction patterns over time. Mameli et al. (2015) utilized a similar approach to identify the discursive patterns of each classroom activity. Previous studies have shown that the single social network presents the overall interaction of the classroom, and adding temporal analysis can reveal the classroom participation of individual learners. Thus, this study attempts to utilize social network analysis to uncover the overall and individual dialogic engagement over time.

3. Methods

3.1 Participants

This study was conducted in a second-grade primary classroom in Hong Kong, China, with the participation of 20 students and their teacher. The teacher holds a master's degree and is a senior teacher with seven years of teaching experience. Prior to the official launch of the intervention, we informed students' parents of the interventional plan and obtained their consent. The classroom consisted of 7 boys and 13 girls with an average age of eight years. The teaching content focused on learning basic programming concepts through graphical operations, such as sequences, loops, control, and events.

3.2 Design of the Intervention

The intervention was divided into two stages, as shown in Figure 2. Prior to the intervention, we conducted two workshops to train teachers on the use of APT and CDA. This guaranteed that the teacher could proficiently use APT as the discourse framework during the class and gain basic knowledge of CDA used by teacher-research collaboration before each class. In the follow-up stage, we carried out three sessions of the intervention over the course of three weeks. During each session, we used video cameras to record the complete classroom for approximately 35 minutes per lesson. We then used CDA to analyze and visualize classroom dialogue interaction by converting the audio from the videotape to text. Based on the CDA analysis, we co-designed a plan for instruction improvement, such as providing opportunities for students who spoke less during the previous class or adding some discussion questions to guide students thinking.

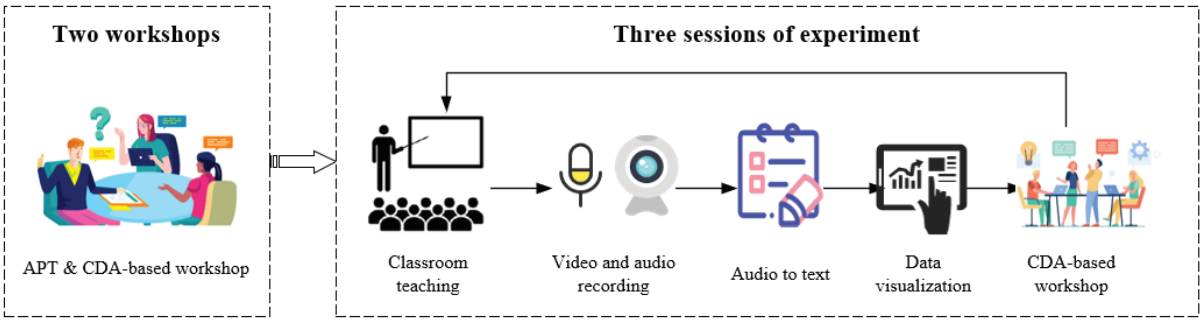


Figure 2. Design of the Intervention.

3.3 Data Collection and Analysis

This study aimed to investigate the impact of using CDA as a teaching assistant tool to facilitate students' dialogic engagement. To achieve this goal, video data of the instructor's teaching were utilized as the primary data source of analysis. The analysis process involved two main steps. First, audio data from the videotape was transcribed into text data with the timestamp, teacher ID, and student ID, using the transcription tool iflyrec. Second, the text data were converted into SNA network data using Python packages such as numpy and networkx, following the methodology outlined in Bokhove (2016) and Mameli et al. (2015) research. In this approach, the sender is considered the source node, the receiver is the target node, and the word number of utterance is the weight of the edge. For example, if

student A spoke to student B for 20 words, this would correspond to the data in SNA as source node A, target node B, and the weight of the edge as 20. Additionally, when the teacher speaks to the whole class, the teacher is regarded as the source node, and all the students in the class are the target nodes. The class responds as a group to the teacher in a similar manner. Based on the SNA data, we examined the dialogic engagement of students as a whole and also analyzed the dialogic engagement of the individual learner.

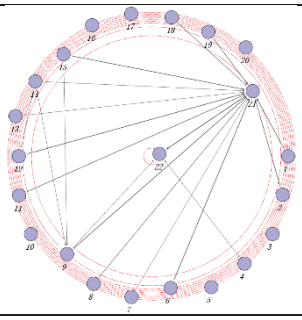
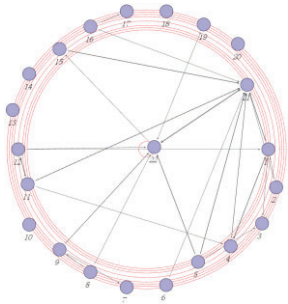
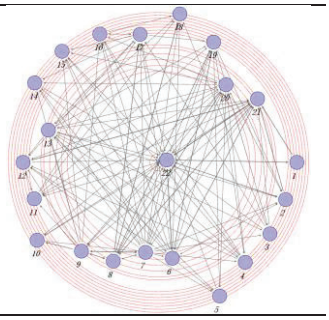
Six subject-specific tests provided by the teacher were utilized to measure the learning performance of students. We administered a pre-test and a post-test before and after the intervention, respectively, with each test being completed in approximately 10 minutes. To facilitate ease of calculation, we converted test scores to percentages. A paired-sample t-test was employed to determine if any differences existed between the pre- and post-test results.

4. Results

4.1 Overall Dialogic Engagement

Table 1 represents the overall dialogic engagement in the classroom, revealing that the teacher (node 22) was the central node in all three lessons. As the intervention progressed, classroom dialogue interactions gradually increased, as evidenced by the visual graphs and network data, where the network density significantly increased from 4.76% to 30.52%, and the number of arcs grew from 22 to 141. In the first lesson, only 22 talk turns were established in the entire class, while there was a slight increase in the second lesson. In the third lesson, the number of classroom dialogue interactions increased to 141, indicating more opportunities for student-student and student-teacher dialogue. The core nodes correspondingly added student node 7 and node 18.

Table 1. *Networks and Basic Metrics of Overall Dialogic Engagement in the Classroom*

	Lesson 1	Lesson 2	Lesson 3
Visualization			
Number of Node[a]	22	22	22
Number of arcs	22	30	141
Network density	4.76%	10.82%	30.52%
Core nodes	node 22	node 22	nodes 22, 7, 18

a. Nodes include node 21 for ‘entire class’ and node 22 for the teacher. Node labels from 1 to 20 represent student IDs.

In Figure 3, we observe the relationship between the out-degree of node 22 (teacher) and network density. The out-degree of node 22 refers to the number of times the teacher speaks to the students. Interestingly, Figure 3 indicates an inverse relationship between the out-degree of node 22 and network density. Specifically, as the number of times the teacher speaks to the students decreases, the overall network density gradually increases. In the first lesson, the teacher spoke 75 times, and the overall network was relatively sparse with a density of 4.76%; in the second lesson, the teacher spoke 59 times, and the network density

increased to 10.82%; And in the third lesson, the number of teacher explanations decreased to 48, while the network density increased to 30.52%.

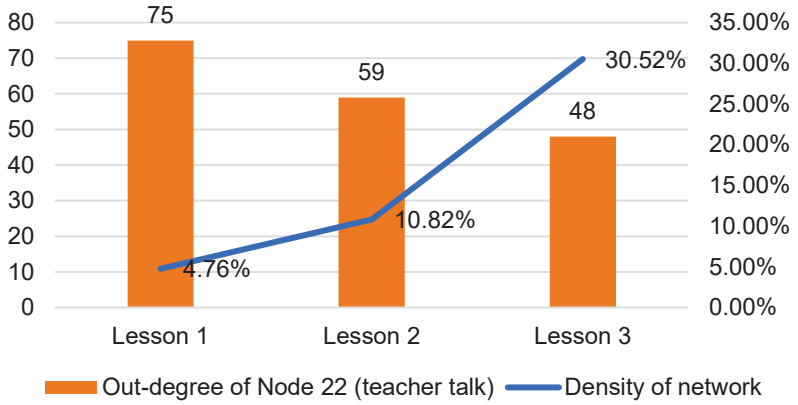


Figure 3. Out Degree of Node 22 (Teacher) and Network Density.

4.2 Individual Dialogic Engagement

Figure 4 displays individual students' dialogic engagement in the classroom during the three lessons. In the first lesson, the average number of times students spoke was 2.5, and the maximum number of times a student spoke was 8 (node 9). Six students did not participate in the classroom dialogue (e.g., nodes 3, 5, 10), and three students participated in only one class talk (e.g., nodes 4, 7, 13). In the second lesson, the average number of times students spoke was slightly lower at 2.35, and the maximum number of times a student spoke was 8 (node 1). Seven students did not speak in class (e.g., nodes 7, 10, 13, 14), and three students spoke only once (e.g., nodes 3, 6, 19). In the third lesson, the average number of times the students spoke was 7.3, and the maximum number of times a student spoke was 20 (node 7). Only one student did not speak (node 18), and three students only spoke once (e.g., nodes 5, 14, 15).

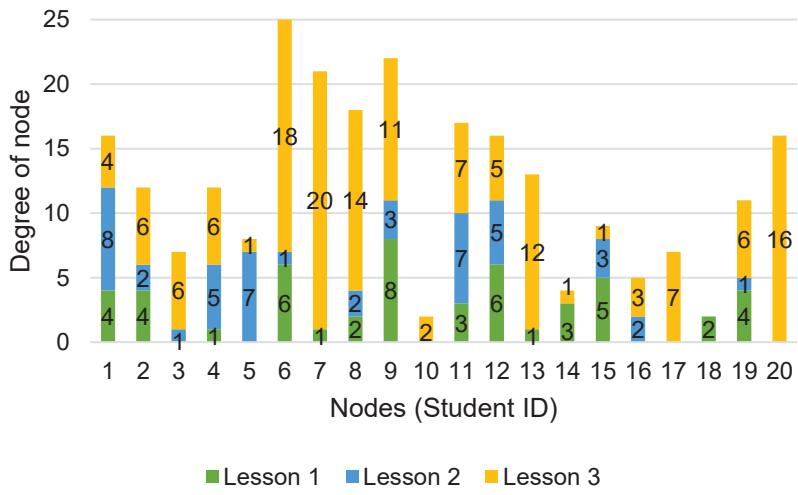


Figure 4. Individual Dialogic Engagement in the Classroom.

Figure 4 also reveals slight differences in each student's engagement in classroom dialogue during the three lessons. The participation of some students in classroom dialogue gradually increased (10 students, including nodes 3, 4, 7, 8, 10, 11, 13, 16, 17, 20), while some students' participation in classroom dialogues decreased (5 students, including nodes 1, 5, 14, 15, 18). Some students' participation in classroom dialogues fluctuated to a certain

extent (4 students, including nodes 2, 6, 9, 19), while others remained relatively constant (1 student, node 12).

4.3 Learning Performance

Table 2 illustrates the statistical outcomes of overall learning performance, including the pre-test (M = 62.28, SD = 16.08) and the post-test (M = 82.35, SD = 13.75). Results from the paired-sample t-test indicated a significant difference (t = -4.697, p <. 001) in learning performance before and after the intervention, with the post-test scores significantly higher than the pre-test scores.

Table 2. *Paired-Samples t-test of the Pre- and Post-test Learning Performance*

	n	*Mean*	*SD*	*t*	*p*
Pre-test	20	62.28	16.08	-4.697	<.001
Post-test	20	82.35	13.75		

Figure 5 presents the individual learning performance of students, with more than half of the students demonstrating higher scores on the post-test than the pre-test. When dividing students into low- and high-engagement groups based on the mean value of dialogic engagement during the three sessions, the analysis results revealed that the learning performance of the students in the high-engagement group (n = 9, M = 84.97) was slightly higher than that of the students in the low-engagement group (n = 11, M = 80.21); however, there was no statistically significant difference in learning performance between the two groups (t = -.76, p = .457).

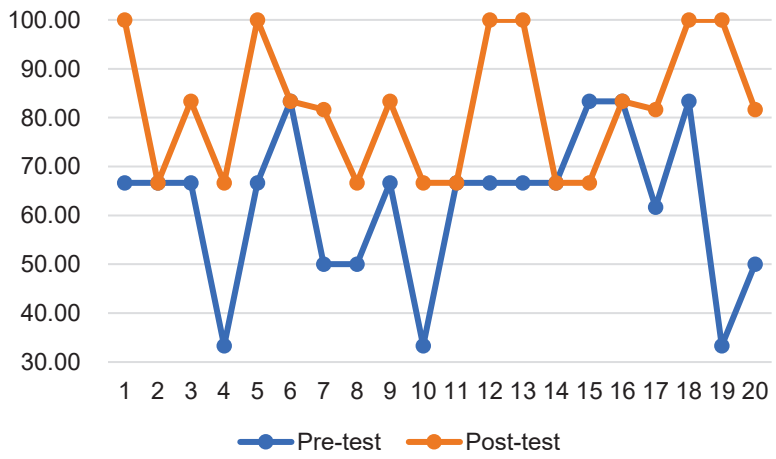


Figure 5. Individual Learning Performance of Students.

5. Discussion and Conclusion

The present study aimed to investigate the impact of visual learning analytics as a teacher assistance tool on students' engagement in classroom discourse. While previous studies have demonstrated that dialogic frameworks or analytics-based tools can benefit classroom instruction (Chen, 2020; Chen & Chan, 2022), there remains a lack of effective scaffoldings to support teachers' improvement regarding talk-based classroom instruction. In this study, we introduced a richer classroom dialogue analyzer that included interactive statistical and social network graphs that served as a teacher assistance tool to visualize classroom dialogic progress information and provide evidence to support the improvement of classroom instruction. Our findings from social network analyses indicated that visualization-based support contributed to both overall dialogic engagement and individual student engagement. Furthermore, subsequent tests found that students' academic performance also increased.

From the perspective of overall classroom engagement, we observed that the less the teacher spoke, the more students expressed their thoughts during lessons, as indicated by the growth of network density. The visual graphs may have helped the teacher become more aware of her speech and understand that a high level of teacher talk meant that opportunities for students to speak were more limited. Consequently, she consciously used APT to guide students to think and speak in subsequent classes (Major, Smørdal, et al., 2022; Major, Warwick, et al., 2018). Similar findings can be reported in van der Veen et al. (2017) and Chen et al. (2020), where teachers consciously encouraged and supported student talk, leading to improved communicative performance. The visualization-based tool can further guide teachers and researchers in negotiating how to improve classroom instruction and provide targeted support. To a certain extent, the tool responds to the need for evidence-based support for classroom instruction (Urhahne et al., 2010). As Amarasinghe et al. (2022) have suggested, designing and orchestrating daily classroom scenarios is a demanding task, and advanced technologies, such as learning analytics or data mining, can assist teachers in tackling the complexity involved in their daily work.

Individual student's dialogic engagement improved, with over half of the students demonstrating more engagement in classroom talk during the three lessons, as indicated by the out-degree of students' nodes. However, it should be noted that, given the fixed lesson time, some students may have multiple opportunities to speak, leading to fewer opportunities for others. This highlights the need to consider adding other technical tools to support students' talks when designing activities. For example, online discussion forums could provide students with opportunities to express their ideas (e.g., Ratan et al., 2022); additionally, an adaptive learning system could be incorporated to respond to individual learning needs (e.g., Wu et al., 2017).

Our analysis of learning performance data revealed a statistically significant increase in students' academic achievement from pre- to post-test stages. We also compared student groups with varying levels of dialogic engagement and found that the high-engagement group slightly outperformed the low-engagement group, although this difference was not statistically significant. We will further investigate the relationship between students' dialogic engagement and their learning performance by considering students' other characteristics and learning preferences (Bond & Bedenlier, 2019; Halverson & Graham, 2019). In doing so, we can help teachers obtain a better understanding of students' engagement in classroom dialogue and how this relates to their academic achievement.

6. Limitations and Future Work

This study investigated the influence of teachers (supported by a discourse-based visual tool) on students' dialogic engagement in the classroom. The findings indicated that this approach has the potential to foster students' dialogic engagement. However, as this is an ongoing project, there are some limitations to the current study. First, the three-week duration of the intervention made it difficult for us to estimate its long-term impact on student classroom participation. In the coming months, we will continue to conduct extended interventions to explore the impact of visualization tools on both teachers and students. Second, the lack of a comparison group and the small scale of the intervention may limit the generalizability of the research findings. In future research, we will scale up the intervention and explore the impact of discourse-based visualization on both teachers and students. Third, we focused on data sources derived from classroom videos and achievement tests, without considering data sources regarding changes in the participation processes of students or teachers. Consequently, we were unable to conduct a thorough analysis of the impact of visual support on both teachers and students throughout the intervention. In the next stage of the project, we will collect additional sources of data, such as teachers' reflective logs, classroom observation notes, and interviews with both teachers and students. These additional data sources will provide a more comprehensive understanding of the intervention and improve the accuracy of our overall conclusions.

Acknowledgements

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