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RESEARCH

Enhancing students' dialogic reflection through classroom discourse visualisation

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Abstract
Fostering students' dialogic reflection in the classroom entails promoting diverse perspectives and collaborative aspects of reflective thinking. However, few studies have developed visualisation tools to create a collaborative environment that fosters dialogic reflection, especially for young learners. This study aimed to investigate the efficacy of visualising classroom discourse to enhance students' dialogic reflection. Two information and communication technology (ICT) teachers and their students ($n = 53$) from a Hong Kong primary school participated in a 3-month study. After engaging in visualisation-supported dialogic reflection, students' subject knowledge of ICT improved, accompanied by an increase in the proportion of words spoken by students during lessons. Interviews with the two teachers and eight students underscored the positive impact of visualising classroom discourse, which enabled students to embrace alternative problem-solving approaches and actively engage in both collaborative group work and whole-class discussions. This study illuminates the advantages of employing classroom discourse visualisation as a reflective tool. Beyond mere revisiting, students can view experiences from multiple perspectives and reconstruct their knowledge. Furthermore, this approach fostered accountability for students' contribution during classroom interactions, ultimately improving their learning outcomes. These findings advocate for the development of evidence-based, dialogic reflective tools specifically designed for young learners to optimise their learning experiences.

Keywords Asynchronous learning · Dialogic reflection · Productive classroom talk · Visualisation · Collaborative learning · Mixed methods

Introduction

Dialogue and reflection are two defining characteristics of humans, which are fundamental for human learning, development and higher mental functions (Gillespie, 2007; Hamzah et al., 2024; Vygotsky, 1978). By integrating these two critical aspects, dialogic reflection emerges as a powerful concept that embraces a dialogic approach to reflection, fostering

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richer articulation and deeper analysis in learning (Chung & Fisher, 2022; Mann & Walsh, 2013). However, dialogic features are often missing in common reflective practices. This absence can be attributed to several factors, including the lack of data-led accounts, a predominant focus on the individual, an overreliance on written reflection, and the use of inappropriate reflective tools (Mann & Walsh, 2013). In classroom environments, the spontaneous and dynamic nature of teacher–student interactions can impede their ability to reflect on classroom discourse, as the conversation may be forgotten or inaccurately recalled. Technological advancements offer an opportunity for students to more objectively review their experiences, bridging time and space by facilitating ad hoc reflections and encouraging thoughtful contemplation before engaging in reflective practices (Prilla, 2015). However, few studies have explored the development of visualisation tools to create a collaborative environment that supports dialogic reflection, especially for young learners. The concept of 'dialogic reflection' emphasises reflection occurring in a collaborative context, a process that can be maximised through the appropriate use of technology and pedagogy. Harnessing technology's potential, this study aims to facilitate students' reflection through data-driven cues, visualising classroom discourse for their enhanced understanding. By transforming classroom talk into visualisation analysis, the study creates a collaborative learning space that promotes dialogic reflection amongst students and fosters productive classroom discourse.

Dialogic reflection

Reflection is a deliberate process of questioning our beliefs and practices to validate our actions, identify solutions to problems and predict the outcomes of our future choices. As Dewey (1933, p. 9) puts it, reflection is '(a) a state of perplexity, hesitation, and doubt; and (b) an act of search or investigation directed toward bringing to light future facts which serve to corroborate or to nullify the suggested belief'. Dialogic reflection can refer to the process or the outcome. From the sociocultural perspective, the dialogic reflection process can either be intrapersonal or interpersonal (Vygotsky, 1978) and interactions could happen between an individual and an artefact, or amongst individuals. Dialogic reflection embraces multiple views, which could be generated within oneself, that is, 'self becomes an object to oneself' (Gillespie, 2007, p. 678), or discussion with others. Sociocultural theory posits that individuals learn from their social interactions, whilst also emphasising how collective understanding emerges from interactions amongst individuals. For the functioning of this article, we focus on the reflection in a community, that is, 'discourse with others' (Mann & Walsh, 2013, p. 297). In terms of the participants, here we see dialogic reflection similar to 'collaborative reflection' or 'co-reflection' (Prilla, 2015; Yukawa, 2006) and 'reflection through critical friendship' (Farrell, 2001; Hatton & Smith, 1995), which is the reflection that occurs through the discourse amongst participants who give voice to one's own thinking, whilst being heard in a constructively critical way, for mutual development and gaining insights going beyond individual results (Farrell, 2001; Hatton & Smith, 1995; Jiang & Zheng, 2021; Prilla, 2015; Yukawa, 2006).

As the outcome, whether alternative views and others' perspectives are concerned could be an indicator for typology or quality of reflection. Dialogic reflection could be seen as a type of reflection that parallels descriptive reflection and critical reflection (Jay & Johnson, 2002), or it can be referred to as an *advanced* or *critical* level of reflection, compared with relatively *superficial* levels including routine/technical reflection (Ward & McCotter, 2004) and stimulated/habitual/descriptive reflection (Hamzah et al., 2024; Hatton & Smith, 1995;

Mena-Marcos et al., 2013). Dialogic reflection highlights the inquiry part of reflection, featuring cycles of deliberative and cognitive weighing claims and viewpoints, exploring alternative solutions and gaining new insights (Hatton & Smith, 1995; Mena-Marcos et al., 2013; Ward & McCotter, 2004).

Dialogic reflection on classroom talk

Reflection can focus on a wide array of elements and events in the learning and teaching process. One of the important aspects is classroom interaction during a lesson, as certain ways of organising classroom talk are productive for learning (Michaels & O'Connor, 2015). To make a classroom productive, teachers need to pay attention to both broad dialogic principles as well as specific mechanisms of dialogic interaction (Hennessy et al., 2021). Students also need to take accountabilities as learners in the classroom, whose talk should be accountable to knowledge, reasoning, and community (Michaels et al., 2008; Resnick et al., 2010). According to Michaels and colleagues (2008), accountability to the learning community involves actively listening to fellow participants, building upon their ideas, and asking questions to clarify or expand on propositions. This fosters a collaborative learning environment where students can engage in meaningful discussions and develop a deeper understanding of the subject matter. Moreover, by embracing diverse perspectives and cultivating a culture of open dialogue, students are better equipped to evaluate their learning processes and outcomes.

Reflecting after the learning activities means the technology should first help retrieve learning experiences and then support the communication to exchange ideas on the experiences (Zhang et al., 2023). To mediate reflection on classroom dialogues, the technology should support students' (1) noticing and documenting the evidence of classroom talk and (2) creating a dialogic space where participants could collaboratively reflect based on their noticing and evidence. For (1), video recordings of classroom episodes have been widely used. For example, in teacher professional development programmes, videos are often used to stimulate discussions amongst teachers and facilitators to enhance teachers' professional vision and noticing (Li & Walsh, 2023; van Es & Sherin, 2008). In contrast, videos are less commonly used to support students in noticing and reflecting on their engagement performance but used to support their acquisition of content knowledge or reviewing lessons (e.g. in Massive Open Online Courses, Yang, 2024). However, videos inherently capture rich, during-activity contexts to stimulate learners' reflection on their performance, especially in classroom settings characterised by a dynamic and interactive nature. In such contexts, videos offer meaningful activity-based cues to support students' engagement and reflection on their dialogic performance during classroom activities. Despite this potential, how video recordings could be used for students' reflection is less explored.

For (2), peer asynchronous discussion is one of the primary means of inviting collective reflection in an online environment. The adoption of asynchronous discussion provides learners with the opportunity to present and critically evaluate the opinions they receive, usually with mediating learning resources, including criteria, exemplars and learning materials (Wood, 2021). On a forum, students can articulate and explicitise the tacit knowledge gained from reflection (i.e. 'theorising their practice', Tsui, 2009, p. 429; Prilla, 2015). In addition, it provides a collaborative learning environment that supports deep learning, offering logistical advantages including removing the constraints of space and time, and affording availability for students to revisit the full discussion relevant to their learning later (Koszalka et al., 2021). In the context of computer-supported collaborative learning

(CSCL), videos of classroom activities provide a rich context for students to reflect and interact. Computer-mediated communication tools (e.g. 'chat' and 'email' functions) further facilitated thread-based discussion and collaborative reflection amongst peers and instructors through instant interaction with a record to trace (Yukawa, 2006), especially on information retrieval and cognitive dimensions (Yang, 2024).

Visualising classroom talk for young learners

Studies on using technology to support young learners' dialogic reflection on classroom discourse are relatively scarce. In terms of collaborative reflection, Baykal and colleagues' (2021) systematic review points out that amongst studies on technology-mediated collaborative reflective practices that benefit children, in a substantial proportion of these studies (120 out of 141 papers), reflection is not carried out by children themselves but rather by adults, such as teachers, caregivers and other stakeholders. For collaborative reflection, the process could happen in the form of reflective essays/sheets (Sinervo et al., 2021; Hu et al., 2022), online chat discussions (Eshuis et al., 2019) and forum postings (Jin, 2017). When designing technology to support reflection, temporal perspectives are essential. These perspectives encompass leveraging the past (objective events), drawing from the memories (subjective experiences), envisioning the future (setting goals) and embracing slowness (meditations) (Bentvelzen et al., 2022). To focus on the reflection during or after the learning experience, monitoring or recalling the details presents an extra challenge, particularly for young learners. To address this issue, video recordings have emerged as a popular method for documenting the evidence and presenting an objective record of the learning event (e.g., Celepkolu et al., 2021; Sinervo et al., 2021).

As a core function of learning analytics dashboards, visualisation enhances the comprehensibility of the presented information (Valle et al., 2021). This is achieved by uncovering intricate patterns within educational data, which would otherwise be challenging to discern (Teasley, 2017). Visualisation of classroom talk has the potential to elicit dialogic reflection, and it could be realised in a range of formats; for example, barcodes (Colley & Windschitl, 2020), pie charts and interactive line charts (Celepkolu et al., 2021; Nennig et al., 2023). The design of visualisations necessitates careful consideration of learners' needs to ensure their suitability as reflective tools. Whilst visual representations are intended to help students, they could lead to confusion when learners simultaneously engage with visual representation (depicting information) and acquire new knowledge from visual displays (Rau, 2017). Moreover, the choice of metaphor employed in the visualisation should be intuitive and comprehensible to reduce students' cognitive load when interpreting concepts to be conveyed (Jin, 2017). In addition, researchers should attend to design aspects, including layout design, graphic quality, user interface design, system support design and interaction design (Norouzi et al., 2021).

In terms of visualising students' collaborative discourse, Hu and Chen's (2021) systematic review also pointed out that only 57% of the tools target supporting learners, whilst the rest focussed on use by educators or researchers. For those works focussing on children's collaborative reflection, most tools focussed on the cognitive dimension of discourse, using a post hoc approach mirroring some features of talk (Hu & Chen, 2021). For whole-class interaction, studies usually focus on teachers (e.g. as a form of professional development, Magnusson et al., 2023; van Es & Sherin, 2008), highlighting teachers' abilities and responsibilities of orchestrating classroom talk. Visualisation for students usually focusses on monitoring and reflecting on group work dynamics, especially on their contribution

during collaborative activities (Celepkolu et al., 2021; Hu et al., 2022), during which teachers' mediating role is seldom considered. For young learners, how to visualise classroom discourse for reflection, considering the contribution of both teachers and students, is less explored. Considering this, we propose a visualisation-supported dialogic reflection (VSDR) approach in which students' dialogic reflection is mediated by the visualisation of classroom talk. In this approach, visualisation methods are integrated with classroom activity videos to support students' context-based group discussion, where visualised representations offer comparable information to encourage deeper dialogic reflection and foster improvement. To investigate the effectiveness of the VSDR approach and reveal the mechanism of how visualisation supports students' dialogic reflection on classroom talk, this study focusses on the following research questions:

1. To what extent does the VSDR approach impact student learning outcomes and class participation?
2. How does visualisation support dialogic reflection for students?

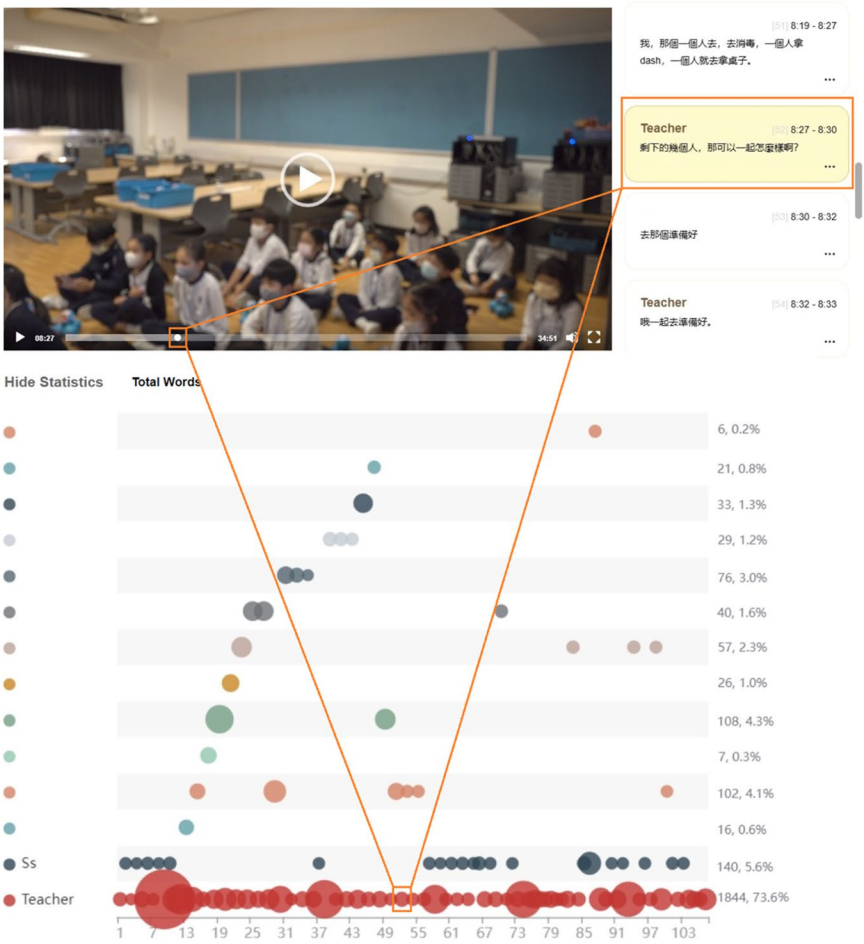
Method

To address the research questions, we first present the visualisation platform employed in the study, followed by a description of the study context, participant involvement and pedagogical design. We then detail the data collection methods, including pre–post tests, video recordings and interviews. Lastly, we outline the analytical approach, which incorporates both quantitative and qualitative techniques to analyse the data and fulfil the study's objectives.

Platform for visualising classroom discourse

In this study, we used and adapted the classroom discourse analyser (CDA, Chen et al., 2020), one of the representative platforms to visualise classroom discourse from lesson videos. The CDA platform was to support students' dialogic reflections by providing them with the visualisation and analytics of classroom talk.

As shown in Fig. 1, CDA enables users to review the visualisation of the lesson recording. After uploading a classroom video recording, the transcript of its classroom talk is displayed and transformed into bubbles of different sizes to represent the different lengths of speech in a turn (a big bubble means a long turn) and different colours to represent different speakers through CDA. Both bubbles and transcripts are synchronised with the video. Teachers can present the whole recording or extract video segments for students' review. CDA has been applied in teachers' professional learning contexts, enhancing their use of productive classroom talk and self-efficacy (Chen et al., 2020; Chen & Chan, 2022). For student learning, CDA has been integrated into classrooms to promote low-achieving students' epistemic understanding of discourse in a knowledge-building classroom (Tong et al., 2024). In addition, it supported emergency remote teaching by addressing the challenges raised during the pandemic and engaging students in active learning activities through segmenting lesson videos, visualising classroom interaction and fostering knowledge co-construction using discussion forums and quizzes (Wang et al., 2024).



Notes. In the visualisation, 'Ss' denotes a group of students or all students speaking simultaneously, while the names of the individual students are covered. Notably, in this example, at least 12 students in the class spoke during the lesson. The size of each speech bubble corresponds to the number of words spoken by the individual. The statistics on the right show 'Total Words'; that is, the integer displayed alongside each line indicates the total word count for that speaker, while the corresponding percentage reflects their contribution relative to the total words spoken during whole-class talk.

Fig. 1 An interface of the classroom discourse analyser platform (Chen et al., 2020)

Context and participants

The research was conducted in four second-grade classes from a primary school in Hong Kong. We conducted a 3-month classroom intervention collaborating with two information and communication technology (ICT) teachers and 53 students, with the platform (CDA) supporting VBDR. Both teachers, Hazel and Leo (pseudonyms) have more than 15 years of experience teaching ICT subjects. We briefed Hazel and Leo on

the functions of the platform and productive classroom talk before the intervention. Students were supported by their respective teachers when using the platform. In Hazel and Leo's classes, students were randomly assigned, and the comparative results presented in the results section demonstrate that their pre-test academic performances were similar across these classes.

Pedagogical design of VSDR

To carry out the intervention, each teacher and their two classes form a group (i.e. two groups of teachers and students in total). As the school management team objected to using a control group in the educational context, we did not use an intervention and a control group for comparison. To better figure out the role of VSDR in this content, we thus adopted the design of a higher dose and a lower dose of visualisation for participating teachers and students. For Hazel's groups, our research team visualised her lesson video recordings 14 times, with each lesson lasting for about 30 min; for Leo's groups, we visualised his lesson video recordings 8 times, with each lesson lasting about 30 min. Here, visualisation refers to the research team helping generate a visual representation of the classroom talk in classroom videos using CDA on the basis of teachers' video recordings of their lessons. After the visualisation transformation, teachers could choose to view the visualisation by themselves and then select clips for students to view. To help students participate in and document their dialogic reflection, the teachers used a discussion forum to support students' dialogic reflection on their visualisation during class. In this online forum, teachers crafted topics for student reflection and offered technical support to students during VSDR. The four stages of VSDR are specified in Fig. 2.

For the first stage of VSDR, Hazel recorded lesson videos every week (high dose), whilst Leo recorded lessons bi-weekly (low dose). During ICT lessons, students typically sat on the ground when listening to a teacher, and they sat in circles for group activities. A tripod-mounted camera was positioned at the front of the classroom to capture discourse interaction amongst all the students and the teachers, ensuring comprehensive documentation of their participation during whole-class discussions. We provided guidelines to the

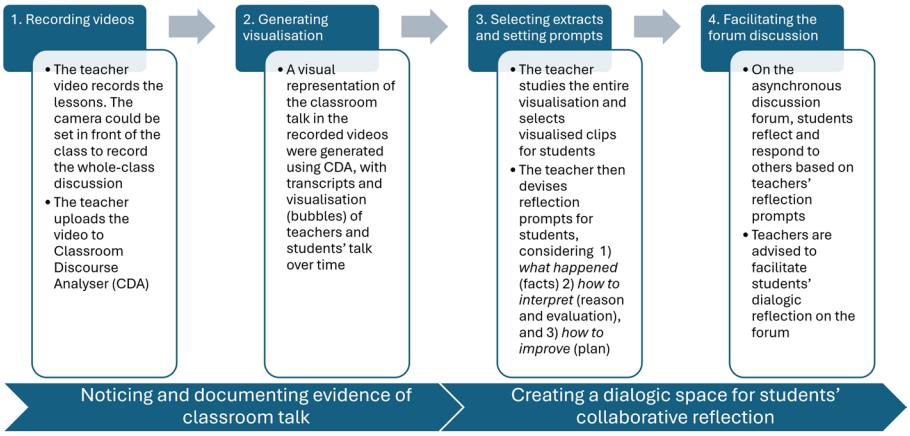


Fig. 2 Four stages in implementing VSDR

teachers regarding video recording and selection, and teachers were aware that selected video clips were used for subsequent reflection. After recording, the teachers uploaded the videos to the CDA.

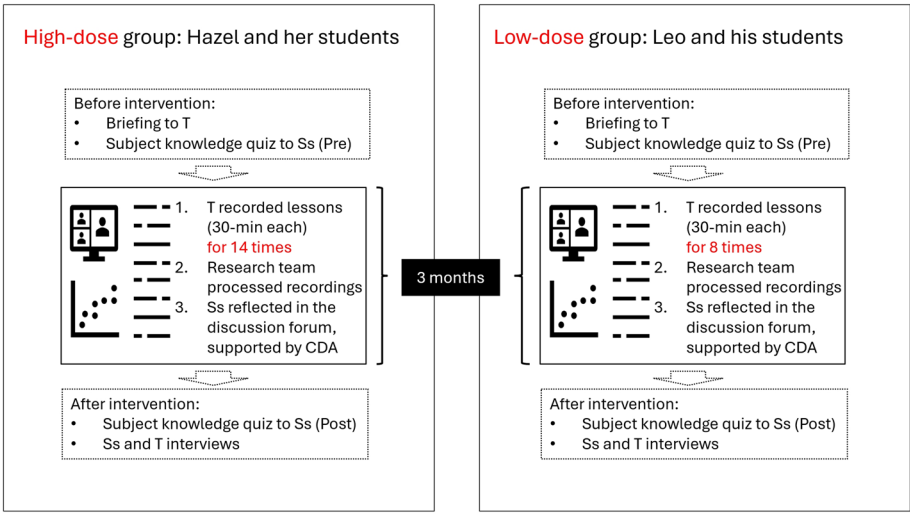
In the second stage, the research team processed the videos and generated visual representations of the recorded videos (around 30 min each for the entire lesson). A typical representation mainly contained a transcript and graphical bubbles on a chart to depict the discourse interactions between the teacher and students in the video throughout the lesson (see Fig. 1). In the third stage, Hazel and Leo individually reviewed the video clips, and then they selected specific segments where relevant visual representations could be leveraged to support students' reflection in class. To facilitate the discussion forum, they devised reflection prompts centred around three key questions: (1) 'what happened' (facts), (2) 'how to interpret' (reason and evaluation) and (3) 'how to improve' (plan).

In the last stage, Hazel and Leo invited students to use iPads during class time to engage in discourse reflection via the discussion forum. This process involved analysing video clips recorded the previous week, accompanied by transcripts and visualisations of classroom discourse. During this reflection session, teachers guided students to review the video clips, comprehend the visualisation content and contemplate the provided prompts. Students were encouraged to reflect on and respond to these questions. When most students completed the task, teachers prompted them to review their peers' responses and contribute their own insights and feedback. For VSDR, students could reflect on the visualisation in class or at home. Hazel and Leo suggested their preference for in-class use, because they could provide technique support during student reflection for grade-two students (around age 7) and avoid privacy concerns of parents viewing classroom recordings.

During the study, the ICT lessons focussed on computational thinking, which was grounded in programming a robot called Dash. Dash is a robot that can nod, move with wheels, emit lights in various colours, make sound and identify obstacles, which could be programmed through applications such as Blockly. There were two main tasks for Dash. First, it became a dancer as the students programmed a dance. The task was to familiarise students with Dash and programming. In another, Dash was a waiter who delivered food whilst avoiding obstacles amongst fake dining tables, and the students needed to programme the movements of Dash. In this task, students need to first decompose the problem, abstract it to focus only on the solution, recognise the pattern from small scale to large scale, test the codes and debug for the final design. These steps align with the characteristics of computational thinking, that is, decomposition, abstraction, algorithms, debugging, iteration and generalisation (Shute et al., 2017), but were adjusted for young learners.

Data collection and analysis

In this case study, we collected multiple sources of evidence to establish a chain of evidence, which strengthens construct validity through convergent lines of inquiry (Yin, 2018). To investigate whether and how students' learning can be enhanced through the approach, we used the students' pre- and post-test assessment of subject knowledge to collect quantitative data. We also collected qualitative data by recording classroom videos, analysing forum discussions and conducting interviews with both students and teachers after the intervention (see Fig. 3).



Note. 'T' denotes 'Teacher', and 'Ss' denotes 'Students'.

Fig. 3 Procedure and data collection during VSDR

The pre- and post-tests of knowledge on computational thinking were designed by two teachers with the same level of difficulty and were administered before and after the implementation. For post-interviews, we designed a stimulated recall interview and used the platform data as the recall stimuli. We conducted a 1-h interview with both teachers and a 30-min interview with four pairs of students from the two groups ($n=8$). Stimulated recall interviews helped with reducing memory decay for introspection in complex environments and brought consonance between prompts and cognitive organisation (Lyle, 2003).

To answer the first research question, after checking the normality of data, paired-sample *t*-tests were conducted to see whether there was a significant increase in the pre- and post-test of each subject. For the second research question, the qualitative data, including interviews, classroom discourse and discussion on the forum, were analysed using the constant comparative method (Strauss & Corbin, 1998), focussing on pattern matching and explanation building of the case (Yin, 2018).

Results

Through analysing the data, VSDR exhibited a positive impact on student learning and participation, which was reflected in the students' questionnaire results and the analysis of lesson recordings. From the qualitative data, we found that VSDR facilitated students' adoption of alternative problem-solving strategies and active involvement in collaborative group work and whole-class discussions. The details of the results were presented under their corresponding research questions.

RQ1. To what extent does visualisation-supported dialogic reflection (VSDR) impact student learning outcomes and class participation?

First, to examine whether students' subject knowledge of ICT was comparable at the beginning of the intervention, an independent samples *t*-test was performed. In the pre-test, there was no significant difference in students' subject knowledge between groups [$t(51) = 0.642$, $p = 0.524$]. Although the 27 students in the low-dose group achieved slightly higher average scores in the subject knowledge tests (M = 4.96, SD = 1.02) compared with the 26 students in the high-dose group (M = 4.77, SD = 1.18), this difference was not statistically significant.

Second, a paired samples *t*-test was performed (see Table 1) to evaluate changes in their subject knowledge of ICT from pre-test to post-test for both low-dose and high-dose groups. For the low-dose group, despite an increase in mean scores in ICT subject knowledge from the pre-test (M = 4.96, SD = 1.02) to the post-test (M = 5.19, SD = 0.92), this improvement was not statistically significant [$t(26) = 0.844$, $p = 0.406$], whilst for the high-dose group, there was a statistically significant enhancement in ICT subject knowledge, with scores rising from the pre-test (M = 4.77, SD = 1.18) to the post-test (M = 5.65, SD = 0.56) [$t(25) = 3.537$, $p = 0.002$]. The result suggests that only the students in the high-dose group had improved learning outcomes significantly over time.

Lastly, to assess the proportion of words spoken by students, we analysed recordings from the first two lessons (pre) and the last two lessons (post) recorded by teachers (see Fig. 4 and Table 2). Each lesson, focussing on the theme of computational thinking, lasted around 30 min. For these recordings, the stationary camera was set in the front of the classroom to capture the whole-class discourse interaction. Despite an increase in the total words spoken by students in the low-dose group (from 1434 to 2080) and a decrease in the high-dose group (from 1389 to 1209), both groups showed an increased percentage of student contributions. Specifically, the low-dose group's contributions rose from 20.27% to 30.85%, whilst the high-dose group's contributions increased from 13.98% to 25.98%. For teachers, there was a decrease in the total words spoken by both during the lesson (for the low-dose group, from 5639 to 4663; for the high-dose group, from 8548 to 3445).

RQ2. How did visualisation support dialogic reflection for students?

Reflecting on the alternatives in task completion

Mediated by the teacher, the visualisation and revisiting of the classroom videos could help students reflect on how group work tasks could be improved. From the interview, Hazel pointed out that revisiting the task from another perspective was one of the goals of the reflection task:

Table 1 Low- and high-dose groups' performance in ICT subject knowledge

	Dose	*n*	Pre *M (SD)*	Post *M (SD)*	*t*	*df*	*p*
ICT subject knowledge	Low	27	4.96 (1.02)	5.19 (0.92)	0.844	26	0.406
	High	26	4.77 (1.18)	5.65 (0.56)	3.537	25	0.002**

**$p < 0.01$

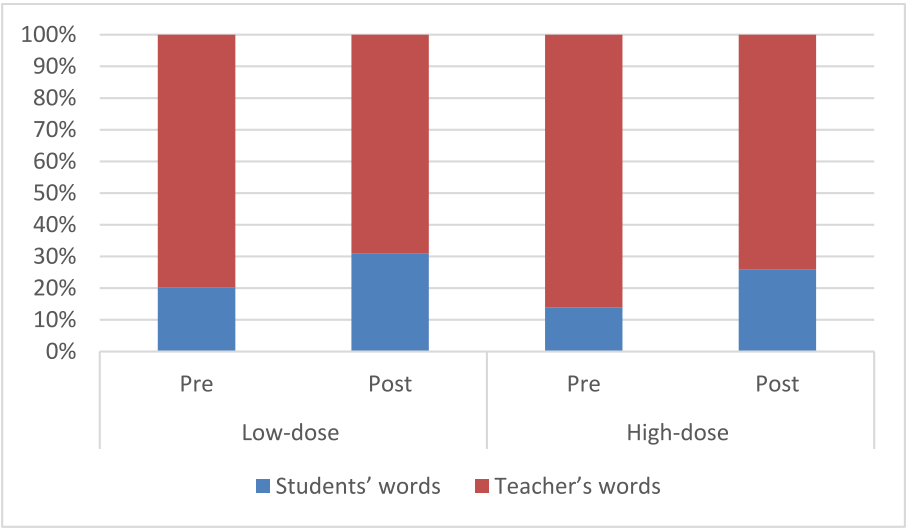


Fig. 4 Proportions of words spoken by teachers and students (two lessons, around 60 min in total)

Table 2 Words spoken by teachers and students (two lessons, around 60 min in total)

	Time	Students' words	Teacher's words	Total words	% of students' contribution
Low dose	Pre	1434	5639	7073	20.27%
	Post	2080	4663	6743	30.85%
High dose	Pre	1389	8548	9937	13.98%
	Post	1209	3445	4654	25.98%

> When students work on their own hands-on tasks, they don't have a comprehensive idea of how and why things work or do not work. When reviewing their and other groups' performance, students' perspectives are broadened, noticing problems that may have been ignored before. We can guide and discuss important issues. I think this is quite helpful (Hazel's interview).

Dialogic reflection is evident in the following excerpt (Excerpt 1) from students' discussion forums. The excerpt was taken from the reflection session after students' first attempt at coding, which illustrates how Hazel used the visualisation of classroom videos to help students reflect on content knowledge. Hazel selected four clips showcasing different groups' performances of the dance of Dash, which is a robot that performs on the basis of students' coding. The original task was for students to design a 20-s dance using Dash. After watching their own and other groups' performances, students reflected in the forum on the basis of this prompt: 'Please answer the following questions based on your group's performance: 1. What aspects do you feel the most satisfied with? Why? 2. What do you think was the biggest difficulty you encountered during the entire activity? How did you solve the problem? 3. What do you think there is room for improvement in future activities?'.

Excerpt 1

Discussion forum based on visualisation of classroom video clips (Hazel's group)

Student 05
16 March 2023 1:35 PM
1. I think what our group does well is that when we encounter problems, we can discuss them together as a group. 2. I think the biggest problem we encountered during the entire task was that our dance lasted more than twenty seconds. Let's just remove some of the dance steps. 3. To improve, we should add different types of dance moves by Dash

Student 19
16 March 2023 1:42 PM
1. I think the most satisfying thing is that I and my partners work closely when programming. 2. I think the biggest problem we encountered was that the members of our group didn't press the 'Start' button at the same time, which affected our group's performance. 3. I think that in subsequent activities, I can ask the team members to press together, so that there will be no problems

…

Student 01 replying to **Student 05**
16 March 2023 1:47 PM
It only exceeded 20 s when we said 'wee' at the end, not the rest of the dance

…

Teacher Hazel replying to **Student 01**
16 March 2023 2:33 PM
I also agree with your point of view, and I appreciate your willingness to think at all times

Teacher Hazel replying to **Student 05**
16 March 2023 3:19 PM
I'm excited to see your future design! I hope you will add this consideration to the design for your next task

…

Student 14 replying to **Student 19**
20 March 2023 9:35 AM
I agree with you

Student 01 replying to **Student 19**
20 March 2023 9:36 AM
I think you did a good job of programming it, but the dance took more than 20 s. You can make it a little shorter next time

…

The excerpt from the discussion forum shows (a) how students see the alternative ways of solving the task and suggest ways to improve their own, (b) how students reflect in a dialogic manner by agreeing and disagreeing with peers and (c) how Hazel mediates the reflective dialogues on the discussion forum. After revisiting the students' own group and other groups' Dash dance, Student 05 was impressed by other groups' dance moves by suggesting adding different types of dance moves, although this contradicted the problem identified (the dance was already too long). Student 01 commented on his groupmate Student 05's reflection and pointed out that counting the 'wee' from the groupmates (instead of the robot) into the 20 s could be controversial. During the process, Hazel attempted to mediate the dialogic reflection process by praising Student 01's willingness to think. However, Hazel did not point out the contradiction in Student 01's reflection but only expressed excitement to see the future design. Students enjoyed reviewing others' performance and reflecting on it, as said by Student 12:

> I like this activity (check the visualisation then discuss it in the forum) because we can check out other students' ways of completing the task. Others can also see

what we have done well. Everyone can think about it and add the good aspects next time to make the dance better (Student 12 interview, Hazel's group).

Reflecting on strategies in group collaboration

Students' dialogic reflection is also seen in how they can adjust their strategies in group collaboration for the next phase of learning. The following excerpt (Excerpt 2) from the discussion forum demonstrates how Leo used visualisation to help students reflect on students' collaboration process. During video-taking in the lesson, Leo focussed on how students collaborate in groups by creatively putting the camera next to each group for several minutes. This video was transformed into a visualisation for the discussion forum along with this prompt: '1. What do you think of the cooperation and performance of your group? 2. Do you feel that you have done your best to help team members complete the task? 3. In what areas do you think the team needs to improve?'.

Except 2

Discussion forum based on visualisation of classroom video clips (Leo's group)

Student 16
14 March 2023 11:35 AM
1. I am happy that the light emitted was beautiful! 2. I learned how to programme sound for the robot and work with others. Through a million times of practice, we finally get the robot to dance. 3. I think the most important thing is collaboration. 4. Next time, I should listen carefully to others' thoughts and opinions

Student 08
14 March 2023 11:36 AM
The best part is our Dash does not crash, and we always improve our codes even when one of the groupmates makes our codes messy. I learned that I should be patient when my groupmate makes mistakes, so we can be efficient. I hope our group will do better next time!

…

> **Student 05** replying to **Student 08**
> *17 March 2023 11:29 AM*
> What about your group? How can your group improve?
>
> **Student 15** replying to **Student 08**
> *17 March 2023 11:32 AM*
> How many times did you rehearse?

> **Student 17** replying to **Student 08**
> *17 March 2023 11:35 AM*
> Collaboration is necessary. The teamwork would not succeed if there is no collaboration, even if everyone is a master. I also think practice makes perfect. Good job!
>
> **Student 21** replying to **Student 17**
> *20 March 2023 2:23 PM*
> Yes, I agree with you

…

Student 16
20 March 2023 2:24 PM
Thank you all for the comments

The excerpt from the discussion forum illustrates how students reflected on the basis of their performance in class, supported by visualisation. Student 16 noticed the importance of collaboration in the group, and he jotted down the intention to improve by listening to others' thoughts and opinions. The ranked visualisation of the total words spoken (see Fig. 5) suggests that Student 16 spoke the most amongst the students. Student 08 reflected that after reviewing the process, being patient instead of blaming would benefit their group work. Student 05 and Student 15 participated in the dialogue by raising questions relating to the unanswered part of the prompt and reminding Student 08 to focus on the facts. Student 17 further built on Student 08's points, highlighting the value of collaboration, and Student 21 seconded. However, instead of replying to the questions raised, Student 16 only thanked the students for their comments. In addition, it is observed that Leo did not orchestrate the reflection in this or any other reflection practices on the forum, letting only students reflect on the basis of the prompt. Revisiting the learning experience provided soil for reflecting on the alternatives to improve their collaborative behaviours, although there was room for more in-depth discussion.

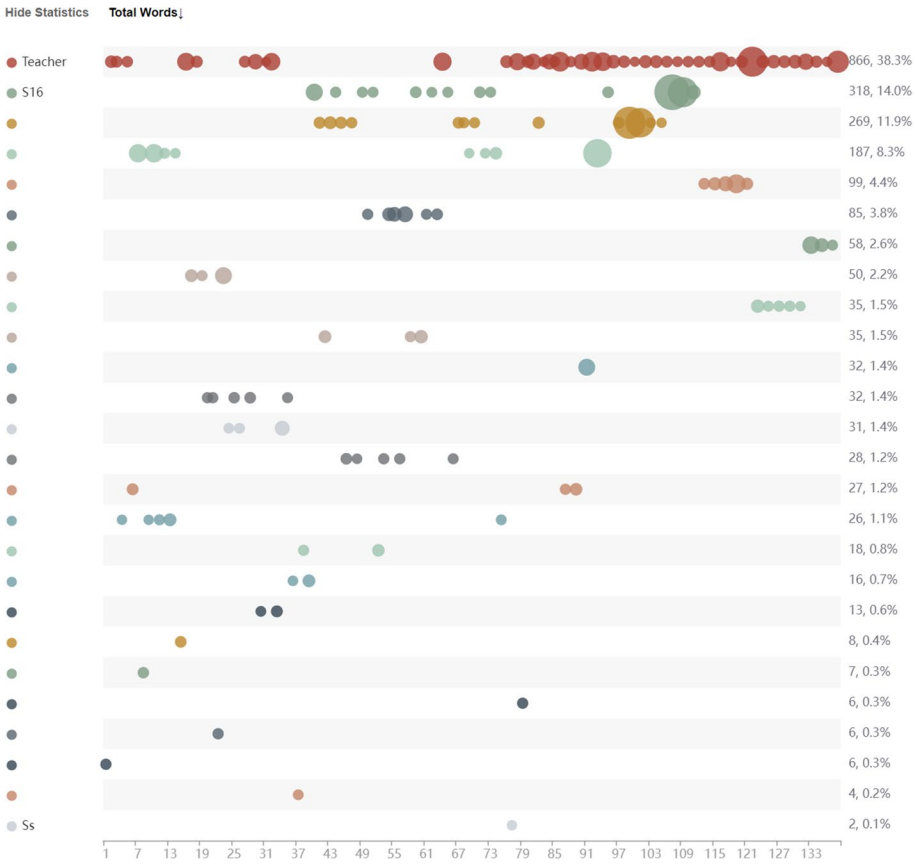
Reflecting on active participation in the whole-class talk

Visualisation also helped their reflection on participating in whole-class talk, which was evident in the students' stimulated-recall interview. Before the start of the interview, the researcher invited a pair of students (Student 16 and Student 03) from Leo's group to log into their account and demonstrate how they used CDA with a laptop.

Excerpt 3

Stimulated recall interview of two students from Leo's group

Interviewer:	… Did you learn anything from the visualisation?
Student 16:	Visualisation? Oh we don't have to look at the entire video. We can see who spoke the most, who spoke first and who spoke later
Interviewer:	So you know the sequence of the speaker…
Student 16:	Yes. [*Student 16 ranked the speaker using a function in the visualisation.*]
Student 03:	Here, these speakers at the top…
Student 16:	Yes, they spoke the most and those at the bottom spoke the least. Of course, sometimes…
Student 03:	They were repeating…
Student 16:	Not just repeating, the teacher sometimes spoke with students at the same time. Am I right? Here was the speech of the teacher. [*The teacher spoke the most in the visualisation chart, with big bubbles and a high percentage.*]
Student 03:	If you have two bubbles, it means you spoke only twice. [*A student spoke twice at the bottom of the visualisation chart.*]
Student 16:	We could see clearly from the bubbles when the students spoke. So we don't need to see the entire video to know who spoke at when
Interviewer:	Do you want to speak more frequently so you can rank at the top in the visualisation?
Student 03&16:	Yes!



Note. Users can click '(Show/) Hide Statistics' and '(Rank by) Total words' to interact with the visualisation. The size of the bubble represents the number of words said in a speaking turn. The number of the horizontal axis at the bottom represents the number of turns, while the different colours on the vertical axis represent different speakers. The number and the percentage on the right are the word count and its proportion in total words, spoken by the speakers in this clip. The teacher spoke the largest amount of words (866 words, contributing 38.3% of total words) and was ranked the top. S16 spoke the second largest number of words (318 words, contributing 14% of the total words) and ranked second.

Fig. 5 Visualisation of classroom discourse (ranked by total words spoken)

In the stimulated recall interview (Excerpt 3), two students took over the interview by entering a dialogue on how they interpreted the visualisation. They reasoned the representation of the bubbles, revealing their understanding of the classroom talk. When a student and a teacher have bubbles of the same size, the students explained that they were 'repeating' or were speaking 'at the same time'. Without guidance from the interviewer, Student 16 used the ranking function in the visualisation (see Fig. 5 as an example), and started to spot who spoke the most and who spoke the least during the session. Both students agreed they would like to rank at the top in visualisation by contributing more. For the whole-class talk, another pair of students expressed their interest in examining the trajectory of their participation by checking the visualisation multiple times:

I hope my teacher can use the platform in the future. I think it is of great help. We can see our performance during the lesson, and how much we spoke, then we could do something about it. If we can see (the visualisation) every day, and if there are fewer and fewer bubbles (of me) or my bubbles are too small, I need to speak more (Student 08 and Student 09, interview, Leo's group).

Discussion and implications

This study examined how visualisation technology as a tool could enhance dialogic reflection amongst young learners through a VSDR approach. In this approach, teachers recorded lessons, selected clips of visualisation and designed reflection prompts. Students participated in dialogic reflection on the discussion forum with reference to visualisations of classroom interactions. We found that the VSDR approach could enhance students' learning outcomes and class participation. Quizzes revealed increased subject knowledge for both groups, but only the high-dose group showed statistically significant performance improvement. Lesson recordings indicated a rise in the proportion of student contribution. In addition, the VSDR approach has the potential to help students see alternatives in task completion, become more aware of the strategies in group collaboration and be encouraged to participate actively in the whole-class talk.

By supporting students to revisit their own and others' learning processes using videos and visualisations, our approach contributes to the literature on task debriefing. Debriefing can occur either during or after an activity, with studies showing mixed results regarding its effectiveness. Van Heukelom et al. (2010) found post-activity debriefing more effective because students could focus on the task without interruption and experience the consequences of their mistakes. In contrast, Bilgin et al. (2015) found that the immediacy of during-activity debriefing outweighed the concentration advantages of post-activity debriefing, as students could recall details more vividly when memories were fresh. The VSDR approach has the potential to integrate these benefits, allowing students to fully engage in the task and later reflect on it with detailed evidence and visualisations. This combination is likely to enrich the reflection process in debriefing.

Visualising classroom talk for dialogic reflection

In our study, visualisations integrated with students' classroom videos supported their dialogic reflection by providing insights, enabling exploration, and facilitating comparison-three dimensions of technology-supported reflection (Bentvelzen et al., 2021). Learners gained insights through examining classroom situations from fresh perspectives, exploring representations in the visualisation, and comparing others' performances whilst tracking their own across lessons. To support dialogic reflection, the technology must go beyond pure revisiting; it should allow users to see the experience from a different viewpoint and reorganise their knowledge from multiple perspectives (Fleck & Fitzpatrick, 2010). This allows for an enriched experience for joint reflection, during which students benefit not only from receiving feedback but also from the activity of providing feedback to peers (Eshuis et al., 2019).

Students' ability to understand, reason and manipulate the visualisation suggests that the visualisation tool can help young learners. Representation dilemma (students need to learn

new content from *new* visual representation; Rau, 2017) might pose threats to students' learning through reflecting with the tool. We can see that when students interact with the visualisation, especially when checking who spoke the most, it presents dual meanings that could be interpreted by students. In group work, the students would think about whether they have dominated the discussion; whilst in whole-class talk, they would try to contribute more to the discussion. This echoes Celepkolu and colleagues' (2021) finding that young learners have increasingly rich experience interpreting and reasoning what visualisation represents. In addition, the design of the visualisation metaphor followed the principles of using appropriate and effective colour combinations when designing the layout, and allowing for changing the information provided when designing the visual interaction (Norouzi et al., 2021).

Although there was a debate as to whether student word count could indicate equal participation in group work (Strauß & Rummel, 2021), the visualisation of student discourse during collaboration in this study served as a group awareness tool that helped students monitor their social participation. Group awareness refers to the participants' knowledge of their collaborators' current behaviour and commitment (Rojas et al., 2022), and its social aspect pertains to participants' perception of how well the group is working together (Bødker & Christiansen, 2006). Students' attention to group awareness was evident in the discussion forum. For instance, Student 16 expressed the intention to listen to others and avoid dominating the discussion as a group member, whilst Student 08 highlighted the importance of being patient instead of blaming each other. With both visualisation and teachers' prompts, the VSDR approach likely enhanced students' group awareness.

An enhanced group awareness also echoes the call for accountability of talk in the learning community (Michaels et al., 2008; Resnick et al., 2010). In terms of accountability to reasoning, in the discussion forum, students were asked to elaborate on what they have written in the reflection (e.g. 'How can your group improve?') or their response was extended by others' comments (e.g. 'Collaboration is necessary. The teamwork would not succeed if there is no collaboration, even if everyone is a master'.). Students also pursued accountability to knowledge during dialogic reflection (e.g. commenting on 'a million times of practice' by asking 'How many times did you rehearse?'). With the prompts from teachers and questions from peers, students were reminded that they have a responsibility to their learning community and to be accountable for their talk in their future collaborative practices.

Discussion forum as an extension of learning space

With the insights and exploration generated from visualisation, discussion forums provide space for students to explore the process of their learning, document their thoughts and exchange views asynchronously. This approach aligns with Lantz-Andersson and colleagues' (2022) study that video clips of classroom video prompted retrospective reflections (looking back), and the collaborative environment with reflectors interacting with each other facilitated prospective reflections (planning forward). Meta-analysis suggests that students' motivation is a key factor in the success of asynchronous learning (Zeng & Luo, 2023). In the VSDR approach, visualisation enhances students' interest in exploring participation patterns they might otherwise miss, and teachers stimulated the discussion amongst students by setting meaningful prompts on the discussion forum that were worth discussion, as poorly written prompts may lead to 'copy and paste' pitfalls (Furberg, 2009).

On the discussion forum, students collaborate in dialogic reflection by presenting alternative perspectives or challenging other students. This supports the CSCL research, indicating that discussion forums facilitate direct interaction amongst participants, particularly in information retrieval and cognitive aspects, on the basis of the input provided (Yang, 2024). Communication through technology also leaves a traceable record as evidence of learning (Yukawa, 2006). During collaboration on the forum, however, students may exhibit antagonistic behaviours. For instance, Student 15's question, 'How many times did you rehearse?' could be interpreted as mocking Student 08's metaphorical use of 'a million times of practice'. Antagonisation is defined as 'causing tension, including hurtful comments, instigating fights, prodding, putting down partner contributions, and showing annoyance with partner' (Tsan, 2021, p. 1187).

The discussion forum is an extension of classroom space; therefore, the teacher's role in monitoring and intervening in students' antagonistic behaviours could be crucial. Additionally, teachers need to be aware that students can easily identify their classmates' coded numbers and colours by correlating these codifications with the visualising participants in the video clip, potentially leading to further antagonistic behaviours. On the contrary, research has also found that giving autonomy to student groups can enhance their dialogic interaction and engage otherwise disengaged students during collaboration (Slakmon & Schwarz, 2014). Therefore, more work needs to be done to investigate how teachers should contribute to asynchronous postings and forums to balance autonomy and intervention.

In addition to setting prompts, Leo and Hazel did not become too involved in the asynchronous discussion, even when students' reflections contradicted the reflective prompts or did not respond to others' comments, but only said 'thank you for your comments', challenging their accountabilities to standards of reasoning and accurate knowledge. When facilitating student reflection, teachers could posit their roles as co-learners who signpost important issues, pick up the threads and draw them together (Hendricks et al., 1996). Teachers' feedback and further questions could mediate the development of students' learning strategies and metacognition in learning, realising double-loop learning (Liu et al., 2023). Leo and Hazel's limited participation in student reflection may be attributed to the challenge of classroom orchestration, which often involves a teacher's real-time management of activities with multiple constraints, particularly in complex scenarios that utilise technology and require adaptive responses (Dillenbourg, 2013). Whilst asking students to work on the discussion forum, teachers may need to attend to both the digital and physical flow of information (e.g., facilitating discussion on the forum whilst monitoring students' use of iPads), which can introduce burdens and distractions.

To reduce the orchestration load of teachers during dialogic reflection, literature on classroom orchestration systems suggests that technology can empower teachers before and during class for better classroom instruction (Feng et al., 2023). For instance, rather than allowing teachers to freely compose the prompts, the discussion forum could be partially 'scripted' by prompting teachers to pose questions on key topics for students to address (e.g. 'what happened', 'how to interpret', 'how to improve'; Dillenbourg & Hong, 2008; Kirschner et al., 2004). In addition, to help students regulate their replies, instead of commenting on the individual level, teachers could also consider inviting students to tag their thinking types when posting in the forum, which promotes critical thinking (Schellens et al., 2009). For the 'reply' function in the discussion forum, future development may include tagging the thinking types (e.g. identification, definition, exploration, evaluation, integration) when replying to the students' comments to help the student develop

meta-cognitive skills and take accountability during dialogic reflection practice on the discussion forum.

Limitations of the present study

With the use of videos and visualisation of classroom talk, we need to address the privacy and ethical concerns of this approach, and broadly in the CSCL environment. Firstly, although the videos were recorded for the purpose of assisting students' dialogic reflection, teachers were worried that the videos could be seen by parents or third parties. Thus, the asynchronous platform was used only in class, limiting the affordance of using asynchronous discussion forums to save class time. Second, even if the visualisation is a mirroring representation of the classroom talk recording, it is limited to the angle of the camera and the subjects being captured, which may cause bias. This relates to the natural incompleteness of classroom data for all classroom dashboards, as not all the details of the learning and collaboration process could be recorded (Martinez-Maldonado, 2019). Both teachers and students need to interpret the visualisation with caution and reflexibility in the complexity of classroom talk, or it could lead to erroneous conclusions about student performance.

This study also has a few limitations that should be noted. First, the current study is explorative in nature, with a small sample size consisting of only two teachers and their students. Teachers' choice of video clips and their formulation of reflection prompts could potentially impact the implementation of the VSDR approach. Future research should involve a larger sample of teachers and students to more comprehensively assess its effectiveness. Secondly, whilst we utilised word count as a metric for evaluating student contributions both in the visualisation presented to students (size of bubbles) and as a research method reflecting student gains, this measure may not adequately reflect the quality of student talk. Since the visualisation prompts students to concentrate on their contribution in relation to their peers, students might just echo what their teacher or other classmates have said. Future visualisation designs should consider analysing and visually representing the quality of student input (e.g. whether student responses included examples, justifications or reasoning), potentially using varying shapes or brightness in visualisation bubbles. Researchers also need to investigate the impact of the VSDR approach on the quality of students' participation. Lastly, we did not assign any activities to the low-dose group during periods when the high-dose group reflected on visualisation. In the future study, the same reflection prompts could be assigned to students at the same frequency for both high-dose and low-dose groups, one using the VSDR approach and the other using face-to-face discussion, for a more rigorous experimental design.

Conclusions

The present study broadens the perspectives on how visualisation supports dialogic reflection amongst teachers and students. Grounded in the research of classroom talk, we believe that meaningful dialogues in the classroom and the discussion forum require collaboration both between teachers and students and amongst students. Our study investigated how visualisation technology supported the reflection process in which teachers and peers helped

students understand classroom interaction that led to alternative solutions to tasks, and better awareness in group work and whole-class discussion.

Classroom interaction at the social level is crucial when learners engage in collaborative, hands-on learning activities that incorporate technology. We contribute to the research outputs of the CSCL community by demonstrating interactions and activities stimulated by capturing, analysing and visualising discussions. Through the VSDR approach, students were able to deepen their understanding of problem-solving, and the dialogic reflection took place through revisiting, exploring and comparing the evidence, posting reflections and making suggestions to others. Visualisation is a promising reflective tool that affords dialogic reflection, as the experience is discursive, data-led and focusses on building a community (c.f. Mann & Walsh, 2013). By triangulating data from quizzes, lesson videos, discussion forums and interviews, practical implications are yielded for designing dialogic reflective experiences. Future research should consider improving the visualisation by using it to reflect the quality of students' contributions, and collecting large-scale quantitative data on students' dialogic reflective practices mediated by visualisation for an enriched understanding.

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Data Availability The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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