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A Closer Look at Instructor Use and Sensemaking Processes of Analytics Dashboards: Past, Present, and Future

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Abstract

There is a growing interest in the research and use of automated feedback dashboards that display classroom analytics; yet little is known about the detailed processes instructors use to make sense of these tools, and to determine the impact on their teaching practices. This research was conducted at a public Midwestern university within the context of an automated classroom observation and feedback implementation project. Fifteen engineering instructors engaged in this research. The overarching goal was to investigate instructor teaching beliefs, pedagogical practices, and sensemaking processes regarding dashboard use. A grounded theory approach was used to identify categories related to instructor perceptions. Results revealed that instructor experiences inform both their present use of the dashboard and consequential future actions. A model is presented that illustrates categories included in instructor pre-use, use, and post-use of an automated feedback dashboard. An extension to this model is presented and accompanied by recommendations for a more effective future use of automated dashboards. The model's practical implications inform both instructors and designers on effective design and use of dashboards, ultimately paving a way to improve pedagogical practices and instruction.

Notes for Practice

- Instructors can use automated feedback dashboards as professional development tools to improve pedagogical practices.
- Guiding instructors through the dashboard training can enhance their sensemaking processes.
- Dashboard walkthroughs can be paired with data literacy training to improve instructors' overall experience and use of dashboards.
- Classroom noticing exercises should be incorporated into professional development.
- Regular scaffolding sessions can guide instructors in data interpretation and setting goals.

Keywords: Classroom analytics, automated classroom observation, feedback dashboards, instructor sensemaking, dashboard use, active learning (AL)

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1. Introduction

There is growing interest in the research and use of classroom analytics to help instructors better understand, model, and support teaching and learning processes. The data from traditional learning analytics (e.g., log data analyzed and used in online learning processes) are usually unidimensional (Worsley & Blikstein, 2015) and ignore important contextual information. They provide limited and partial information that may not be sufficient to understand the complex nature of teaching and learning (Martinez-Maldonado et al., 2018). Classroom analytics are complex in nature; they require tools that aggregate data sources and provide concise visuals (Martinez-Maldonado et al., 2018). A more holistic view can be obtained by capturing

classroom analytics data that can significantly contribute to in-depth teaching and learning processes insights (Giannakos et al., 2019).

Dashboards are analytic learning tools that represent and visualize complex data at a glance (Matcha et al., 2019). They can effectively communicate complex classroom analytics data to users (Fernandez Nieto et al., 2022). Instructors find they can use analytics dashboards to gain deeper insights into their students and improve their teaching practices (Li et al., 2021). Currently, the main emphasis in the literature is on data production and instructional outcomes, rather than pedagogical practices and instructor usage that inform this data (Jivet et al., 2017; Valle et al., 2021). There is a critical need for analytics data to be employed as an educational approach guided by pedagogy, not the other way around (Greller & Drachsler, 2012). Pedagogical practices and context, emphasized by van Leeuwen et al. (2021), are pivotal for interpreting dashboard data effectively. Little research has investigated sensemaking processes and instructor dashboard use to inform teaching practices and subsequent actions (Martinez-Maldonado et al., 2020). Data alone is not meaningful if instructors interacting with the analytics are not able to take actions without making sense and reflecting on it (Molenaar & Knoop-van Campen, 2019). Research on instructor use of analytics has focused on dashboard outcomes, rather than on exploring the ensuing sensemaking processes generated by the dashboard analytics (Wise & Jung, 2019).

There is a paucity of research that has carefully examined how instructors respond to and make use of dashboard analytics displays (van Leeuwen et al., 2017). The current literature highlights differences in how instructors use dashboards, how they make sense of the data, and the nature of their subsequent actions (if any) (Molenaar et al., 2021), as well as instructor challenges when acting on the provided data (e.g., Brown, 2020; Dawson et al., 2019). Previous learning analytics research has inadequately addressed how instructors use dashboards to process classroom analytics and their ensuing sensemaking. Instructors' ability to transform the information presented in the data into actionable pedagogical practice is one of the highly touted potential outcomes of dashboard use; yet the literature reveals that most instructors struggle when attempting to connect the data with their teaching practices (Wise & Jung, 2019). This has introduced several problems, as identified in the extant literature; namely, instructors do not adequately interact with their dashboards and they do not report their sensemaking processes nor incorporate results from their sensemaking processes into practice (Jivet et al., 2020). Furthermore, although dashboards have already been used by hundreds of instructors and students, evidence of successful and impactful implementation is still scarce (Li et al., 2021). As such, there is a concern among researchers and practitioners that like other educational technologies that have previously boomed and then faded away, educational dashboards may not have a lasting impact and may fade away as well (Wise & Jung, 2019). In this study, we argue that the issue may not necessarily lie in the technology itself but in how it is integrated into pedagogical practice. By examining the sensemaking processes of instructors in relation to dashboard use, this study aims to contribute to a more effective and meaningful implementation of educational dashboards in the future.

1.1. Research Purpose and Questions

This study investigated the underlying pedagogical practices of instructors and their use of automated feedback systems, the sensemaking processes they embrace when using such systems, and their goals and subsequent actions. The current study addressed the need to unfold instructor sensemaking processes while engaging in classroom multimodal analytics. Its overarching goal was to investigate how instructors make sense of multimodal classroom analytics displayed on dashboards and align them with pedagogical practices. The following research questions were addressed:

RQ1. What are instructors' teaching beliefs and perceptions about pedagogical practices prior to using an automated feedback dashboard?

RQ2. How do instructors use automated feedback dashboards, and what sensemaking processes do they engage?

RQ3: What are instructors' perceived challenges with and recommendations for using automated feedback dashboards?

2. Related Work

The following section describes related work on automated feedback dashboards, instructor use of dashboards, sensemaking processes, classroom noticing, teaching beliefs, and pedagogical practices.

2.1. Automated Feedback Dashboards

Dashboards are increasingly used to display complex analytics data that captures learning and teaching processes in an uncomplicated manner. Few (2006) defined dashboards as "a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance" (p. 34). Feedback dashboards in education provide benefits for novel feedback opportunities and can enhance learning (e.g., Bodily & Verbert, 2017; Verbert et al., 2014). Dashboards can be developed to support teachers and/or students by combining design principles and technologies (Park & Jo, 2015). Feedback dashboards provide automated information in the form of visuals that can be seen at a glance. Automated feedback through dashboards aggregates various classroom activity indicators and presents them in multiple visualizations. As such, the evidence-based data they present have the potential to

improve teaching and learning processes (Sedrakyan et al., 2020). The goals of dashboard feedback in most related studies include the fostering of student learning (e.g., Bodily & Verbert, 2017), visualizing student engagement, and comparing learner actions with their peers or instructor expectations during student performances (Bodily & Verbert, 2017). Feedback dashboards made available to instructors are designed to provide information that supports decision making and reflection while increasing awareness of teaching and learning processes (Sedrakyan et al., 2020).

Most current dashboards that provide automated feedback are limited to mirroring simple information such as the quantity of speech, frequency of clicks, etc., and in most investigations, university logs have constituted the primary source of dashboard data (Sedrakyan et al., 2020). Examples of feedback dashboards developed to support both teachers and learners include GLASS (Leony et al., 2012), Student Activity Meter (SAM; Govaerts et al., 2012), and StepUp! (Santos et al., 2012). However, recent studies (Wise & Jung, 2019; Li et al., 2021) have used feedback dashboards with instructors without specifying the names of the dashboards used.

A growing amount of evidence suggests that automated and evidence-based feedback about instruction is critical for positive changes in teaching practices (Holstein et al., 2018; Palermo & Thomson, 2018; Wise & Jung, 2019). In a traditional classroom, instructors do not receive automated feedback about their own behaviours, nor do they recall many details about student behaviours (Gibbs & Coffey, 2004). Providing automated feedback about the classroom environment can bridge the gap between what instructors recall about their sessions and the actual behaviours that take place. As such, automated feedback can be used as a powerful reflective tool, prompting instructors to reflect on their teaching practices and the efforts invested in their learning activities (Holstein et al., 2018). Thus, linking pedagogical strategies with in-class practices from automated feedback mechanisms may help instructors improve their effectiveness (Sergis & Sampson, 2017). The current study delves into the sensemaking processes that instructors engage in when using automated feedback systems. Specifically, we examine how instructors interpret and act upon classroom analytics displayed on dashboards, thus addressing the gap in the literature about the actual impact of dashboard use on instructor teaching strategies and pedagogical practices.

2.2. Instructor Dashboards and Their Use

A growing body of research emphasizes the role of dashboards not only for understanding students, but also as tools for instructors to reflect on their teaching practices. Deakin Crick et al. (2017) highlighted the potential of analytics for holistic school improvement, emphasizing the importance of visualizations for pedagogical improvements. This is also echoed by Karumbaiah et al. (2023) who highlighted the depth of insights multimodal analytics can offer for collaborative teacher reflection. Martinez-Maldonado et al. (2022) further explored this by showcasing how the Moodoo tracker, a spatial classroom analytics tool, can be tailored to specific educational contexts, thereby characterizing teacher strategies. This aligns with the broader perspective that dashboards can serve as professional development tools, offering actionable insights about classroom practices (Sergis & Sampson, 2017). For instance, Suresh et al. (2021) leveraged advanced machine learning in the TalkMoves application to provide immediate, personalized feedback to instructors on their classroom strategies using natural language processing and automated speech recognition. This approach not only enhances pedagogical strategies but also supports methodologies like “accountable talk,” which fosters meaningful classroom discussions. Prieto et al. (2015) also highlighted the significance of real-time analytics in making on-the-spot pedagogical decisions, thus enhancing the overall teaching and learning milieu.

Instructor dashboards are a specific application of learning analytics dashboards. They allow instructors to monitor student progress and evaluate their own teaching strategies. The use of analytics makes it possible to acquire insightful feedback from data that ordinarily would not be captured or recalled (Ndukwe & Daniel, 2020). For instance, while some dashboards present instructors with visuals that include information about their students (Verbert et al., 2014), others provide information about their own teaching strategies such as classroom management (Park & Jo, 2015). Using information about instructor and student actions can help instructors improve their pedagogical practices (Gašević et al., 2016).

Beyond dashboards, other tools, such as video reflection, have been instrumental in supporting professional development. Marsh and Mitchell (2014) emphasized the role of video in teacher professional development, suggesting that it offers a unique perspective for instructors to critically analyze and reflect on their teaching practices. In the realm of teacher orchestration, Prieto et al. (2015) explored the challenges teachers face in facilitating collaboration, suggesting that tools that reduce the orchestration load can be beneficial for pedagogical improvement. In exploring how teacher characteristics relate to dashboard use, van Leeuwen et al. (2021) emphasized the importance of aligning tools with individual instructor needs and contexts.

2.3. Sensemaking Processes and Classroom Noticing

Sensemaking is the social process of searching for meaningful answers to the question, What drives individual actions? (Weick, 1995). It is a conscious process of understanding and making meaningful connections among patterns that can be acted upon in the future (Klein et al., 2006). Sensemaking “is about the interplay of action and interpretation,” and it is the locus “where meanings materialize that inform and constrain identity and action” (Weick et al., 2005, p. 409). Sensemaking has been researched in education within disciplines such as information sciences, human–computer interaction, and education

(e.g., Butcher & Sumner, 2011; Li et al., 2021; Wise & Jung, 2019). In education, instructors engage in sensemaking processes on a regular basis as they pass through the stages of "finding relevant information, synthesizing [it] across sources, identifying key ideas, and integrating new knowledge into prior understanding and emerging products" (Butcher & Sumner, 2011, p. 34). Sensemaking strategies have been conceptualized to include classroom awareness and noticing, especially in video research within teacher education contexts (Sherin & van Es, 2005). Classroom noticing is a complex, multi-layered process that instructors engage in to make sense of their instructional settings (Sherin & van Es, 2005). Sherin and van Es (2005) also highlighted that classroom noticing is highly contextual and is shaped by multiple factors such as the content and grade level, and the cultural and demographic distribution of the classroom. Research on classroom noticing distinguishes between expert and novice teachers' sensemaking processes (asking questions, interpreting, and inquiring) during their pedagogical practices. A command of classroom noticing and sensemaking is expected to improve instructor actions (Seidel & Stürmer, 2014) and improve student performance and outcomes, as well (Kersting, 2008).

Instructor analytic sensemaking processes have four main components: 1) asking questions, 2) reading data, 3) interpreting, and 4) applying the meaning of data (Wise & Jung, 2019). For instructors using dashboards, it is important to go beyond the data provided by the dashboard and examine their sensemaking processes. This effort can inform the subsequent actions that improve their pedagogy (Wise et al., 2019). Sensemaking situated within analytics requires instructors to understand what is happening, reflect on their practices, and decide what further steps are needed to improve their pedagogical strategies (Wise & Jung, 2019). This study extends the work of Wise and Jung (2019) by investigating how instructor sensemaking processes are aligned with pedagogical practices and are operationalized in the context of using automated feedback dashboard and classroom analytics.

While most feedback dashboards are developed to support learning and teaching, few reveal instructor sensemaking processes (Li et al., 2021) and address the dashboard's actual impact on instructor teaching strategies (Sergis & Sampson, 2017). Primary design for dashboards often focuses on providing data that can inform the development of instructor pedagogical practices, rather than explicitly revealing their sensemaking processes or teaching strategies (Ahn et al., 2019). As noted in several reviews of learning analytics dashboards, there is a critical need for research that links pedagogical models with in-class practices to determine ways to improve instructor sensemaking implementation and teaching practice facilitation (Sergis & Sampson, 2017). How to interpret multimodal data and take appropriate action remain unsolved challenges.

The effectiveness of dashboards is closely tied to the user's data literacy skills. Data literacy, the ability to read, interpret, and derive meaningful insights from data, is crucial for instructors to make informed decisions based on dashboard analytics (Ndukwe & Daniel, 2020). Without adequate data literacy, instructors who use dashboards can fail to bring about desired pedagogical changes. Data literacy impacts user ability to understand the automated feedback that, in turn, can inform their practice and result in actionable insights for pedagogical change.

Instructors should be selective in allocating their attention to specific interactions within the dynamic classroom environment (Holstein et al., 2018). Furthermore, effective noticing goes beyond identifying key moments in the classrooms. Instructors should connect these specific moments to pedagogical strategies.

2.4. Teaching Beliefs and Pedagogical Practices

Instructor teaching beliefs play a critical role in shaping their pedagogical classroom practices (Oleson & Hora, 2014). Previous research has measured changes in instructor teaching beliefs about their implemented pedagogical techniques in various conceptual frameworks (Reeves et al., 2016). The results have shown that professional development programs and pedagogical practice training positively alter their approaches to teaching (Haug & Mork, 2021).

Felder and Brent (2010) found that instructors who aim to improve their pedagogy and better engage students tend to use evidence-based practices, as exemplified by instructors who implement active learning (AL) as a pedagogical practice using authentic examples and a variety of activities during class sessions (Bransford et al., 2000). Strategies used to implement AL include: 1) walking around the room, 2) physically approaching non-participating students, 3) inviting questions, 4) designing participatory activities, and 5) using incremental steps. An instructor's teaching philosophy positively impacts their choice of pedagogical practices. AL practices engage students through real-world applications. The efficacy of AL over traditional lecture-based methods has been empirically substantiated, particularly in the field of engineering education (Prince, 2004; Freeman et al., 2014; Deslauriers et al., 2019). Dashboards as well can serve as pedagogical tools that offer instructors a dynamic way to monitor student engagement and adapt their teaching strategies accordingly.

3. Method

This research is part of a larger design-based project in which we utilized a grounded theory approach to unfold instructor sensemaking processes and to examine their perceptions about the automated feedback dashboard use. We employed inductive, iterative, and participatory techniques for the grounded theory approach (Corbin & Holt, 2005). The choice of an iterative grounded theory approach was based on previous researcher recommendations (Li et al., 2021; Wise & Jung, 2019). It provides

a theoretical foundation for better understanding the sensemaking process of instructors who receive and employ automated feedback. This method provides an extensive description of a relevant context and associated participant perceptions and results in "an integrated theoretical formulation that gives understanding about how persons or organizations or communities experience and respond to events that occur" (Corbin & Holt, 2005, p. 49). The grounded theory recognizes and emphasizes participant agency in the co-construction of data with researchers.

3.1. Context: The Classroom Observation and Feedback Project

This research is conducted within the context of a National Science Foundation (NSF) funded project, TEACHActive, that uses automated classroom observation and feedback to promote pedagogical practices in engineering classrooms. In this project, we deployed an automated observation system, EduSense (Ahuja et al., 2019) that uses machine learning and computational analysis of classroom analytics. EduSense captures audio and video streams using unobtrusive classroom cameras, thereby "instrumenting" the classroom rather than the individual (Ahuja et al., 2019).

This automated observation system offers the advantage of sensing without requiring the instructor to wear a device. The system views both the instructor and students and adapts existing computer vision and audio classifiers to detect classroom behaviours. These classifiers include detection of hand raises, body poses, body movements, and speech acts. The EduSense outputs are derived from learning science theories and correlate with effective instruction (Ahuja et al., 2019). In this research, we deployed the EduSense system for capturing automated classroom behaviours. We extended this system to an automated dashboard, TEACHActive, that visually displays data captured by EduSense and used by engineering instructors (AlZoubi et al., 2021).

While the features displayed on the TEACHActive dashboard might not directly correlate with effective instruction, they have been linked to behavioural engagement and participation. For instance, the hand raises feature may serve as an indicator of student participation with high frequency being correlated with student participation and behavioural engagement (Rocca, 2010). Furthermore, spatial data and kinesthetic patterns highlight actions that frequently occur in specific classroom areas as well as movement information. For example, instructors often move between the right and left sides of the class (Henderson et al., 2011). Additionally, the student vs. instructor speech feature highlights the patterns and ratios of student to instructor speech. A classroom with low instructor talk frequency, high student talk frequency, and a high student-to-instructor talk ratio indicates robust behavioural engagement (Chi & Wylie, 2014). By visualizing and reflecting on these metrics, instructors can better tailor their teaching strategies.

In the initial year of our research, we conducted pilot tests of the TEACHActive system and the dashboard in four classrooms, using simulated instructors (where graduate students assumed the role of an instructor) to evaluate the system's features. The EduSense system was specifically designed for classrooms with no more than 60 students, as it was determined that larger class sizes might result in not all students being effectively captured by the system. Therefore, we selected classrooms that adhered to this size criterion. Additionally, various classroom configurations presented unique challenges. To ensure compatibility, we conducted preliminary visits and tests in potential classrooms to ensure their suitability for the system's deployment.

We designed the TEACHActive feedback dashboard to include visuals that represent classroom analytics metrics extracted and transformed from raw classroom data captured by EduSense. The TEACHActive project components included three main phases: 1) pedagogical model training (e.g., training on AL strategies implementation), 2) automated classroom observation, and 3) feedback and reflection (AlZoubi et al., 2021). Phase 1 included two pedagogical hands-on training sessions during which instructors learned about evidence-based AL methods and effective facilitation behaviours in engineering classrooms (AlZoubi et al., 2021). The AL strategies addressed the following: lecture pauses, a one-minute paper, concept tests, think-pair-share, peer instruction, case studies, co-operative learning, inquiry learning, problem-based learning, and collaborative learning. Instructors were also given tips on how to effectively facilitate AL strategies such as walking around the room, physically approaching non-participating students, inviting questions, and designing participatory activities. Phase 2 consisted of automated classroom observation whereby data from classrooms were captured and automatically analyzed through EduSense. The EduSense system generated abundant visual and audio features derived from learning science theories and correlated with effective evidence-based instruction (Ahuja et al., 2019). Two cameras were placed in classrooms, one facing students and the other facing the instructor in order to capture behavioural classroom indicators (AlZoubi et al., 2021; Baran et al., 2023). Phase 3 included feedback and reflection, whereby instructors receive automated feedback illustrating a visual representation of behavioural indicators in connection with AL strategies (AlZoubi et al., 2021; Baran et al., 2022). Instructors used this feedback to reflect on their current practices and to generate improvements for future sessions.

3.2. Participants and Recruitment Processes

We conducted this research at a public Midwestern land-grant research university, known for its diverse student body and focus on science, technology, and engineering disciplines. This institution is part of a unique group of universities with a historical land-grant mission, committed to making higher education more accessible and focusing on practical research that

serves the community and industry needs. Our conversations with instructors revealed that instructional approaches vary significantly, with many instructors following traditional lecture-based models due to their backgrounds. Yet, there is an emerging interest in incorporating student-centred pedagogies to engage students.

We used the convenience sampling procedure, a type of purposive sampling in which the sample is selected based on relevancy and easy accessibility (Miles et al., 2020). Project participation was open to all engineering faculty (from different departments) interested in implementing AL facilitation strategies in their classrooms. We recruited participants following the Institutional Review Board's (IRB) ethical approval. To increase our participant pool, we utilized various recruitment processes. First, the research team sent email invitations to all department chairs in the College of Engineering. Then, we sent emails to key individuals, such as the associate deans, describing the project and asking that our call for participants be circulated among engineering instructors. Moreover, a snowballing procedure was utilized whereby engineering instructors shared contact details if they thought a colleague would be interested in participating. Purposive sampling was utilized to select participants who showed interest in the research and were teaching in classrooms that fit the research requirements (e.g., class structure, number of students, etc.). Logistical challenges, such as classroom scheduling conflicts and the specific requirements for EduSense software constrained our recruitment efforts. Also, the constraints of the COVID-19 pandemic during the implementation presented unique challenges to our research, limiting participant recruitment due to the requirements of in-person interaction within classroom settings, which was a fundamental aspect of the project's implementation. A total of 15 instructors were recruited for Spring 2021, Fall 2021, and Spring 2022. Table 1 presents the participant demographics. We provided participants with a detailed consent form, visited their classes to introduce the research and gave students a comprehensive notification about the study.

Table 1. Participant Demographics

Age: Mean= 39; Median= 36; St. Dev.= 6.19 **Years of Teaching Experience:** Mean= 7; Median= 4; St. Dev.= 6.29	
	Count
Gender	
Female	8
Male	7
Position	
Postdoc Research Associate	1
Adjunct Assistant Professor	2
Assistant Professor	5
Assistant Teaching Professor	6
Associate Teaching Professor	1
Department	
Chemical and Biological Engineering	2
Civil, Construction, and Environmental Engineering	4
Electrical and Computer Engineering	4
Industrial and Manufacturing Systems Engineering	1
Materials Science and Engineering	2
Mechanical Engineering	2

3.3. Data Collection and Sources

This research was conducted over three semesters: Spring 2021, Fall 2021, and Spring 2022. Each semester, data were collected in four stages: 1) teaching beliefs survey, 2) semi-structured interviews pre-implementation, 3) classroom analytics and reflection prompts, and 4) semi-structured interviews after the implementation. Figure 1 illustrates the phases and data sources.

1) *Teaching beliefs survey*: The teaching beliefs survey assessed instructor pedagogical beliefs and included demographic questions and items from the Approaches to Teaching Inventory (ATI), a valid and reliable tool to measure the extent to which instructors teach toward instructor-centred knowledge transmission versus student-centred conceptual change (Trigwell & Prosser, 2004; see Appendix A). We administered the survey before the AL training.

2) *Semi-structured interview pre-implementation*: Participating instructors received two training sessions on how to implement AL strategies in their classrooms (Phase 1). Following the training sessions, we conducted semi-structured interviews and dashboard walkthroughs with them. The interviews included questions about instructor reflections, challenges, concerns, and their takeaways from the AL training sessions, as well as their expectations from the automated feedback

dashboard, their interpretation of the metrics displayed on the TEACHActive dashboard, and final concerns and recommendations. Throughout the dashboard walkthroughs, we asked questions about their comprehension and interpretations of the displayed metrics to assess their data literacy. All participating instructors come from engineering disciplines and thus have a solid foundation in data interpretation and analysis of the displayed metrics.

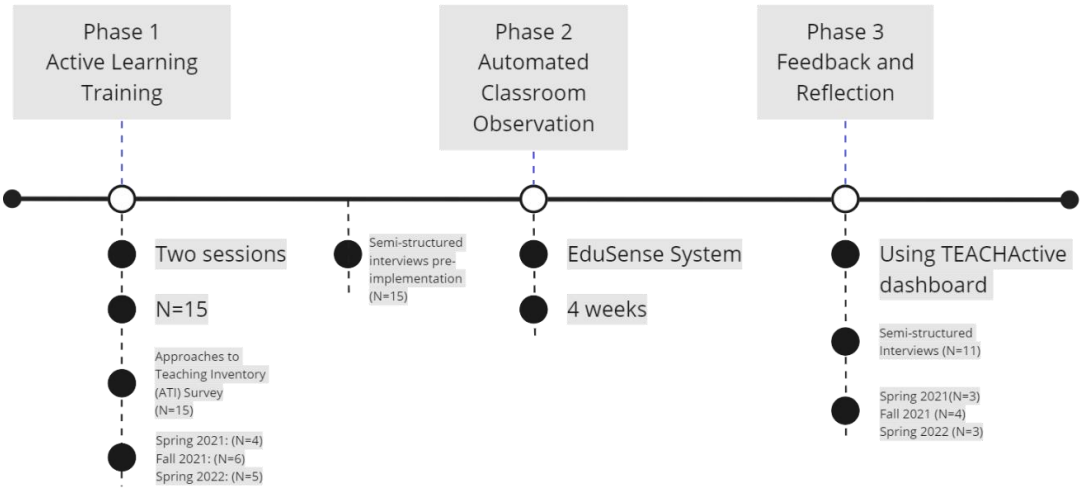

Figure 1. Phases and data sources.

3) *Classroom analytics and reflection prompts*: Implementation of automated classroom observations occurred for four consecutive weeks (Phase 2). Behavioural indicators were tracked by EduSense, an automated observation system (Ahuja et al., 2019). Data from the behavioural indicators were displayed as classroom analytics on the TEACHActive dashboard designed to be part of this research. Following each automated classroom observation session, instructors were notified via an automated email that their individually presented dashboard classroom analytics data (Phase 3) could be accessed on the dashboard. They were asked to review the classroom analytics and complete short reflection prompts. Appendix B illustrates the first and second version of questions that constituted the reflection prompts, and Figure 2 illustrates an example of classroom analytics displayed on the dashboard. Figure 3 shows a reflection prompt in the hand raise section.

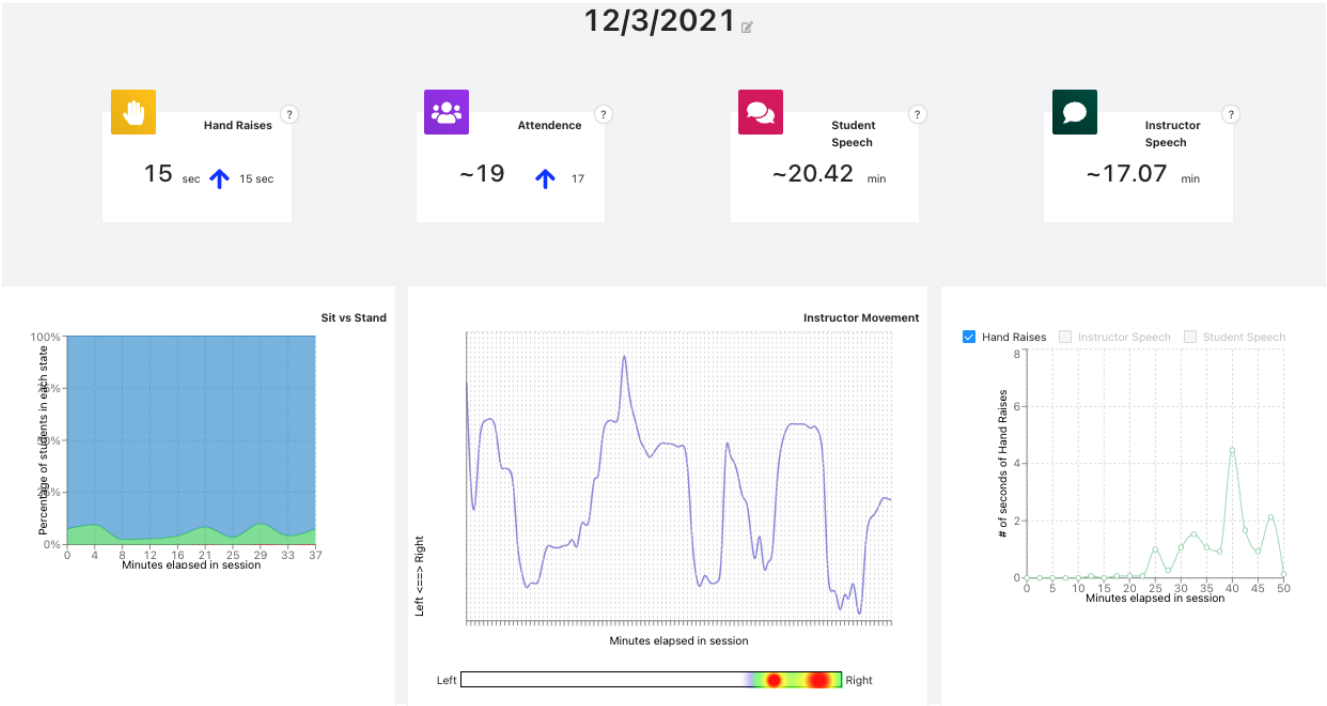

Figure 2. An example of classroom analytics metrics displayed on the dashboard.

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4) *Semi-structured interviews post implementation*: After the four-week automated observation period, we conducted semi-structured interviews with instructors. Data from interviews provided in-depth understanding of their sense-making of the analytics data, how they use their pedagogical knowledge to interpret the feedback dashboard data and what actions they took in response to the displayed data (see Appendix C).

3.4. Data Analysis

Data from the ATI survey was analyzed qualitatively using descriptive statistics. Interview data were recorded and transcribed verbatim, and the transcripts were analyzed for accuracy. Transcripts were then imported to MAXQDA for further analysis. Open, axial, and selective code types were employed throughout the study to form and evolve a series of relationships into a theoretical framework (Strauss & Corbin, 1998). This process began by open coding sensemaking concepts and processes that formed dimensions "along a continuum or range" (Strauss & Corbin, 1998, p. 117). Researchers identified the following themes regarding instructors: teaching beliefs, perceptions about pedagogical practices, views of classroom analytics, sensemaking processes, challenges using the system, and suggestions for improvement. Table 2 illustrates an excerpt of the codebook that includes different themes, codes, subcodes, and example quotes. These continual iterations throughout open and selective coding are academically termed "constant comparisons" and "theoretical comparisons." They led to the formation of conceptual categories, which in turn revealed connections between categories during the axial coding process. An open-ended data exploration was coded if significant data was obtained before theoretical saturation was achieved (Strauss & Corbin, 1998). A final and vital analysis element was the copious use of "memos" ("code," "theoretical," and "operational" notes) that served as an explicit means to conceptualize raw data throughout the coding process (Strauss & Corbin, 1998).

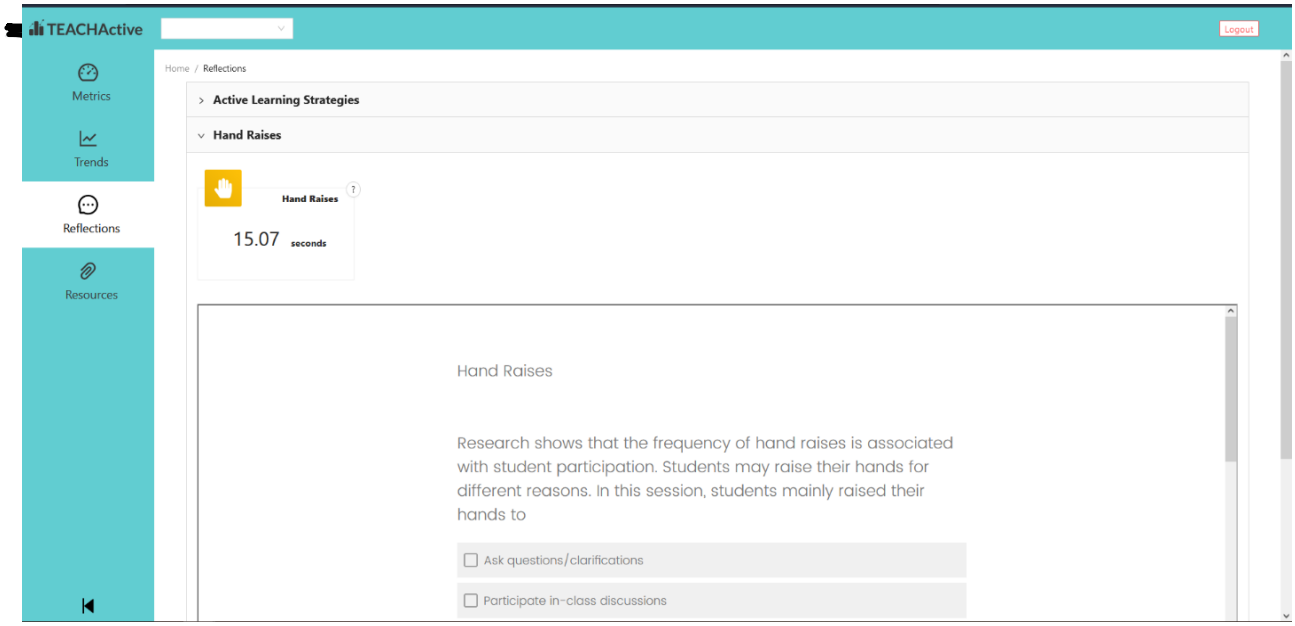

Figure 3. Reflection prompt example (section about hand raises).

Table 2. Themes, Codes, Subcodes, and Examples

Theme	Definition	Code	Subcode	Definition	Example
Instructor Teaching Beliefs	Instructor foundational pedagogical inclinations	Teacher-focused	Knowledge transmission	Instructor intent to directly convey information	"I always start by asking questions about my classroom session."
			Assessment	Instructor intent to transmit information for the sake of formal evaluations	"It was harder for me to translate the broad information we learned about active learning to my own classroom setting."

Theme	Definition	Code	Subcode	Definition	Example
		Student-focused	Interactive learning	Instructor recognition of the value of student participation in knowledge acquisition	"Checking my sessions allowed me to notice moments at specific times that I would not recall regularly."
			Changing conceptions	Instructor intent to change student conceptions	"I've tried various AL techniques, but I am never quite sure if they're effective."
Instructor Perceptions about Pedagogical Practices	Instructor views on their own teaching methods	AL implementation	Diverse implementation	Range of strategies employed by the instructors	"I always start by asking questions about my classroom session."
			Contextual challenges	External factors influencing pedagogical decisions	"It was harder for me to translate the broad information we learned about active learning to my own classroom setting."
			Striving for engagement	Efforts to improve student engagement	"Checking my data made me more conscious and aware of things that are happening in my classroom that I was not aware of."
Instructor Views on Classroom Analytics	Instructor perspectives on the feedback dashboard	Perspectives on dashboard	Developmental perspective	Rooted in the idea of continuous growth	"I expect the dashboard to provide me with data about my classroom that I am not aware of, and I can interpret accordingly."
			Normative perspective	Rooted in the idea of adhering to established standards	"I've learned various AL strategies during the training, but knowing which ones truly resonate in a real classroom setting would be invaluable."
Sensemaking Processes	Instructor processes of understanding and interpreting the dashboard	Sensemaking categories	Classroom session inquiry	Initial questions about their classroom session	"I always start by asking questions about my classroom session."
			Classroom noticing	Becoming more aware of classroom practices through observing and interpreting data	"Checking my sessions allowed me to notice moments at specific times that I would not recall regularly."
			Reflection	Continuous process of thinking about classroom behaviours and practices	"The reflective practice allowed me to realize that I need to ask students more questions, walk around more in the classroom, and give them at least a 10-minute activity every class."
Challenges of Using the System	Technical and pedagogical challenges faced by instructors	Technical challenges	Accuracy discrepancies	Discrepancies in data accuracy	"I couldn't see the value of reflecting on something that I know is incorrect."
			Access issues	Technical barriers in accessing the dashboard	"I was not able to access the dashboard when I was off campus because my VPN connection was not working on my device."
		Pedagogical challenges	Translating pedagogical practices	Difficulty in translating real-world teaching practices to dashboard metrics	"It was harder for me to translate the broad information we learned about active learning to my own classroom setting."

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Theme	Definition	Code	Subcode	Definition	Example
			Misalign-ment of metrics	Perceived misalignment between dashboard metrics and AL practices	"Most instructors agreed that speech was one of the metrics most related to active learning, while the sit vs. stand metric was least related to their practices."
Suggestions for Future Implementa-tions	Recommen-dations for enhancing future dashboard implemen-tations	Recommen-dations	Peer sharing	Sharing classroom analytics with peers	"I am mostly interested in knowing what other instructors saw and to compare my findings with them."
			Data interpreta-tion training	Training to help participants better understand and interpret the data	"I think you need to provide instructors with training on the classroom analytics features, what they mean, how to read and understand data visualizations, and how to make meaningful interpretations of the data."
			Expert scaffolding	Guidance and scaffolding by an expert in AL implementation and data interpretation	"I would like to check with someone with high expertise their interpretations about my classroom analytics and practices and see if I am on the right track."

4. Results

Analysis results revealed three main themes: 1) instructor teaching beliefs and pedagogical practices, 2) instructor views about classroom analytics and use of automated feedback dashboard, and 3) suggestions for future implementation.

4.1. Instructor teaching beliefs as a foundation for pedagogical practices

Prior to the project's implementation, the instructors (n=15) responded to 16 items in the ATI survey that measured the extent of instructor beliefs in teacher-centred knowledge transmission vs. student-centred conceptual change. Items in the ATI survey were divided into two categories: 1) teacher-focused (eight items) and 2) student-focused. This bifocal perspective enables a comprehensive understanding of the instructors' pedagogical inclinations. Figures 4 and 5 illustrate the means and standard error of instructor responses to each of the ATI items in the teacher-focused and student-focused categories.

4.1.1. Instructor teaching beliefs: Teacher focused items analysis

Instructors had moderate to high levels of intention to transmit information, as revealed by their responses to items 3, 5, and 6 (M=3.85, M=3.92, M=3.54, respectively). This suggests a traditional approach to teaching, where instructors are the primary source of knowledge. However, the low levels of intent to transmit information for the sake of formal assessments (M=1.62) suggests that while instructors value direct knowledge transmission, they may not see it as the most effective method for assessment. Instructors had neutral responses to items related to course structure (M=3.00), which could indicate a flexibility in their teaching approach, or perhaps a reflection of the diverse contexts in which each instructor taught.

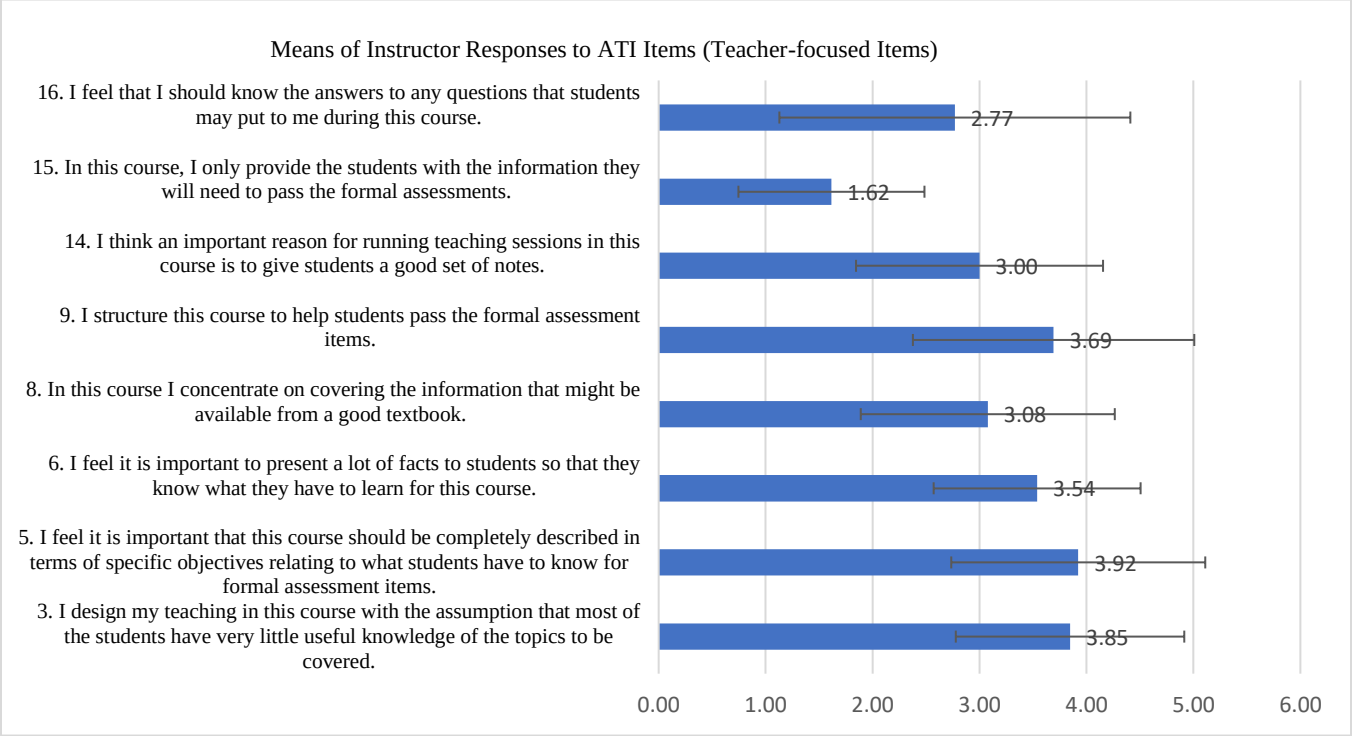

Figure 4. Instructor responses to ATI teacher-focused items.

4.1.2. Instructor teaching beliefs: Student-focused items analysis

Instructors had moderate to high levels of teacher–student discussions, as revealed by their response means associated with items 1, 2, and 7 (M=4.31, M=4.08, and M=4.23, respectively). This indicates their recognition of the value of interactive learning, where students are active participants in knowledge acquisition. However, they had low to moderate levels of intent to change student conceptions as revealed in their responses to items 4, 10, 11, and 12 (M=2.62, M=2.77, M=3.31, and M=3.00, respectively). This could be due to variety of reasons such as their desire to avoid potential conflicts in the classroom.

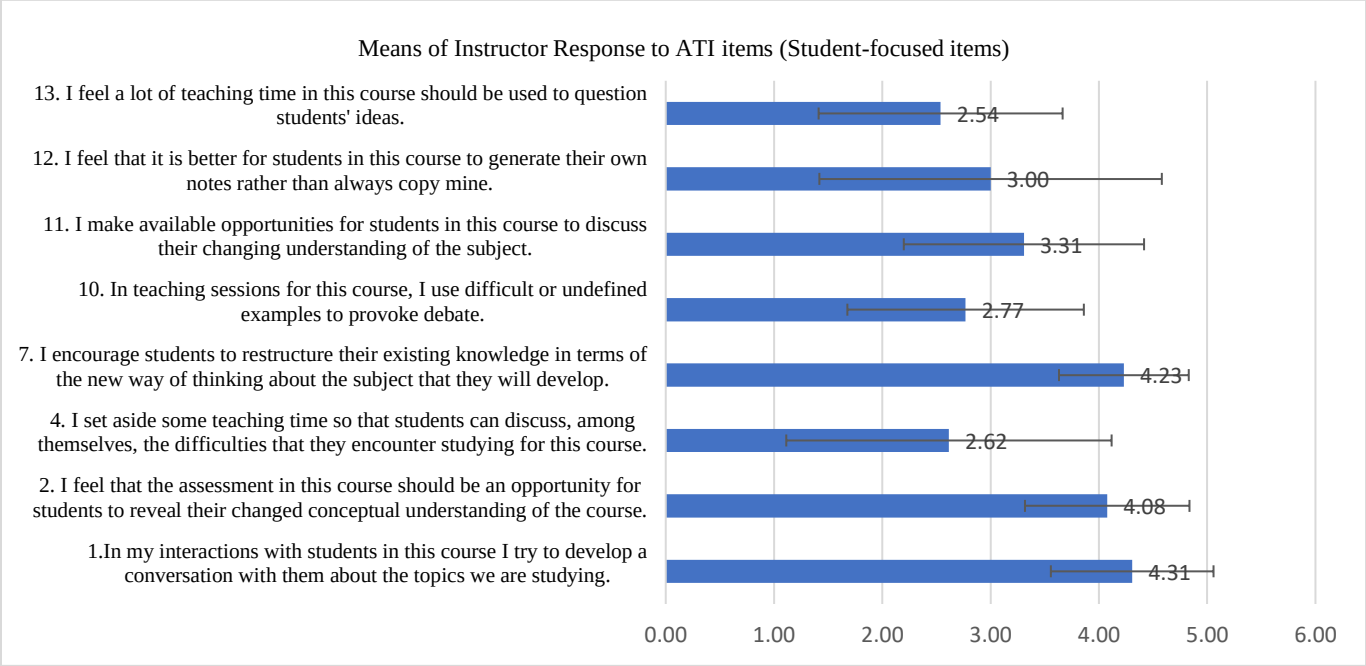

Figure 5. Instructor responses to ATI student-focused item.

4.2. Instructor Perceptions about their Own Pedagogical Practices

The descriptive results from the ATI survey provided an initial understanding of the instructors' pedagogical tendencies that inclined regarding adopting student-focused approaches when engaging students in discussions and interactions. However, instructors leaned toward a more traditional mode of direct knowledge transmission when asked about empowering students to independently construct their own conceptions and understandings. In the subsequent semi-structured interviews, instructors were probed with open-ended questions to delve deeper into their pedagogical practices and provide a more comprehensive understanding of their perspectives and primary insights from the AL training sessions.

4.2.1. Current pedagogical practices

All participating instructors (n=15) reported integrating aspects of AL strategies in their courses to some extent. The adoption of strategies such as team-based learning (TBL), problem-based learning, and in-class discussions suggests that instructors use diverse teaching methods to engage students in a variety of ways. The recurring themes from instructors' current pedagogical practices include the following: 1) diverse implementation of AL strategies, 2) contextual challenges, and 3) striving for engagement. Table 2 highlights quotes from instructors about their AL implementation in courses.

Diverse implementation: The range of strategies employed by the instructors, as presented in Table 2, highlights their diversity of approaches to AL. This suggests that while there is a collective move toward AL, the journey is individualized, with instructors navigating their unique challenges and contexts.

Contextual challenges: Responses such as the adaptation of TBL due to the pandemic highlight the external factors influencing pedagogical decisions. Most instructors highlighted the challenges of translating the broad information they learn about AL to their own classroom settings.

Striving for Engagement: The emphasis on in-class problems, group work, and discussions indicates a collective aim to improve student engagement. However, the varied strategies suggest that finding the most effective method is an ongoing process, with instructors continuously refining their approach based on feedback and experience.

Most instructors emphasized that their intention to implement AL stemmed from student engagement problems, especially in large lecture halls. Participation during AL training was perceived as beneficial by all participating instructors.

4.3. Instructor Views about Classroom Analytics and their Use of the Automated Feedback Dashboard

This section explores instructors' preliminary views on the automated feedback dashboard and then their subsequent sensemaking processes while using the system, as well as the challenges they faced. Instructor views about classroom analytics and the use of automated feedback resulted in four main themes: 1) instructor perspectives on automated feedback dashboard, 2) instructor sensemaking processes and outcomes, 3) perceived challenges of using the system, and 4) suggestions for future implementation.

4.3.1. Instructor perspectives on automated feedback dashboard

Prior to the implementation, we asked instructors about their objectives and expectations when using an automated feedback dashboard that displays visuals from their multimodal classroom analytics. All instructors perceived this as an opportunity for professional development and professional growth, and it fell into two main categories: 1) developmental perspective and 2) normative perspective. These views are the foundation for understanding instructor perspectives prior to using the automated feedback dashboard.

A. Developmental perspective

The developmental perspective is rooted in the idea of continuous growth. It was predominantly observed among instructors with more extensive teaching experience (more than five years). Instructor responses revealed the following goals: 1) to expand their knowledge, 2) to engage in reflective practices, and 3) to implement new strategies.

Expanding knowledge: Most instructors believed that using an automated feedback dashboard would offer insights into areas of their teaching they might not have previously considered. For instance, one instructor said, "I expect the dashboard to provide me with data about my classroom that I am not aware of, and I can interpret accordingly." Instructors envisioned the dashboard as a potential source of insights that could reveal new dimensions of their teaching effectiveness and student engagement.

Reflective practice: Many instructors emphasized the potential of the dashboard to foster deeper reflection on their teaching methods. One instructor with six years of experience noted, "The data could serve as a mirror, reflecting back my classroom dynamics, pushing me to think critically about my choices." Expectations for the dashboard to catalyze reflective practice indicated that instructors seek self-improvement and are committed to improving their teaching practices.

Implementing new pedagogical strategies: Many instructors shared that the insights from the dashboard will allow them to integrate new teaching strategies. An instructor with seven years of teaching experience shared, "If the dashboard shows that certain techniques I am using are not as effective, I am eager to experiment with new methods." Instructor willingness to

consider new teaching strategies upon interacting with the dashboard revealed their intention to act upon the automated feedback they receive.

B. Normative perspective

The normative perspective is rooted in the idea of adhering to established standards. Instructors with less teaching experience perceived the dashboard as a tool for seeking validation and guidance. Specifically, some instructors approached the dashboard as a toll to validate and align their teaching methods with what is generally known as "good" or "effective" teaching. Instructors' normative perspectives revealed the following themes: 1) seeking validation, 2) desire for best practices, and 3) learning from data.

Seeking validation: Some new instructors expressed uncertainty about AL implementations. For instance, one instructor shared, "I've tried various AL techniques, but I am never quite sure if they're effective. I hope the dashboard will provide that clarity." Novice instructors' quest for clarity on the effectiveness of their teaching strategies through the dashboard illustrates their seeking validation and developing their pedagogical strategies.

Desire for best practices: Instructor aspirations to align with perceived "best practices" was evident. An instructor in their first year of teaching said, "I've learned various AL strategies during the training, but knowing which ones truly resonate in a real classroom setting would be invaluable." The aspiration to identify and align with best teaching practices reflects a foundational phase of professional development where the displayed metrics can be used as valuable benchmarks.

Learning from data: Instructors with normative perspective expressed a desire to learn directly from the data on the dashboard. One instructor mentioned, "If I can see which parts of my lecture spark the most engagement and where students seem to disengage and disconnect, I can adjust my approach accordingly." Instructor willingness to learn from the dashboard data demonstrates their need for evidence-based teaching practices.

4.3.2. The cyclic nature of instructor sensemaking processes

Data were captured during the implementation, and then automatically analyzed and presented visually on the TEACHActive dashboard. Instructors who participated in the implementation (n=11) were asked about their use of the dashboard and the sensemaking processes they engaged in to interpret data and make appropriate decisions. First, instructors shared their interactions and use of the dashboard in general terms. Then, more specifically, they shared their sensemaking processes as they received different data excerpts from their sessions. Instructors walked the researcher through how they used the dashboard, what types of inferences they made, and their step-by-step processes while using the system. Examples of classroom analytics data that were shared with participants are shown in Figures 2 and 3.

The sensemaking processes that instructors reported were categorized as follows: 1) classroom session inquiry, 2) classroom noticing, and 3) reflection. These categories were cyclical rather than linear.

4.3.3. Classroom session inquiry

Instructors reported that during their first encounter with the dashboard, they had questions about their classroom session and their "actual" implementation of AL. For example, one instructor stated, "I always start by asking questions about my classroom session." Another used questions such as these: "Am I using the time wisely in my classroom? Am I speaking most of the time? What active learning strategies did I use during my session?" Asking questions as an initial step was a common practice among all instructors who used the dashboard.

A. Classroom noticing

Participating instructors viewed their data on the dashboard over several sessions (between three to eight sessions). Instructors found the dashboard useful in displaying visuals and felt that the display made it easier to make summative checks and visualize their class sessions at a glance. Instructors felt that interacting with the dashboard promoted their classroom noticing. Classroom noticing is operationalized as one becomes more aware and conscious of their classroom practices through observing and interpreting data. By using the dashboard for classroom noticing, instructors reported that it became easier to describe, interpret, and explain some of what was happening in their classrooms. For instance, one instructor shared, "Checking my sessions allowed me to notice moments at specific times that I would not recall regularly. So, the number of seconds the hands were raised was highest during minute 20 and I believe this is when I opened up for classroom discussion." Another instructor reported, "Checking my data made me more conscious and aware of things that are happening in my classroom that I was not aware of." Yet another instructor affirmed, "I became more conscious about integrating active learning strategies into my teaching practices knowing that I can detect them through the system." Dashboard usage guided instructors in recognizing critical and specific patterns that occurred during their classroom sessions.

B. Reflection

Participating instructors found that classroom analytics appearing on the dashboard prompted them to reflect on their classroom behaviours and provided them with an opportunity to think about how they might improve their instructional practices.

According to their reports, reflection was a continuous process that transpired throughout the implementation. The dashboard included a reflection prompt section that instructors were asked to complete after viewing their classroom analytics. Only three instructors completed them, however. Most felt it was time consuming and redundant, as they were already reflecting on their data and discussing it with the researcher during the post-implementation interviews. Instructors developed reflective practice by generating ideas and takeaways of what worked and what did not work during the class session. For example, one instructor shared, "I was able to reflect [on] how I am using the class time through the time-stamped moments." Another indicated, "The reflective practice allowed me to realize that I need to ask students more questions, walk around more in the classroom, and give them at least a 10-minute activity every class."

The cyclic nature of instructor sensemaking processes facilitated by the automated feedback from the TEACHActive dashboard fostered an iterative loop of inquiry, noticing, and reflection that led to more awareness of subsequent actions they can take in their pedagogical strategies.

4.3.4. Perceived challenges of using the system and implications for sensemaking

The implementation of TEACHActive's automated feedback system presented instructors with both technical and pedagogical challenges that actively shaped their sensemaking processes and hindered it at times.

A. Technical challenges

The technical challenges perceived by instructors revealed two main themes: accuracy discrepancies and access issues.

Accuracy discrepancies: The metrics displayed on the dashboard had a few accuracy level discrepancies. However, most instructors still found the classroom analytics visuals useful. Instructors used the discrepancies as a starting point for critical evaluation, questioning the data's reliability, and seeking alternative means of verification. For example, when discrepancies arose, instructors were prompted to cross-reference dashboard data with their own observations or student feedback, leading to a more holistic approach to understanding classroom dynamics. They were able to compare a session with the following one; they could visualize their progress even if the data were not entirely accurate. However, one instructor did not use the dashboard, explaining, "I couldn't see the value of reflecting on something that I know is incorrect."

Access issues: Some instructors reported technical challenges related to an inability to access the dashboard link. One instructor shared, "I was not able to access the dashboard when I was off campus because my VPN connection was not working on my device." Instructors who faced these access issues had less interaction with the automated dashboard, which hindered their use and sensemaking processes.

B. Pedagogical challenges

The pedagogical challenges perceived by instructors included translating pedagogical practices and misalignment of metrics.

Translating pedagogical practices: Some instructors found it challenging to translate pedagogical practices, such as AL implementation strategies, they had acquired to what they saw on the dashboard. As such, it was hard for them to translate the displayed metrics into actionable insights for their pedagogical practices.

Misalignment of metrics: Most instructors did not perceive all metrics to be in alignment with the AL implementation. For instance, most instructors agreed that speech was one of the metrics most related to AL, while the sit vs. stand metric was least related to their practices. Also, instructors shared a common challenge: not knowing what numbers they should see on the dashboard to indicate that AL was taking place.

To support meaningful sensemaking, the automated system must be technically reliable and aligned with instructor pedagogical practices. Future developments of the system could involve instructors in a participatory design process, ensuring that the dashboard evolves to meet their needs and effectively supports their sensemaking and pedagogical improvements.

4.3.5. Suggestions for future implementations

Instructors provided recommendations and suggestions to guide future iterations and implementations. Recommendations were categorized into three main categories: 1) peer sharing, 2) data interpretation, and 3) expert scaffolding.

A. Peer sharing

All instructors agreed that it would have been very helpful to share their classroom analytics and sensemaking processes with their peers to compare data. They thought that seeing only their own data without benchmarks or an understanding of what others were doing might be misleading and unfruitful. For instance, one instructor shared, "I am mostly interested in knowing what other instructors saw and to compare my findings with them." Similarly, another stated, "I would like to see examples of good teaching practices and generate a dialogue with other folks." Providing opportunities to practise analyzing and interpreting peer dashboards would allow instructors to understand how others engage in classroom activity, as well as engage them in a community of practice.

4.3.6. Data interpretation training

None of the instructors who used the system had problems interpreting the visuals and/or data. Since they had prior experience with dashboard interfaces, interpreting and analyzing the data through sensemaking processes was not new to them. However, when they were asked for future implementation recommendations, most instructors suggested that training be added to help participants better understand and interpret the data, thus allowing them to see how the data aligns with their pedagogical practices. One instructor stated, "I think you need to provide instructors with training on the classroom analytics features, what they mean, how to read and understand data visualizations, and how to make meaningful interpretations of the data."

B. Expert scaffolding

Most participating instructors indicated that the TEACHActive dashboard usage would have been more helpful if it were guided and scaffolded by an expert in AL implementation and data interpretation. Experts could adjust the guidance levels and types as needed to further instructor sensemaking processes, thus optimizing instructor experiences and enhancing their future decision-making processes. For example, one instructor shared, "I would like to check with someone with high expertise their interpretations about my classroom analytics and practices and see if I am on the right track." Expert scaffolding allows instructors to translate the data into actionable pedagogical changes by bridging the gap between data and practice.

5. Discussion

Results from this study reveal that the adoption of AL strategies by engineering instructors is dependent on their traditional beliefs about teaching and learning. According to Oleson and Hora (2014), instructor teaching beliefs play a crucial role in shaping their classroom practices. Instructors are constantly in the process of searching for meaningful answers that drive their pedagogical practices. This can be explained through the sensemaking process (Weick, 1995). Instructors prioritized allowing students to construct their own understanding of the knowledge rather than transmitting information to students. Thus, they were more likely to adopt AL strategies. This inclination toward student-centred approaches can be seen as a manifestation of their sensemaking processes, where they interpret and act upon classroom dynamics in a way that aligns with their beliefs.

Moreover, the use of an automated feedback dashboard presents both opportunities for professional development and growth as well as challenges. As highlighted in the literature, feedback dashboards aim to enhance learning and teaching processes (Sedrakyan et al., 2020). Sensemaking is described as the process of searching for meaningful answers that drive individual actions (Weick, 1995). The dashboard serves as a tool that triggers and informs instructor sensemaking, offering a lens through which they can reflect, interpret, and act upon the data presented. Instructors who used the dashboard perceived it to reflect on their own teaching practices. However, they also encountered some challenges that hindered their ability to fully benefit from using the dashboard. To overcome these challenges and fully realize the potential benefits of using an automated feedback dashboard, instructors need more support in understanding the data, making meaningful interpretations, and aligning it with their own pedagogical practices. This can be achieved through providing opportunities for peer sharing, training on data interpretation, and expert scaffolding.

Synthesizing our findings yielded a model that shows a continuum from past to future instructor experiences as they use and interact with automated feedback dashboards. This model, in many ways, mirrors the sensemaking process described by Wise and Jung (2019), where instructors engage in activities of curiosity identification, asking questions, and interpreting data. Figure 6 illustrates the proposed model. This model illustrates the past as pre-use, the present as use, and the future as continuous use. Before using the dashboards, instructors shared their own teaching beliefs, pedagogical practices, and data literacy (understanding and interpreting data), as well as what they expected to learn from using a feedback dashboard. This pre-use phase aligns with the findings of Reeves et al. (2016) that instructor teaching beliefs and practices are shaped even before any intervention. The present consisted of using the dashboard and interacting with it through the sensemaking process.

As per the results of this research, while instructors were using the dashboard, their sensemaking processes took place in a spiral and cyclic way, as illustrated in Figure 6. The post-use (or not) happens in the future after using the dashboard, and consists of instructor decision making and changes in pedagogical practices. This post-use phase resonates with the findings of Li et al. (2021), emphasizing the importance of effective use of tools in instructor decision-making processes. Continuity is about instructors' future decision making as a function of past experiences while they interact with the dashboard in the present. Through experience and interaction with the dashboard, instructors can construct knowledge that will inform future actions to improve their pedagogy. Therefore, the past, present, and future continuum would embrace instructor sensemaking and decision making accordingly. The intersection of the continuum with the interaction function would attract their efforts to the present and become invested in the future. The point of intersection between continuity and interaction acts as the point of attraction — a magnetic field that draws instructor sensemaking processes as energetic forces to yield greatly valued future experiences for post-use, helping to improve their pedagogical strategies.

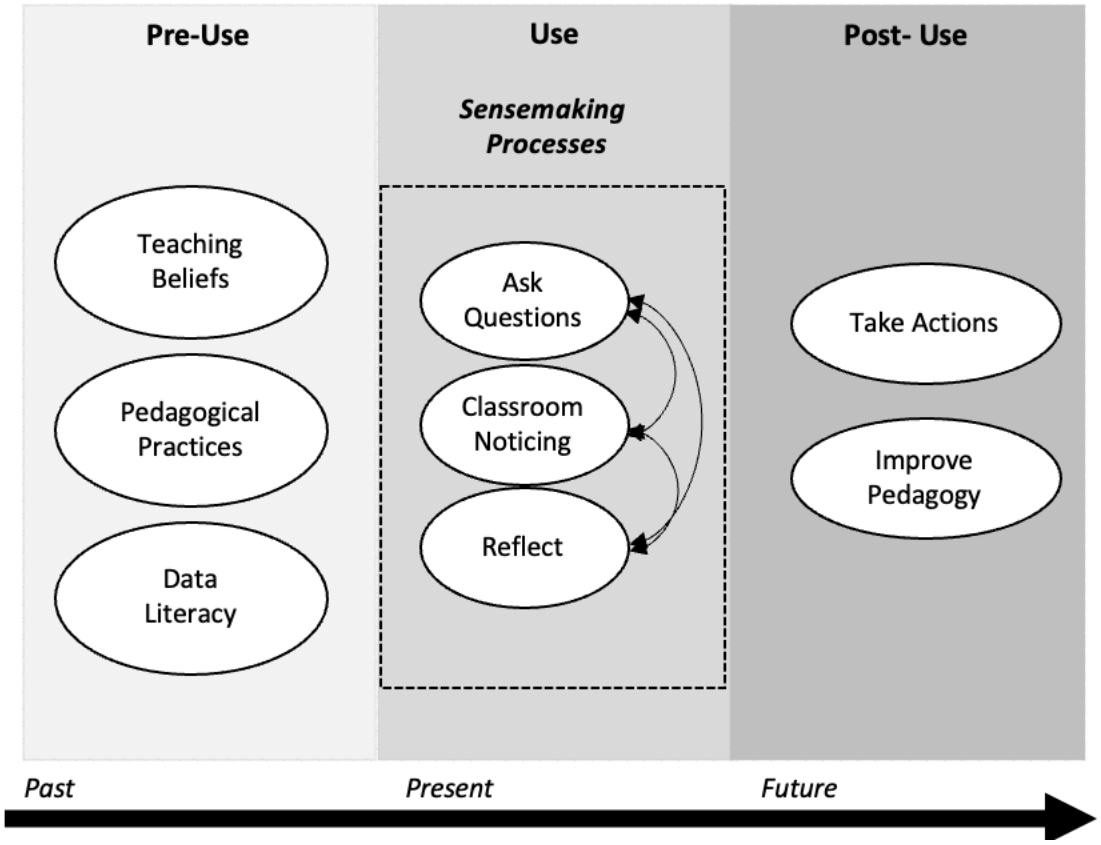

Figure 6. A model illustrating instructor pre-use, use, and post-use of dashboards.

5.1. Pre-Use: Teaching Beliefs, Pedagogical Practices, and Data Literacy

Instructors who agreed to participate in the implementation held teaching beliefs and pedagogical practices prior to this experience, of course. Instructor teaching beliefs, pedagogical practices, and data literacy are represented as past experiences in the model's continuum. Previous research has revealed that instructor teaching practices are tightly related to their beliefs about teaching. Similarly, in this research, instructors who participated in the implementation had moderate to high levels of intention to integrate student-focused approaches, and they were to some extent already implementing AL strategies. Instructors believed in student-centred approaches and wanted to enhance and improve their teaching practices through the training and the use of automated feedback dashboard.

Instructor participants had some prior understanding of data and its interpretation; they had earlier interactions with various dashboards and understood how the systems work. However, they emphasized the importance of training users who did not have similar experiences to understand data and interpret it prior to using the dashboard. Previous literature has highlighted the lack of data literacy skills (understanding and interpretation of data) and how it affects the effective use of dashboards (Kitto et al., 2017). Knowing how to use dashboard data and interpreting it allows for its integration into instructors' daily practices (Rienties et al., 2018). Thus, the proposed model and study results strongly suggest that instructor teaching beliefs, pedagogical practices, and data literacy skills may have a direct relationship with and effect the present use of automated feedback dashboards.

5.2. Use: Dashboard Use and Sensemaking Processes

Instructors who use dashboards progress through various sensemaking processes that involve multiple activities and outcomes. The learning analytics literature has identified sensemaking activities that include areas of curiosity identification, asking questions, interpreting data (reading data and explaining patterns; Wise & Jung, 2019) as well as awareness and reflective practices (Verbert et al., 2014). Additionally, studies that have used video observation have identified teacher noticing and professional vision as factors involved in sensemaking strategies (Seidel & Stürmer, 2014). Instructors who have used the TEACHActive dashboard have identified a continuous cycle of events that take place during its employment: questioning, classroom noticing, professional visioning, and reflecting. While many instructors reflected on their practices, it is worth highlighting that, in the interviews, they mentioned lack of action after the sensemaking process. This inaction can be attributed

to various factors such as uncertainty about the next steps, lack of trust in the data, lack of confidence in the data interpretation, time constraints, or external constraints that limited taking action based on the insights derived from the dashboard. This inaction entails the importance of further support and guidance for instructors after the sensemaking process.

5.3. Post-Use: Taking Actions and Improving Pedagogy

Dashboard usage informs instructors' future actions and positively changes their pedagogical practices. Previous research has revealed that instructor decision making and pedagogical responses depend on their effective use of tools (Li et al., 2021). As instructors view the dashboard, analyze data on it, and make meaningful interpretations, they improve their decision making and pedagogical responses (Wise & Jung, 2019). In this study, instructors reported that they became more aware of what is going on in their classrooms that enabled them to make more informed pedagogical decisions. The actual pedagogical actions implemented post-dashboard interaction were not tracked as part of this research.

5.4. Recommendations for a More Effective Use of Feedback Dashboards

The continuum presented in the model entails instructors' past, present, and future experiences using dashboards. The instructor can determine the impact of dashboard use actions taken to improve their pedagogical practices. Consecutive dashboard results can be contrasted to provide evidence of change. Based on the results of this research, recommendations for a more effective use of the automated dashboard and an overall more positive experience includes interventions before, and while using it, to better inform future usage. These interventions include the following: 1) training, 2) expert scaffolding, and 3) peer sharing. Figure 7 presents a model extension with interventions.

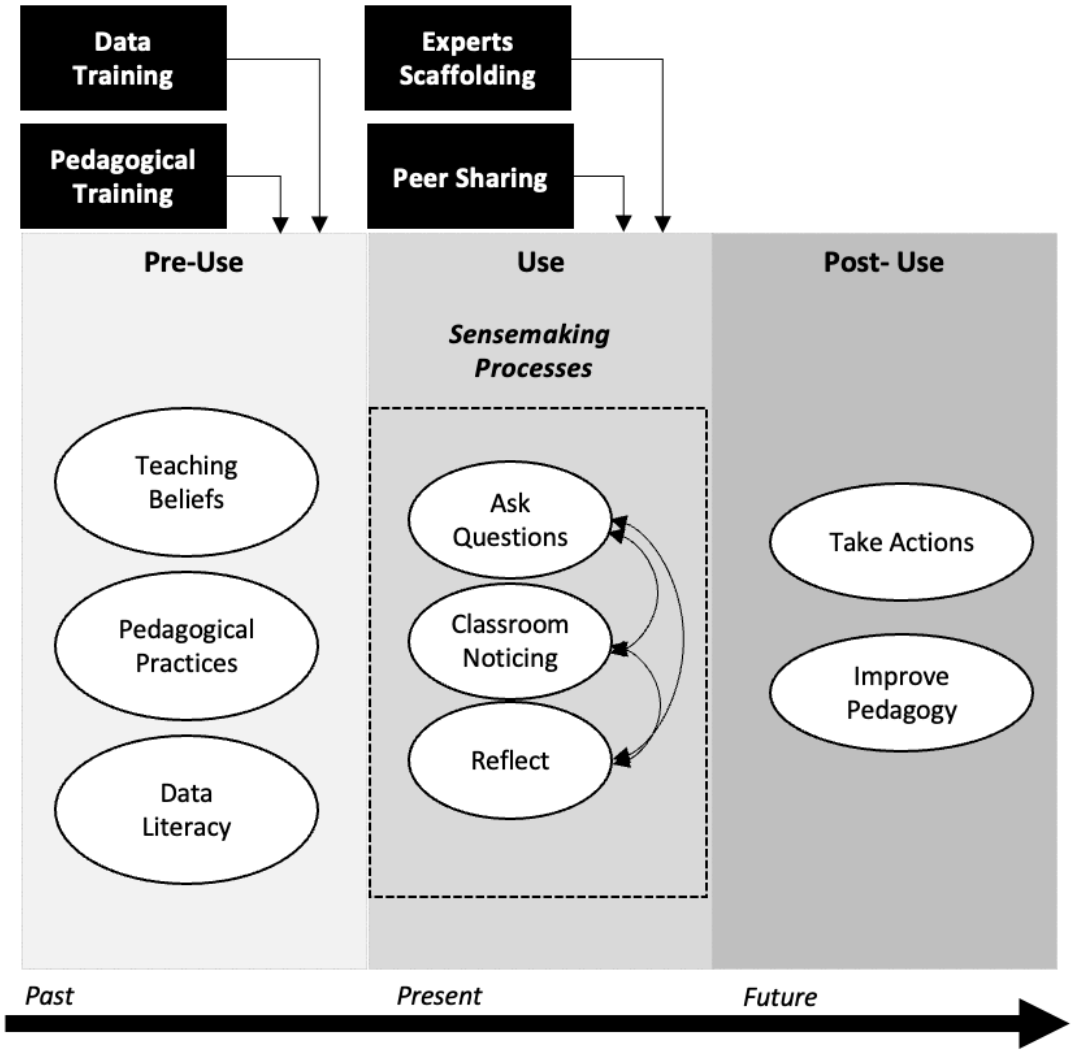

Figure 7. Model extension with interventions.

5.4.1. Training

Two aspects of dashboard training would be of particular benefit to instructors: 1) using, reading, and interpreting data, and 2) pedagogical practices such as AL. Such training provides instructors with a better understanding of how to align data with pedagogical practices.

5.4.2. Expert scaffolding

While using dashboards, instructors would benefit from scaffolding wherein they discuss the alignment between their classroom practices and visualized data with an expert. Scaffolding sessions make it easier for instructors to understand how to interpret their practices and set goals for change.

5.4.3. Peer sharing

Peer sharing with other instructors is a valuable opportunity for instructors to draw meaningful connections between their data and classroom practices during conversations and discussions. Previous research has demonstrated the importance of having access to examples from other instructors when using analytics to inform pedagogical practices (Wise & Jung, 2019).

5.4.4. Limitations

This study's main limitation relates to the instructor sample and the TEACHActive analytics data provided for instructors. All participating instructors implemented AL strategies in their classrooms to some extent, and most were teaching professors with a primary focus on teaching practice rather than research. The sample size was smaller than anticipated since the research required instructors to be teaching face-to-face during COVID-19 restrictions, which presented significant challenges. Another reason for the smaller sample size was related to the EduSense system used that has a set of requirements including classroom size and camera set-up structure, which was challenging to arrange in some cases, even when instructors were willing to participate. In addition, the data visualized on the dashboard was bounded by the metrics captured by the EduSense.

The findings in this study were based on instructor perceptions and reflections without tracking the subsequent classroom actions taken. It is also noteworthy that all professors came from engineering departments, indicating a pre-existing level of data literacy that ameliorated the need for additional training in this area. Future research can sync instructor reflections with future classroom observations to provide a more comprehensive analysis of the impact of the dashboard use. Additionally, exploring student use of the same dashboard could offer valuable insights for comparison with instructor experiences.

6. Contribution of the Study and Final Remarks

This study examined engineering instructor use of an automated dashboard and its relationship to their teaching beliefs, pedagogical practices, and actions taken post-use. Results from this research revealed that participating instructors' teaching beliefs and pedagogical practices tend toward student-focused approaches. Moreover, instructor use of the dashboard and sensemaking processes are reported. This research further synthesized the results into a model that illustrates how instructor use of the dashboard exists on a continuum between the past (pre-use), present (use), and future (post-use). The model can be used as a conceptual framework for future studies about instructor dashboard use. Future work can help validate and refine this model with different types of dashboards. Future research can extend this model to a larger instructor participant sample while taking student perspectives into consideration.

This research offers a comprehensive understanding of how engineering instructors interact with automated feedback dashboards. By integrating the literature on teaching beliefs, pedagogical practices, and sensemaking, this study bridges the gap between theoretical knowledge and practical application. It provides an in-depth understanding of the opportunities and challenges instructors face when using such dashboards and offers actionable recommendations for enhancing their effectiveness. Furthermore, by presenting a model that captures the continuum of instructor experiences, this study contributes a valuable framework for future research and development in the domain of educational technology and pedagogical practices. Future research may focus on quantifying the impact of actions taken by instructors and their pedagogical changes on student outcomes, thereby closing the feedback loop of this sensemaking process.

Declaration of Conflicting Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Appendix A

Survey Questions

Section 1: Demographics

Date:_____ Participant #:_____

- Gender: _____
- Age:_____
- Highest degree earned: _____
- Center/Department/College: _____
- Faculty Status (full time, part time, etc.):_____
- Position/ Title: _____
- Years of experience: _____
- Active Learning Implementation in Classrooms [yes, no] _____

Section 2: Teaching Beliefs

This survey is adapted from Approaches to Teaching Inventory (Trigwell and Prosser, 2004) that was designed to explore the way that instructors go about teaching in a specific context or subject or course. This may mean that your responses to these items in one context may be different to the responses in another context or subject. For this reason, we ask that you describe your context.

- Please describe the subject/course that you are teaching in [semester, year].
- Do you implement active learning strategies in this course? If so, please describe the active learning strategies that you use.

For each item please circle one of the numbers (1-5). The numbers stand for the following responses:

1- This item was **only rarely** true for me in this subject.
2- This item was **sometimes** true for me in this subject.
3- This item was true for me **about half the time** in this subject.
4- This item was **frequently** true for me in this subject.
5- This item was almost always true for me in this subject.

Please answer each item. Do not spend a long time on each: your first reaction is probably the best one.

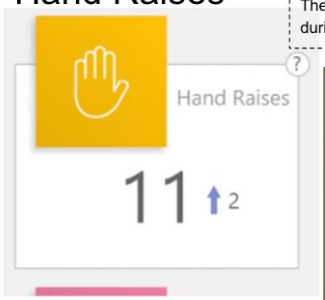
1. I design my teaching in this course with the assumption that most of the students have very little useful knowledge of the topics to be covered.
2. I feel it is important that this course should be completely described in terms of specific objectives relating to what students have to know for formal assessment items.
3. In my interactions with students in this course I try to develop a conversation with them about the topics we are studying.
4. I feel it is important to present a lot of facts to students so that they know what they have to learn for this course.
5. I feel that the assessment in this course should be an opportunity for students to reveal their changed conceptual understanding of the course.
6. I set aside some teaching time so that students can discuss, among themselves, the difficulties that they encounter studying for this course.
7. In this course I concentrate on covering the information that might be available from a good textbook
8. I encourage students to restructure their existing knowledge in terms of the new way of thinking about the subject that they will develop.
9. In teaching sessions for this course, I use difficult or undefined examples to provoke debate.

10. I structure this course to help students pass the formal assessment items.
11. I think an important reason for running teaching sessions in this course is to give students a good set of notes.
12. In this course, I only provide the students with the information they will need to pass the formal assessments.
13. I feel that I should know the answers to any questions that students may put to me during this course.
14. I make available opportunities for students in this course to discuss their changing understanding of the subject.
15. I feel that it is better for students in this course to generate their own notes rather than always copy mine.
16. I feel a lot of teaching time in this course should be used to question students' ideas.

Appendix B

Reflection Prompts (version 1)

Hand Raises



The total frequency of detected hand raises during the class session.

Reflection Prompts Page
Show the above image;
- <add this sentence > The number of hand raises in this session is 11

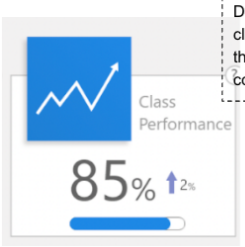
Students mainly raised their hands during this session to
- Ask questions/clarifications
- Participate in-class discussions
- Other_____

Are you satisfied with students' number of hand raises
- **Yes**
- **No (if they choose no, ask a follow up question: Why)**

Would you like to set a goal for next session?
Yes/ No
If yes / they may choose
- Trigger more student discussions to increase hand raises
- Other_____

Is this metric descriptive/ indicative of what's happening during class time
Yes/No

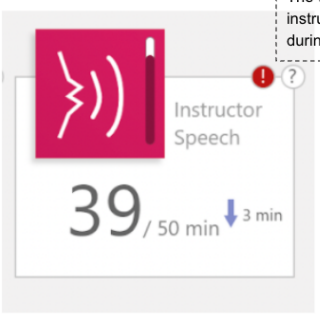
Average Class Performance



Did you do any graded activity in this class session? You may enter manually the average class performance and compare them with future sessions!

Reflection Prompts Page
Since this is optional and to be added manually, do we still add reflection prompt?

Instructor Speech



The total frequency of instructor talk (in minutes) during the class session

Reflection Prompts Page
Show the image;
- <add this sentence > You spoke for 39 minutes during this session

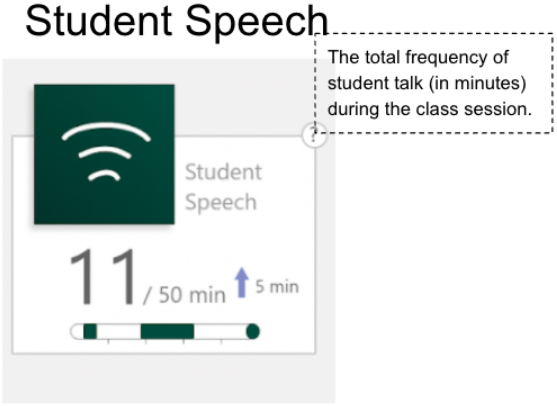
Did you expect that you will be speaking for this time?
- yes/no

Your talking was mainly
- Lecture
- Explaining new concepts
- Answering Questions/ Clarifying

Are you satisfied with the number of minutes you spoke
- Yes
- No (if they choose no, ask a follow up question: Why)

Would you like to set a goal for next session?
Yes/ No
If yes / they may choose
- Talk less than 39 minutes
- Other_____

Is this metric indicative/ descriptive of facilitating strategies in class?
Yes/ No
For each ask a follow-up question why



Reflection Prompts Page
Show the image;
- <add this sentence > Students spoke for 11 minutes during this session

Did you expect that they will be speaking for this time?
- yes/no

(with the no- follow-up ;
- No I expected more
- No I expected more

Did you include
Students were mainly
- Asking questions
- Participating
- Discussing with others
- Other_____

Are you satisfied with the number of minutes you spoke
- Yes
- No (if they choose no, ask a follow up question: Why)

Would you like to set a goal for next session?
Yes/ No
If yes / they may choose
- Increase student speech time
- Other_____

Reflections (version 2)

Quick Description of the class session

- Date & Title
- Objectives of class
- Topic

What active learning strategies did you use in this class (if any)

- Collaborative Learning
- Problem-based Learning
- Inquiry Learning
- Concept Tests
- Think-Pair-Share
- Cooperative Learning
- Case based Teaching
- Peer Instruction
- Team Based Learning
- 1 Minute Paper
- Other (please type in your response)
- I did not use active learning during my class

Let's reflect more on your class session! Please complete the following questions.

Nb of Hand Raises (displayed)

1. Research shows that the frequency of hand raises is associated with student participation. Students may raise their hands for different reasons. In this session, students mainly raised their hands to
   - Ask questions/clarifications
   - Participate in-class discussions
   - Other (type in any other reason) _____

2. Did you expect to have this number of seconds of hand raises?
    - Yes
    - No
    - If the answer is No
    - Please explain why and what was your expectation.

3. What would be your ultimate goal for the number of seconds of hand raises during your sessions?
    - Increase them
    - Decrease them
    - Keep them as they are
    - I can't think of a goal right now

4. Follow-up question: in case the answer was " increase them" or "decrease them"

5. What are some small actions you can take to reach your goal?
    - Ask students more questions
    - Encourage students to ask more questions
    - Trigger more participation through activities
    - Polling
    - Other (type in any other reason) _____

6. How do you perceive the number of seconds of hand raises to be related to your active learning implementation?
    Scale it (from 1 to 5)
    Highly related
    Not related
    etc.
    It's related to my active learning
    I think that the number of seconds of hand raises are related to my active learning implementation
    Strongly agree
    Agree
    Neither agree nor disagree
    Disagree
    Strongly disagree

_____

Instructor Speech (displayed)

1. Your speaking was mainly
    - Lecture
    - Give instructions about class activities/ projects
    - Explaining new concepts
    - Answering Questions/ Clarifying
    - Other _____
    -
2. Did you expect that you would be speaking this much?
    - Yes

- No
- Other (type in any other reason) _____

3. If the answer is No/ other
   - Please explain why and what was your expectation.

4. What would be your ultimate goal for the total frequency of instructor speech?
   - Increase it
   - Decrease it
   - Keep it as it is
   - I can't think of a goal right now

5. Follow-up question: in case the answer was "decrease it" or "increase it"

6. What are some small actions you can take to reach your goal?

7. How do you perceive the frequency of instructor (your) speech to be related to your active learning implementation? Is this metric indicative of your facilitation of active learning strategies?

_____

Student Speech (displayed)

1. Students' speech was mainly based on
   - Asking questions
   - Participating
   - Discussing with others
   - Other_____

2. Did you expect to have this number of seconds of student speech?
   - Yes
   - No
   - If the answer is No
   - Please explain why and what was your expectation.

3. What would be your ultimate goal for the frequency of student speech?
   - Increase them
   - Decrease them
   - Keep them as they are
   - I can't think of a goal right now

Follow-up question: in case the answer was "increase it"

What are some small actions you can take to reach your goal?

How do you perceive the frequency of student speech to be related to your active learning implementation?

Instructor Movement (displayed)

1. Are you satisfied with where you moved during the class?
    - Yes
    - No
    - If the answer is No
    - Please explain why and what was your expectation.

2. What would be your ultimate goal for movement
    - Move around more
    - Move around less
    - Keep it as it is
    - I can't think of a goal right now

Follow-up question: in case the answer was " move around more/ or move around less"

What are some small actions you can take to reach your goal?

How do you perceive the instructor movement to be related to your active learning implementation?

Sit vs stand

Overall Reflection on this class session

How did this class go? What was the thing that helped students engage in the class session? What needs improvement? If you were to teach this class again, what would you change/ do differently?