TeamTeachingViz: Benefits, Challenges, and Ethical Considerations of Using a Multimodal Analytics Dashboard to Support Team Teaching Reflection

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Abstract

Team teaching in higher education can be challenging, especially for educators managing large classes with limited pedagogical training and few opportunities to reflect on their practices. Emerging sensing technologies and analytics can capture and analyse patterns of collaboration, communication, and movement of team teaching. Yet, few studies have presented these data to educators for reflection. To address this gap, we examine the benefits, challenges, and concerns of presenting multimodal teaching data (positional, audio, and spatial pedagogy observations) to educators via the `TeamTeachingViz` dashboard. We evaluated `TeamTeachingViz` in an authentic classroom context where educators explored their own data and team teaching strategies. Multimodal data was collected from 36 in-the-wild classroom sessions involving 12 educators grouped in various combinations over 4 weeks, followed by semi-structured interviews to reflect on their practices. Findings suggest that educators improved their self-awareness by using data-driven insights to understand their movements and interactions, enabling continuous improvement in team teaching. However, they noted the need for additional data, such as student behaviours and speech content, to better contextualise these insights.

CCS Concepts

• **Human-centered computing** → **Visualization systems and tools**; *Collaborative and social computing*; *Empirical studies in visualization*; • **Applied computing** → *Collaborative learning*.

Keywords

teaching analytics, LA dashboard, multimodal learning analytics, co-teaching, teaching reflection, spatial pedagogy, in-the-wild

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1 Introduction

The massification of higher education and the increasing diversity of student needs have raised new challenges [25, 26]. Traditional lecture-based instruction, where a single lecturer delivers content to a passive audience, often fails to meet the varied learning requirements of large, heterogeneous students. To address these challenges and effectively manage large-scale classrooms, many higher education institutions have adopted *team teaching*–a collaborative approach in which multiple educators simultaneously instruct in the same physical classroom [15, 52]. Proven effective in K-12 education [23, 57], this approach allows educators to share responsibilities and address diverse student needs. However, in higher education, many educators have little experience with team teaching and are often required to adopt this teaching approach without adequate preparation or support. This limited experience can make it challenging to optimise shared classroom space for better student learning outcomes [16]. Indeed, the concept of *spatial pedagogy* [33] has emerged as a response to this challenge, emphasising the effective use of shared classroom spaces to improve interactions between educators, students, and the learning design [22]. Yet, to support educators in understanding and improving these interactions through reflection [17, 48], it is crucial to move beyond mere conceptualisation and find scalable ways to capture and analyse teachers' behaviours in the classroom.

Teaching Analytics (TA) has emerged as a promising sub-field of learning analytics that focuses on analysing the teaching-learning process through educators' data [8, 27, 53]. Since teaching in physical classrooms is inherently complex, recent works have demonstrated that integrating multiple data sources can provide a more comprehensive view of teaching behaviours. For instance, various sensing technologies—including video [e.g., 1, 43], audio [e.g., 39, 56], and classroom positioning data [e.g., 30, 58, 59, 61] have been previously used in Multimodal TA (MMTA) research to capture and analyse educators' behaviours in physical learning environments. While multimodal teaching data analyses have offered valuable research insights, previous studies have provided limited direct benefits to educators due to challenges in making these data accessible. This underscores the need to explore the benefits and challenges of making educators' teaching behaviour data visible to support their reflection on spatial pedagogy and team teaching practices.

Some recent research has partly addressed this gap by developing reflection TA systems that offer data-informed insights [44, 49] usually in the form of TA dashboards [e.g., 4, 39]. For example, *TEACHActive* [4] uses *EduSense* to promote teachers' reflection based on teaching practices visualisations integrating video and audio. Nevertheless, MMTA dashboards [e.g., 4, 12, 39, 44, 61] have primarily been designed for individual teaching, not for team teaching contexts, and lacked a theoretical foundation like *spatial pedagogy* [33], which focuses on classroom teaching dynamics.

No study has yet explored teachers' perceptions when reflecting on their in-person team teaching dynamics. Since spatial pedagogy [33] and co-teaching [15, 52] are relatively new theoretical frameworks, this study aimed to assess their potential benefits and evaluate whether these concepts resonate with educators. In addition, there is a very limited investigation into the ethical implications of integrating multimodal data into TA dashboards for educators' use, particularly concerning issues of privacy, data accuracy, and trustworthiness [3, 7, 59].

To address the research gap in educators' reflections on collaborative teaching, the practical application of spatial pedagogy and co-teaching, as well as the ethical concerns related to an MMTA dashboard, we conducted a *Design Through Matchmaking* [10] study. In the study, we evaluate educators' perceptions of the benefits, challenges, and ethical concerns of an MMTA dashboard (`TeamTeachingViz`) to support reflection on team teaching practices. `TeamTeachingViz` integrates multimodal data, including indoor positioning and voice activity (captured via sensors), as well as spatial pedagogy behaviours (captured via observations). Multimodal data was collected from 12 instructors during 36 team teaching *in-the-wild* (curricularly authentic) sessions, followed by semi-structured interviews with the educators to present and discuss their own data. This study aims to advance research on reflective practices in team teaching by providing educators with data-driven insights into their collaborative classroom dynamics, while also addressing the ethical considerations of integrating multimodal data into teaching analytics.

2 Background and Related Works

2.1 Team Teaching and Co-Teaching Strategies

Team teaching is an instructional approach in which *two or more* educators collaborate to deliver a class within the same classroom environment [6]. Much of the existing research has focused on co-teaching, which primarily examines pairwise interactions between two educators [5, 6, 13]. However, team teaching can be viewed as an extension of co-teaching, involving the combination of multiple pairwise interactions among educators working together. Six main co-teaching strategies have been identified in the literature, ranging from minimal collaboration to highly interactive approaches that require shared responsibility among co-educators [52]. These strategies are detailed later in Table 2 (Section 3.2) and include: *"One Teaching, One Assisting", "One Teaching, One Observing", "Alternative Teaching", "Tag-team Teaching", "Parallel Teaching"*, and *"Stationary Teaching"*. They are primarily designed for K-12 education to address various learning needs and promote inclusion, allowing educators to adopt different roles in the classroom, such as the main educator, assistant, or observer [23]. While K-12 education differs from higher education, educators still need to consider which group of students they will focus on – whether that is the entire class, small groups, or individuals [51, 52]. By adopting various roles and attention management strategies, educators can leverage conceptual insights from co-teaching literature to collaboratively address specific learning needs within the same learning space.

2.2 Spatial Pedagogy

A teacher's positioning in the classroom plays a crucial role in managing the environment and engaging with students [6, 58]. Spatial pedagogy conceptualises the movement and positioning patterns teachers use within learning spaces while interacting with students and resources [57]. Rooted in proxemics, which examines how physical spaces and intentional movements shape engagement with people and objects [33], spatial pedagogy categorises classroom spaces into four types that are detailed later in Table 1 (Section 3.2): *Authoritative*, *Supervisory*, *Interactional*, and *Personal*.

Early research on spatial pedagogy relied on human observation to understand how classroom spaces influence teaching. For example, a six-week study [47] found that teachers' proximity positively impacted student attitudes and performance. More recent studies have used position-tracking to explore spatial pedagogy in classrooms [30, 37, 57]. One study found that teacher visits often correlated with improved student behaviour, like reduced idleness [30]. Without access to these insights, teachers may have missed opportunities to support students, highlighting the need for tools that effectively communicate such findings.

These data analysis papers [30, 37, 57] aim to understand the strategies educators use in physical classrooms but place less emphasis on how educators can be supported with spatial pedagogy. There remains a notable gap in advancing research focused on how spatial pedagogy can facilitate educator reflection and improve classroom practices.

2.3 Related Work: Sensing Teaching Activity in the Classroom

Feedback on teaching is most effective when it is grounded in accurate, evidence-based data [1]. Most existing TA dashboards designed to support reflection have focused on single data modalities. For example, one study visualised student interaction networks from online discussion forum logs, enabling teachers to tailor lessons based on student discussions [28]. Another was among the first to explore the use of positioning data, visualised as heatmaps summarising teachers' physical movements in tutorials, helping educators reflect on how they allocated time across student groups [35]. Similarly, ClassInSight [39] used audio data to categorise teachers' discourse patterns (e.g., inviting elaboration or providing evaluation). In [39], teachers initially experienced surprise or dissonance during reflection sessions when the data differed from their expectations, but this eventually led to deeper insights and new goals.

While the above studies may provide valuable insights for teachers' reflection, focusing on a single modality can lead to incomplete analyses. With the availability of sensors and advancement of large data processing, sensing technologies may offer a comprehensive approach by combining multimodal data from various sources [1, 12, 44, 45, 61, 62, 62]. For instance, *TEACHActive* [4] combines video and audio data to help teachers reflect on their pedagogical practices by visualising statistics on hand raises, body movement, and speech acts from both educators and students. Despite the potential of MMTA dashboards to facilitate educator reflection, most existing systems are designed for individual teaching scenarios and primarily emphasise the use of students' learning data. To the best of our knowledge, no current MMTA solution is specifically tailored to support reflection on team teaching practices based on spatial pedagogy, even though this approach is getting more common in higher education classrooms.

2.4 Research Questions

A recent survey of 100 educators showed greater acceptance of collecting data on themselves than on their students, particularly for audio and position data [59]. This indicates that implementing the MMTA solution in authentic classrooms might be more desirable if it focuses on educators rather than students. Understanding the perceived benefits can help researchers and developers assess how well data-intensive innovations promote reflective practices among educators [37, 39, 61]. However, limited work has focused on presenting multimodal analytics directly to educators [29].

To address this gap, we explore educators' perceptions by presenting them with visualisations of their positioning, voice activity, interactions with students, and co-teaching strategies, derived from authentic classroom data. These visualisations were delivered through an MMTA dashboard, prompting the research question: **What are the perceived *benefits* for educators in accessing their multimodal teaching data (positioning, voice activity, and spatial pedagogy observations) through an MMTA dashboard to support reflection about team teaching? (RQ1)**

While exploring the benefits of an MMTA dashboard is valuable, it is equally important to examine the practical challenges educators may encounter. If educators struggle to interpret or interact with the data, the ability of these tools to promote reflection and professional development could be hindered. For example, complex multimodal data, such as positioning and voice activity, may be difficult for educators to understand without sufficient guidance [39]. Hence, we formulated our second research question: **What do educators perceive as practical *challenges* for accessing their multimodal data in the TA dashboard to support their reflection about team teaching? (RQ2)**

Exploring the MMTA dashboard for educators' potential use necessitates consideration of ethically responsible practices [7, 34, 54]. Integrating Shneiderman's human-centred AI ethical principles–safety, reliability, and trustworthiness–into the design of such dashboards offers a promising but underexplored opportunity to develop responsible analytics tools [14, 42, 50]. Drawing inspiration from recent LA works that discussed these ethical principles [3, 36], we asked our final research question: **What are educators' perceptions of ethical concerns in terms of safety, reliability, and trustworthiness, when accessing their multimodal team teaching data in the TA dashboard? (RQ3)**

3 Methods

3.1 Learning Context

Team teaching has become a standard instructional teaching practice at a university in Australia, where multiple educators collaborate to enhance the learning experience. This study was conducted in the Databases subject at both undergraduate and master's levels, which typically runs as a 2-hour session per week. The study spanned 36 sessions, with nine sessions conducted per week over four separate weeks. The classes followed their usual format, where three educators used a team teaching approach to collaboratively deliver the content in a single classroom session [15].

3.2 In-the-wild Multimodal Data Collection

During the classroom sessions, each educator was assigned an identifying colour (Red, Green, and Blue) and wore both an indoor-positioning sensor and a personal microphone to record their spatial and verbal data, respectively (see Fig.1). Educators wore a waist bag containing a *Pozyx UWB* to capture their body orientation

Figure 1: Three higher education educators wore individual microphones (red) and indoor-classroom positioning sensors (yellow) while co-teaching in a classroom, and a researcher coded their spatial pedagogy behaviours (blue labels) through in-the-wild observation.

and spatial coordinates (x-y) at a frequency of approximately *1Hz*. Moreover, each educator was equipped with a wireless headset microphone (*Shure PGA31*) to capture their voices.

In addition to sensor data, educators' spatial behaviours were captured via human observation to contextualise the multimodal data based on learning theory [18, 20, 24]. For this, we adopted the spatial pedagogy framework (see Section 2.2) to develop the codebook to categorise the observed educator behaviours, reflecting both the spatial and interactive dynamics of the classroom as outlined in Section 2.1. The codebook is shown in Table 1, it covers the four distinct types of classroom spaces: *Authoritative*, *Supervisory*, *Interactional*, and *Personal* spaces, as proposed by Lim et al. [33]. We adapted the behaviours to our context, for example, we differentiated the use of *Authoritative* space for lecturing versus providing supplementary support or clarification in order to link these behaviours to the co-teaching strategies.

To ensure the reliability of the codebook, two observers independently coded the spatial pedagogy behaviours from Table 1 in first two pilot classroom sessions. Discrepancies in coding were resolved through additional refinement and clarification of the codebook. Both observers independently coded behaviours in the second pilot classroom, yielding a Cohen's Kappa = 0.75 (good agreement). Then, one of the two observers coded team teaching in real-time for the rest of the sessions. Coding frequency was based on distinct actions, with a new code added for each change in the educator's behaviour.

3.3 Design

We adopted the *Design Through Matchmaking* approach from Human-Computer Interaction to adapt an existing solution from one domain to another [10]. Specifically, this approach allowed us to adapt an existing technological solution from nursing simulation team dynamics (*TeamSlides*, an MMLA dashboard and data collection system [19]) to the context of team teaching in classrooms. To address our research questions, `TeamTeachingViz`, a functional MMTA dashboard[1] was designed. This dashboard leverages educators' multimodal data, including indoor positioning and audio captured via sensors from the MMLA system mentioned above [19], as well as spatial pedagogy behaviours observed by humans. The dashboard's design is informed by spatial pedagogy theory and co-teaching strategies (see Section 2). This approach enabled educators derived insights from their own data and practical evaluation of a solution without the overhead of ideating from scratch at early design stages [60], which is particularly beneficial since educators may not fully grasp the design possibilities using data analytics [36, 40]. As a result, it facilitates matchmaking between TeamTeachingViz's capabilities (technological innovation) and educators' experience and understanding (domain knowledge), allowing them to reflect while critically discussing its benefits, challenges, and ethical considerations.

`TeamTeachingViz` has a "Welcome Page" that shows all sessions. In one session, it consists of three elements displaying visual/text information. All visualisations can be dynamically adjusted by controlling the time slider at the top of the dashboard (see Fig. 2- ❶ - time filter). This allows educators to filter data by specific time intervals, enabling a detailed exploration of particular moments (e.g., class topics). For instance, educators can focus on the initial part of the lesson to analyse their engagement in the classroom or examine the coverage of the classroom between different lesson segments managed by other co-educators.

Classroom Position-Voice Activity Map. Fig. 2- ❷ provides a comprehensive overview of all three educators' interactions by mapping the position and verbal activities within the classroom. A voice activity detection (py-WebtcVAD[2]) algorithm was used on each educators' collected verbal data to extract the time frames when educators talked [62]. This timestamped data was combined with spatial (x,y) coordinates to generate a hexagonal-binary[3] classroom map (inspired by sports analytics) that previous works have used to visualise team dynamics [19]. The more prominent the hexagon's colour (filled-in hexagon), the more the educator talked in that position.

Spatial Pedagogy Indicators. Fig. 2- ❸ displays tabular information designed to quantify and visualise classroom teaching

[1]Web app stacks: *ReactJS*, *D3*, *NodeJS*, and *Flask* – GitHub repository: https://github.com/riordanalfredo/TeamTeachingViz

[2]https://github.com/wiseman/py-webrtcvad

[3]https://github.com/ebaek/NBAShotTracker

Table 1: Codebook for human observations to categorise educators' behaviour using the spatial pedagogy framework

Category	Behaviour	Definition	Examples
Authoritative	Lecturing	Educator uses visual aids to instruct/demonstrate; formal teaching from a central position.	Lecturing without visuals, using slides, digital material walk-throughs.
	Supplementing	Educator takes over the lead, which is needed for clarity or making corrections.	Making announcements, giving additional instructions, providing clarifications.
Supervisory	Monitoring	Educator moves between tables, observing the classroom without direct interaction or individual observation.	Walking around, looking for students who will request individual assistance (i.e., students raise a hand).
	Surveillance	Educator observes students individually, often without openness to interaction.	Looking at students' work/laptops from behind.
Interactional	One-to-one consultation	Educator directly interacts with one student in a dialogue.	Talking to a student, answering questions, or providing feedback.
	One-to-many consultation	Educator provides guidance or clarification to a group of students.	Interacting with multiple students, clarifying task instructions for a group.
	Educator-educator interaction	Educator communicates with another educator during the lesson.	Discussing lesson plans, instructing each other.
Personal	Preparing	Educator engages in other non-teaching tasks and spends time alone.	Handling administrative tasks, preparing for the next lesson stages, using personal devices (i.e., laptop).
	Watching lecture	Educator pays attention to the main educator's lecture instead of observing the class or helping students.	Observing another lecturer, monitoring the class passively.

activities distribution based on spatial pedagogy behaviour observations (as described in Table 1). This representation displays the percentage of time each spatial pedagogy strategy was observed for each educator during the selected time period, as adjusted using the time slider. Moreover, the data can be further filtered by clicking a header button. For example, clicking "Interacting" will display bar charts showing the percentage of each educator's spatial pedagogy behaviours (i.e., One-to-one, One-to-many, and Educator-educator interaction).

Co-teaching Strategies Panel. Fig. 2- ❹ shows a panel purposed to complement the information presented in the other elements by communicating the team teaching dynamics observed during the session. Specifically, it provides a textual description of the co-teaching strategies [13] employed by different pairs of educators, detailing the educators involved in each approach and the percentage of the class they engaged in the most common strategy. To identify educators' co-teaching strategies, we mapped the combination of spatial pedagogy behaviours from Table 1 to the co-teaching strategies mentioned in Section 2.1. Table 2 presents the results of this mapping.

We developed a *rule-based algorithm* to determine the co-teaching strategies for each pair of educators (three possible combinations) at every timestamp. Then, we quantified the proportion of time each strategy was utilised and identified the most common strategy for each pair. To generate the text shown in the panel, conditional statements were used to differentiate scenarios where no co-teaching strategies are observed, one strategy dominates, or different strategies are observed between pairs. Inspired by Fernandez-Nieto et al.'s work [21], the results were then formatted into a narrative, using the percentages and descriptions of interactions between each educator.

3.4 User Study

The data collection process was structured across four weeks, with the subject coordinator (T1) supervising 12 educators (T2-13, avg. four years of teaching experience) participating in 36 two-hour-long sessions, grouped in various combinations, with no researcher intervention. Of the 12 educators, 4 identified as male, while the remaining 8 identified as female. Fig. 3 details the educators' participation, years of teaching experience, and their involvement in specific sessions. As seen in Fig. 3, several educators participated in multiple sessions. Educators' participation in this data collection was voluntary, and they could withdraw anytime (MUHREC ID 28905).

3.4.1 Post-hoc Study with Educators. After a three-week period, as suggested by the subject coordinator due to realistic workloads, we invited educators to participate in a post-hoc evaluation of `TeamTeachingViz` after the teaching period had ended, where they discussed the dashboard's benefits, challenges, and ethical considerations. Eight of the twelve educators participated in the semi-structured individual interview (T2-T9). The subject coordinator was also invited to the interview to provide additional insights and a broader perspective on the reflection process (T1). All educators accessed `TeamTeachingViz` only once during their interview.

The post-hoc study consisted of an individual one-hour interview and was structured into three parts: 1) general teaching and team teaching experiences, 2) exploration of their own data and reflection

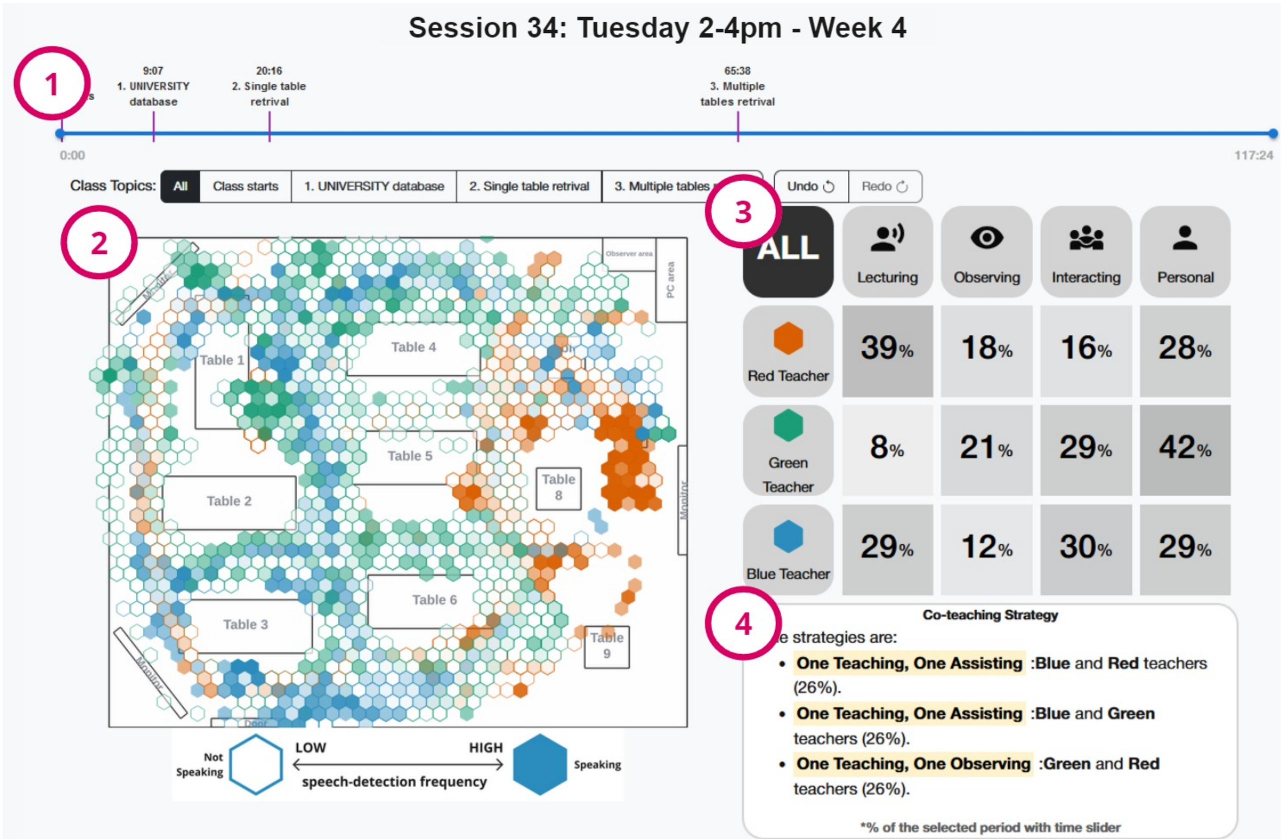

Figure 2: User interface of `TeamTeachingViz` of a classroom session: ❶ navigation panel with a time-filter slider, ❷ a classroom position-voice activity map indicating speech-detection frequency on space usage, ❸ spatial pedagogy indicators, illustrating the distribution of observed activities, and ❹ co-teaching strategies panel showing the most frequent strategies of each pair of educators.

Table 2: Co-teaching strategies observed in the classroom with their observable spatial pedagogy behaviours

Co-teaching Strategy	Description	SP Behaviours Combination
One Teaching, One Assisting	One educator leads the lesson while the other circulates among students, offering individualised support.	Lecturing + One-to-one consultation, Lecturing + Surveillance
One Teaching, One Observing	One educator leads the instruction while the other observes the lecture and students	Lecturing + Watching, Lecturing + Monitoring
Alternative Teaching	One educator instructs a larger group while the other provides instruction to a smaller group	Lecturing + One-to-many consultation
Tag-Team Teaching	Both educators delivering classroom at the front classroom	Lecturing + Supplementing
Parallel Teaching	Both educators helping students, none of them providing formal lecture	Combination of One-to-one or One-to-many consultation
Station Teaching	Divides the students into small groups that rotate through different stations	Both of One-to-many consultation

using `TeamTeachingViz`, and 3) discussions on benefits, challenges, risks, and future considerations. In the first part of the interviews, educators shared their experiences and strategies in team teaching, reflecting on challenges and preparation methods. The second part of the interviews involved explaining `TeamTeachingViz`'s capabilities and requested educators to reflect on using the dashboard,

Educators (Teachers)	Years of teach. exp.	Num. of sessions:	Pilot		Week 1									Week 2								
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
T1	19	0	Subject coordinator (no classroom data)																			
T2	1	8				Blue					Red				Green					Green		
T3	8	5			Green																Green	
T4	1	22	Red	Red	Red	Red	Red		Green	Green				Blue	Blue	Blue		Red	Red			
T5	3	4											Red									Blue
T6	7	13		Blue				Green		Blue			Green				Red		Blue			Green
T7	4	9						Red		Red		Red					Green		Green			
T8	2	10					Green				Green					Green				Red	Red	
T9	9	10	Green	Green	Green	Green								Red	Red							
T10	-	9						Blue	Blue								Blue	Blue				
T11	-	5							Red									Green				
T12	-	13	Blue		Blue		Blue				Blue			Green		Red				Blue		
T13	-	4										Blue									Blue	

Educators (Teachers)	Years of teach. exp.	Num. of sessions:	Week 3									Week 4								
			21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
T1	19	0																		
T2	1	8		Red					Red				Blue					Blue		
T3	8	5							Green	Red									Red	
T4	1	22	Blue	Blue	Blue		Green	Green				Green	Green	Red		Red	Red			
T5	3	4									Green									Blue
T6	7	13				Blue		Red			Red				Red		Blue			Red
T7	4	9				Green		Blue		Green									Blue	
T8	2	10			Red									Blue	Blue		Green	Red		
T9	9	10	Green	Green								Red	Red							
T10	-	9				Red	Red				Blue				Green	Green				
T11	-	5					Blue									Blue				Green
T12	-	13	Red		Green				Blue			Blue		Green				Green		
T13	-	4								Blue									Green	

Figure 3: A table of educators and classroom sessions across four separate weeks of data collection. T1 was the subject coordinator with 19 years of teaching experience. T2–T9 were educators who participated in data collection and follow-up interviews. T10–T13 (blacked out) were educators who participated in data collection but did not attend follow-up interviews.

where educators provided informal feedback and design suggestions.

In the final part of the interviews, we asked educators questions about `TeamTeachingViz`'s benefits, challenges, and ethical considerations to address our research questions. Regarding **RQ1**, inspired by AlZoubi and Baran's work [4], which examined educators' beliefs about the system's benefits to support their teaching practice in the short and long terms, we asked educators: *"What do you perceive as the short- and long-term benefits of using TeamTeachingViz?"*. For **RQ2**, drawing inspiration from the same study, we asked educators about practical challenges they faced while accessing their data for reflection, such as *"What were the challenges you experienced when using TeamTeachingViz for your team teaching reflection? How would you improve it?"*. For **RQ3**, we asked educators six questions about potential ethical concerns regarding safety, reliability and trustworthiness [50], inspired by Alfredo et al.'s work [3]. Example questions included: *"Do you have any ethical concerns to reflect on this data? Who should see it? Do you have data privacy or transparency concerns?"*.

Once the interviews were completed, educators answered System Usability Scale questions (SUS) through a post-interview questionnaire [55] to quantify the practical challenges (RQ2). A complete interview protocol is available in the Supplementary Material[4]. Each educator was compensated with a $50 gift card for completing the interview. All interviews were recorded with the educator's consent and subsequently transcribed using OpenAI `Whisper` [46].

3.4.2 Data Analysis. We conducted deductive-inductive analysis [9]. This approach combines a top-down application of predetermined categories from interview questions (deductive) with a bottom-up emergence of themes from the data (inductive) to ensure a rigorous and comprehensive qualitative data analysis. First, we extracted the utterances corresponding to the relevant interview questions. Then, two researchers individually identified key topics within each question (deductive), and emerging themes were discussed and summarised collaboratively (inductive). Any disagreements were then consulted with a third researcher to reach a consensus.

To address **RQ1**, we used deductive analysis to examine educators' answers from the interviews about the short- and long-term practices of `TeamTeachingViz` to come up with first-level codes derived from literature [4]. We then applied inductive analysis to identify emerging benefit themes, categorising the benefits as either short-term or long-term. To address **RQ2**, we analysed SUS results from the post-interview questionnaire to quantify and organise educators' feedback. The SUS score was calculated by normalising responses to positively and negatively worded questions, summing the adjusted scores, and multiplying the total by 2.5 to convert it to a 0-100 scale [55]. Using a baseline score of 68 for typical web applications [55], we identified the SUS items scoring below this baseline as key areas for improvement. These served as first-level codes in our deductive analysis of educators' responses to interview questions about perceived challenges. We then used inductive analysis to derive their feedback about improvements and future opportunities, organising them into these key categories. Lastly, to address **RQ3**, we conducted deductive analysis on educators' responses to ethical risks and concerns, using safety, reliability, and trustworthiness principles as first-level codes derived from the literature [2, 50]. Then, we applied inductive analysis to identify emerging themes, organising them under those principles.

4 Results

4.1 Perceived Benefits (RQ1)

In the **short-term**, three key themes emerged from educators' feedback on how `TeamTeachingViz` support their reflection process: enhancing self-awareness, offering insights into teaching dynamics and providing data-driven feedback. Moreover, participants mentioned tracking progress over time and supporting professional development as **long-term** benefits of the MMTA dashboard.

4.1.1 Short-term Benefits. All educators (n=9) mentioned that `TeamTeachingViz` provided insights into their teaching practices by making them aware of their movement and interaction patterns during classes (**Self-Awareness**). For instance, T4 emphasised the usefulness of data in prompting reflections, noting: *"I think it's really useful, we need to pay more attention to the activity in the class, the interaction between teachers and between teachers and students"*. Initially, T4 was surprised by the data showing that educator-educator interactions were almost as frequent as educator-student interactions, as they believed they had spent most of their time with the students. Upon further reflection, T4 remembered that their support for a less experienced educator likely led to more interaction with the other educators, unintentionally reducing the time spent with

[4]Interview Protocol: https://figshare.com/s/1d2ec425ca4f98c15cde

students. This prompted T4 to state: *"I have concerns regarding my activity in the class. I need to pay more attention to my activity to consider whether I need to spend more time with the student, rather than only supporting the other teaching assistant [educator]"*.

TeamTeachingViz was also found to be beneficial in understanding **Team Teaching Dynamics** (n = 7). T2 shared an example where the dashboard revealed the distribution of effort among co-educators, identifying who was more active in leading the class and who was less engaged and concluded suggesting that: *"This is something that educators or the team can see after each lecture and they can improve their strategies"*.

Lastly, educators (n = 6) appreciated the TeamTeachingViz ability to provide evidence-informed insights into their teaching practices (**Data-Driven Insights**). T7 highlighted that TeamTeachingViz can promote discussions about co-teaching practices by providing data to support observations: *"This gives us the space to discuss more about the practices within the class with the other educators because we have some proof. We have some data. It's not just based on the observation itself,"* and adding that the graphical illustrations and percentages provided by the dashboard were useful for preparing for subsequent semesters.

Overall, the short-term benefits of TeamTeachingViz were frequently associated with immediate post-class reflections and adjustments. T7 pointed out the value of using data to reflect on specific classes and make informed adjustments for the next session: *"After every class, you can have a look at the data and that would be important for the next class."*

4.1.2 Long-term Benefits. In contrast, long-term benefits that were mentioned by the majority (n = 5) of the educators were using the dashboard to track and compare performance across semesters (**Tracking Progress**). T3, for instance, discussed how long-term usage could facilitate a comparison of teaching strategies from one semester to the next, offering a clear view of whether and how improvements were made. T7 also mentioned the importance of long-term data for professional growth (**Professional Development**), saying: *"In the long term, it is professional development. You can improve your skills, and teaching practices based on the dashboard. And when you got the data for a long time, you can compare the data and see what you have done and what worked well."* Three educators also mentioned TeamTeachingViz benefits in supporting professional development for new educators who just joined the teaching team.

4.2 Perceived Practical Challenges & Revealed Opportunities (RQ2)

The SUS average score was **70.56** ±13.45 (out of 100), indicating good usability with some issues [55] (see Fig. 4). Based on each SUS category that was lower than the typical baseline [55], we summarised our results into four key areas of improvement: feature integration, feature consistency, and minimal learning to use.

Feature Integration (Q5 in SUS): This area refers to the extent to which visualisations incorporate data to comprehensively represent the classroom situation for educators. Most educators (n=5) noted that the lack of integration of student data might result in an incomplete picture of the dynamics between each educator and student in the classroom. They found integrating *"the number and position of students on the table"* (n=2), *"summary of students' audio conversations with educators"* (n=3), *"students' performance data [e.g., overall marks]"* (T8) could help them better understand dynamics between educators and students, ultimately help educators contextualising each classroom better. Similarly, the subject coordinator recommended incorporating student evaluation surveys and feedback on their educators' team teaching practices to better understand students' perspectives and expectations regarding the educators' collaboration. These evaluations could provide additional reference points for educators to reflect across multiple classrooms during the same semester and over time.

Feature Consistency (Q6 in SUS): This area addresses to the perceived challenges of achieving visual uniformity, which influence the educator's ability to understand each feature's functionality. Four educators (T2, T5, T7, and T8) found the purpose of the *Co-teaching Strategies* panel unclear due to inconsistencies with their existing mental model about team teaching. They mentioned that they had implemented *"One Teaching, One Assisting"* according to the designed lesson plan for a team of three educators (i.e., one main educator and two assistants). This results in educators perceiving co-teaching strategies in this panel, which describe educators as pairs– instead of as a trio– as inconsistent with all the other visualisations showing the data about the three educators. To address this challenge, they suggested commenting on the team strategies (instead of pairwise). Additionally, two educators recommended replacing the text with bar charts to align with the existing bar chart format used in the *Spatial Pedagogy Indicators*.

Ease of Use (Q8 in SUS): This area focuses on the perceived challenges in ease of use regarding the impracticality of carrying the positioning tag device. Four educators mentioned discomfort due to the cumbersome nature of carrying the device for two hours during data collection. Although the impracticality during data collection was indirectly related to the use of TeamTeachingViz, educators identified it as a significant factor that could affect their willingness to use the sensors required by the dashboard to visualise their data. Consequently, educators requested alternative methods to capture their position data in the classroom.

Minimal Learning to Use (Q10 in SUS): This area centres around the challenges users face when learning to operate a system that requires extensive training or prior knowledge. While the dashboard offered a wealth of information, its complexity required educators to understand spatial pedagogy and co-teaching constructs first to meaningfully reflect on their team teaching practices. Two educators mentioned that their unfamiliarity with spatial pedagogy terms necessitated further clarification to understand the percentages on the *Spatial Pedagogy Indicators*. Although TeamTeachingViz has tooltips explaining each feature, educators still suggested they needed *"more time to understand visualisations"* (n =3) and *"more scaffolding on the co-teaching strategies"* (n = 4). The subject coordinator further elaborated that the *Co-teaching Strategies Panel* required additional knowledge and training that educators were currently unfamiliar with. To address this, T1 and T5 suggested providing better explanations, such as *"recommended standard co-teaching strategies as baseline"*, to make spatial pedagogy and co-teaching strategies actionable. This would help educators focus on reflecting and improving their teaching practices with minimal learning overhead.

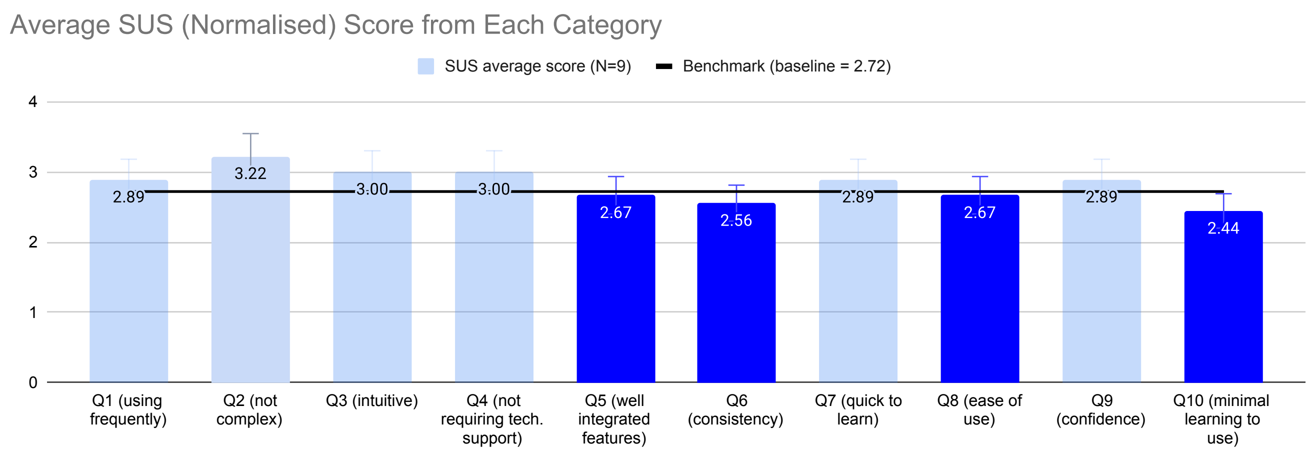

Figure 4: The average SUS score of `TeamTeachingViz` was 70.56 ± 13.45 **(out of 100). Four categories fell below the baseline (68%, 2.72 out of 4), indicating areas of improvement: Integration (Q5), Consistency (Q6), Ease of Use (Q8), and Minimal Learning to Use (Q10).**

4.3 Perceived Ethical Concerns (RQ3)

Data Privacy and Data Sharing (Safety). Most educators (n=7) were not concerned about data privacy or sharing their information with other educators. Still, two educators worried about *"data sharing with subject coordinator"* (T8) and *"possibility to identify colour-labelled educators"* (T5). Four educators saw value in giving the subject coordinator access to the information to assess the effectiveness of the learning design (rotating main educator approach). However, T8 suggested removing data access for the subject coordinator to avoid its use for performance evaluation. In response, the subject coordinator clarified that *"We have to make it clear that we don't judge performance based on this data. This data is more like feedback into the lesson plan instead of feedback to their personal performance review."*.

Data Accuracy (Reliability). Six educators found most of the presented visualisations reflected what educators experienced in the classroom. Although educators found the data accurate, some expressed uncertainty due to the elapsed time since they conducted their classes ($n = 3$). They believed that allowing them to have concise and easily accessible reports like `TeamTeachingViz` immediately after class would enable them to reflect on their teaching practices and plan better during the teaching period. T2 stated: *"If you give them at the end of the semester, then it will not make a big difference, and it takes the whole semester to change one thing [limited actionability]. But if you are looking for something you will try to improve every week, that makes a difference."* Moreover, two educators found that automating the spatial pedagogy observations could make the data more accurate, stating *"If the device captures automatically [referring to the observations], then I believe it will be more accurate."* (T6) and *"If we have a way to capture it [the observations] by devices, I think it's more reliable than you just observe by a human. It was hard to track everything when all educators did it [teaching] at the same time."* (T4).

Contextualisation and Accountability (Trustworthiness). Most educators (n=6) found the system trustworthy and reflective of their classroom activities. Two educators expressed partial trust, while one did not believe the dashboard fully captured classroom dynamics, as it primarily focused on space usage. Additionally, three educators emphasised the importance of contextualising the data. For example, T9 raised concerns about potential misinterpretations of educators' actions without further context. For example, an educator spending a high percentage of time in their *"Personal"* space–rather than interacting with the students–, may appear as lacking attentiveness to the classroom. However, T5 pointed out that *"Helping students [interacting with the students] always may not be needed when the lesson requires students to pay attention to the leading [or primary] educator."* Furthermore, two educators advocated for more data and validation to build trust in future analytics within `TeamTeachingViz`. When discussing data accuracy, some suggested automating the spatial pedagogy observations using rule-based algorithms or machine learning models. However, concerns were raised about the reliability of such potential automation. For example, T1 stated *"If you develop the classification and AI based on one semester's data, it will not be trustworthy enough. You need more than one semester to verify. We still need some manual observation to validate data. After two or three semesters, we can trust it more."*

5 Discussion

5.1 Responses to Research Questions

In response to **RQ1**, our results indicate that the MMTA dashboard can empower educators by improving their reflective practices on team teaching. In the *short-term*, `TeamTeachingViz` has the potential to foster self-awareness by providing insights into movement and interaction patterns, helping educators recognise how they interact with other educators and their personal use of classroom space [37]. Through this self-awareness, which is based on data rather than assumptions, educators can potentially make actionable future goals to collaborate better with other educators [19, 45]. One participant experienced dissonance during a reflection session when encountering unexpected data in `TeamTeachingViz`. This surprise led them to reconsider and plan changes in their interactions with both educators and students. This reaction aligns with the findings of Ngoon et al. [39], highlighting the potential of data-driven insights to provoke meaningful reflection and adaptation in teaching practices. In terms of *long term* benefits, educators recognised the potential benefits of tracking and comparing their performance over time–proven beneficial in [15], leading to professional development through continuous improvement and evaluation of their teaching practices. These anticipated changes align with the findings by Yan et al.[57], where it was observed that educators' classroom behaviours indeed evolve over time.

Addressing **RQ2**, educators' main challenge was the limitation of having access only to their own data, without any student data. This desire for student data seems to contrast with Yang et al.'s survey findings [59], where teachers were less comfortable with collecting students' audio and position data. However, our results indicate that student data remains relevant for educators in supporting their team teaching reflection. To address this tension, there is a need to explore practical yet less intrusive alternatives for collecting classroom data from educators and students, thereby integrating teaching and learning analytics to provide a more holistic view of team teaching [8, 49]. This approach becomes crucial in higher education's massification [26], where the fluctuating number of students in a classroom can complicate data collection processes, including obtaining student consent for privacy considerations [41]. Implementing MMTA dashboards from real classrooms thus requires balancing practical data collection methods with providing educators with comprehensive, actionable insights. In addition, regarding other perceived challenges, extra training or scaffolding may be needed as educators found the *Co-teaching Strategies Panel* not well integrated into their mental model due to a misalignment between their understanding of co-teaching strategies and the dashboard data. A potential approach to address this challenge is to involve educators in several design iterations [3], as previously explored [39, 44]. Additionally, improving educators' data literacy training can support data-intensive teaching practices [38, 49].

Addressing **RQ3**, our study revealed that educators perceived the dashboard's reliability as dependent on human observations, which they believed were susceptible to error and often inaccurate. While automating the coding process using AI to classify spatial pedagogy based on position and conversation context seemed like a logical next step, a hybrid human-AI approach can be more compelling [14]. For instance, a human-in-the-loop approach allows educators to evaluate automated spatial pedagogy behaviour codes, generated using audio and position data, through `TeamTeachingViz` at the end of their classes. This synergy addresses ethical concerns by ensuring that AI classifications are not only validated by human experts but also refined through an iterative process, as highlighted by our subject coordinator (T1). This approach can build competency, transparency, and trust among educators, particularly when involving them as co-designers [41, 60]. Hence, the integration of AI should complement rather than replace human judgment, aligning with recent research that emphasises the importance of human-centred approaches in LA [3]. This approach could enhance safety, reliability, and trustworthiness while enabling continuous improvement and preserving human involvement in design and analysis [18, 59], potentially creating more responsible MMTA dashboards.

5.2 Implications for Research and Practice

Based on the results, we recommend three design considerations that can inform further development of similar TA tools to support team teaching reflection. Firstly, the dashboard should integrate student data while maintaining privacy. This could address educators' desire for comprehensive insights into classroom situations without compromising ethical standards. Data could be de-identified or aggregated, such as in the form of a number and the position of students in the classroom [59], ensuring such interpretation with integrity [37]. Secondly, it is crucial to develop visualisations that are more closely aligned with each learning design and include contextual annotations [21], thereby improving its trustworthiness and relevance for educators' reflection. Design methods in human-centred LA can support this recommendation [3, 11] as demonstrated in prior MMLA research [12, 19, 31]. Lastly, we recommend incorporating mechanisms to compare class sessions over time, offering a broader subject-level perspective for long-term reflection and professional development.

For practitioners and institutional decision-makers, tools like `TeamTeachingViz` can help improve the utilisation of spaces and promote the identification and development of better team teaching practices and professional development programs. However, it is important to address the concerns raised by educators that such tools should not be used for assessing performance. Therefore, institutional guidelines on the use of these tools should be established to ensure appropriate usage, as they can directly impact user adoption [28, 32, 38].

5.3 Limitations and Future Work

This study has several limitations. First, since the study aims to allow educators to access their own data, the number of participants in the follow-up interviews is considerably small. Yet, data collected from the study came from authentic team teaching conditions and therefore provided qualitative value as educators reflected on their own data. Second, the spatial pedagogy and co-teaching elements in `TeamTeachingViz` rely heavily on human observations, which is resource intensive and limits the scalability over multiple classrooms and through time. Given the perceived benefits (in RQ1) and ethical concerns (in RQ3) reported by educators in our study, future work can explore using hybrid human-AI systems to support the labelling process and minimise AI or human bias. In this regard, AI could support researchers by analysing the conversation context, as explored by Ngoon et al. [39], interwoven with the positioning data and contextual information, as explored in other contexts by Zhao et al. [62]. Lastly, we acknowledge the potential limitations in the generalisability of our findings. Other educational settings, such as K-12, may have different lesson plans and classroom sizes in which educators will teach and reflect differently [12]. For example, `TeamTeachingViz` may not be beneficial if the classroom delivery is stationary (i.e., educators only stand at dedicated locations). Yet, we address highly dynamic collaborative teaching classrooms that are moving away from the traditional lecture-based instruction paradigm, a trend that is becoming increasingly common in higher education [15, 51, 52].

6 Conclusion

In this work, we examined the benefits, challenges, and ethical considerations educators perceive when accessing their multimodal data for a reflection on team teaching practices. This was done through the *Design Through Matchmaking* study using `TeamTeachingViz`, a functional MMTA dashboard prototype that presents educators' position-voice activities in the classroom, spatial pedagogy behaviours, and employed co-teaching strategies. The insights gained from this study will support future design opportunities for similar MMTA dashboards in other contexts, ensuring they evolve to support team teaching practically and ethically.

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