Leveraging Engineering Instructors' Professional Development with Classroom Analytics

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Abstract: Faculty professional development is a key factor contributing to the effective implementation of evidence-based teaching in STEM classrooms. We developed TEACHActive, an innovative professional development model that supports engineering instructors' classroom analytics-driven reflective practices. TEACHActive uses machine learning techniques within a camera-based classroom sensing system that tracks behavioral features of interest in classrooms. We rapidly enacted, tested, and revised the TEACHActive model with engineering instructors following the design-based implementation research. This study reports the results of the first iteration completed in the Spring semester of 2021. Specifically, we examined the TEACHActive implementation and deployment in engineering classrooms to analyze instructors' perceived successes and challenges. The paper presents implications for using the classroom analytics-driven professional development with educators in higher education.
Keywords: classroom analytics, professional development, engineering education

Introduction

Applying novel and innovative approaches in engineering pedagogy is critical for instructors' professional development. Despite ample evidence on the effectiveness of transformative approaches in engineering pedagogy (Felder & Brent, 2010; Lattuca et al., 2014), such as active learning, their translation into actual classroom practice has been slow (Shekhar et al., 2015). Research recommends integrating frequent observation, feedback, and reflection opportunities into professional development programs to facilitate instructors' adoption of evidence-based teaching strategies (Gormally et al., 2014). The traditional classroom observation model, where an experienced instructor or a peer provides in-person feedback, can be costly, difficult to scale and sustain. Automated classroom observation and feedback systems hold promise for facilitating professional development models that are linked to instructors' in-class implementation of active learning strategies. The emergence of computational analysis and machine learning techniques provides new ways of understanding classroom behavior and designing feedback systems about the in-class behaviors of teachers and students. Thus, there is a critical need to examine the affordances of automated classroom observation and feedback models in facilitating data-driven teaching and professional development.

In this research, we designed and implemented an innovative professional development and classroom analytics-driven model, TEACHActive, that supports reflective practices of engineering instructors in higher education. TEACHActive includes transforming raw classroom data into meaningful metrics and then using these results to provide practical feedback for instructors (AlZoubi et al., 2021). The model goes beyond traditional one-size-fits-all models by integrating classroom data with continuous, timely, and formative automated feedback while centering instructors as the stewarding agents of pedagogical innovation. TEACHActive is designed and implemented following the design-based implementation research (DBIR) to rapidly enact, test, and revise the model with engineering instructors. This study reports the results of the first iteration completed in the spring semester of 2021. Specifically, we investigated the following research questions: How can the TEACHActive model be implemented for engineering instructor professional development? What are the perceived successes and challenges of the TEACHActive model components?

Literature Review

Active Learning Facilitation Strategies in Engineering Classrooms

The Accreditation Board for Engineering and Technology (ABET), which provides assurance that a college or university program meets the quality standards, requires accredited engineering programs to ensure students meet a list of outcomes by graduation. These seven student outcomes clearly state that future engineers must attain professional skills such as communication, teamwork, problem-solving, and teamwork in addition to technical skills (ABET, 2019). Therefore, engineering instructors must go beyond a traditional lecture approach and integrate learning activities that would create ample opportunities for students to practice these professional skills (Felder & Brent, 2010). In particular, active learning strategies that ask students to collaborate with their peers to solve real-world problems and communicate their solutions to a wide variety of audiences are more likely to produce well-rounded engineers that can produce creative solutions to engineering problems (Bransford et al., 2000).

Active learning is an umbrella term for many instructional methods that require students to actively participate in the learning process rather than passively listening to the instructor (Prince, 2004). Based on the complexity and the time requirement, active learning can take many different forms, from simply pausing a lecture and asking students to write a summary of what has been covered in the lecture to asking them to collaboratively work on real-world problems and projects. The effectiveness of active learning strategies compared to the traditional lecture approach, when implemented well, has been empirically validated and documented in engineering education literature (Prince, 2004; Freeman et al., 2014; Deslauriers et al. 2019).

Instructors may be resistant to change their pedagogical approaches (Tharayil et al., 2018) when they perceive different barriers to implementing active learning strategies in classrooms reflected in their classroom behaviors (Michael, 2007). Those perceived barriers may not reflect classroom reality and could be informed by the classroom data. Derived from the intention that instructor strategies can positively influence active learning implementation, Tharayil et al. (2018) developed a list of facilitation strategies for instructors to integrate into their classrooms. The facilitation strategies include, but are not limited to, (a) walking around the room, (b) approaching non-participating students, (c) inviting questions, (d) designing activities for participation, and (e) using incremental steps. Facilitation strategies can be captured by behavioral indicators of specific classroom activities associated with instructors' implementation of active learning strategies and students' behavioral engagement. This study focuses on instructors' facilitation behavior and students' behavioral engagement through observable indicators from in-class activities. Instructors' facilitation behavior is an outcome measure of their kinesthetic patterns, changes in class activity such as sitting vs. standing, and spatial data from body positions. Students' behavioral engagement is measured from the number of hand raises, student vs. instructor speech, frequency, and speech duration.

Automated Classroom Observation, Feedback, and Reflective Practice

There is a need to link pedagogical theories with in-class practices via rigorous methodologies to determine ways to improve instructors' implementation and facilitation of teaching practices (Avella et al., 2016; Bodily et al., 2018; Sergis & Sampson, 2017). Observation and feedback on instruction are the most effective mechanisms for engineering faculty development (Tolnay et al., 2017). There is growing evidence supporting that receiving automated and evidence-based feedback about instruction is critical for instructors' professional development (Holstein et al., 2018; Rienties et al., 2018). In a regular classroom, instructors do not receive any data about their behaviors, and they recall very little detail about students' behavior (Gibbs & Coffey, 2004). Providing automated observation and feedback about the classroom environment can bridge the gap between what instructors recall about their session and the actual behaviors. Automated feedback can be used as a powerful reflective tool for instructors triggering them to reflect on the teaching practices and the efforts invested in their learning activities (Hassib et al., 2017; Holstein et al., 2018).

Reflective practice is a critical catalyst for improving instructional practices as it allows the instructor to identify instructional problems (Walkington et al., 2001). Self-reflection through data-informed feedback is important because it allows making sense of the provided evidence (Avramides et al., 2015; Wise & Vytasek, 2017). Some of the self-reflection techniques used in engineering education include implementing new teaching practices and reflecting on them following the implementation. In this study, we focus on data-informed reflective practice for instructors to use as a tool for pedagogical change.

TEACHActive: An Integrated Professional Development Model

TEACHActive is a machine learning-based teacher professional development model based on computational analysis of classroom analytics and automated context-sensitive feedback via the TEACHActive dashboard (AlZoubi et al., 2021a). TEACHActive uses EduSense, a computer vision-based classroom sensing system that tracks instructor and student behaviors (Ahuja et al., 2019). TEACHActive utilizes EduSense's customized classifiers and then outputs this data on an automated feedback dashboard, displays the behavioral indicators tracked by EduSense for each session, and provides a progress display that compares the data from different sessions (AlZoubi et al., 2021b). Instructors use the automated feedback on the session and the progress displays to reflect on their pedagogical practices and take actions accordingly. TEACHActive professional development model includes three main components (a) training on using pedagogical models (e.g., active learning strategies), (b) automated classroom observation, and (c) feedback in the form of classroom analytics from automated observation followed by reflective prompts.

The TEACHActive model includes hands-on training conducted before implementing an automated classroom observation and feedback system. During the multiple session training, instructors learn about evidence-based active learning methods, commonly used active learning strategies in engineering classrooms and effective facilitation behaviors. The final session includes an orientation about the automated classroom observation system, sensing technologies, and the dashboard with classroom analytics visualizations. After the training, instructors are scheduled for multiple automated observation and feedback sessions. Before these sessions, EduSense is deployed in their scheduled classroom by installing a computer vision-based classroom system that relies on passive video footage captured by video cameras placed at two vantage points in the physical classroom space to capture the students and the teacher (Ahuja et al., 2019; Kelley et al., 2021). As instructors complete their teaching sessions, they are presented with the classroom analytics on the feedback dashboard designed for the TEACHActive model (AlZoubi et al., 2021a,b). This feedback illustrates the visual representation of behavioral indicators from the classroom in connection with the classroom pedagogies. For example, changes in-class activity (i.e., sit vs. stand), student participation through hand raises, body positions, kinesthetic patterns, are displayed on the feedback dashboard. Instructors are also given reflection prompts as a follow-up on the subsequent sessions to make sense of the changes occurring from one session to another and reflect on the metrics of the sessions.

Method

The TEACHActive is designed following the design-based implementation research (DBIR) method to iterate, test, and refine the model and its components in the context of engineering instructor professional development implemented at a large Midwestern research university. The research was funded by the National Research Foundation (NSF). This paper reports the first iteration that was implemented with four engineering instructors in the Spring semester of 2021. Participating instructors included two males and two females in their early careers from the following departments: Industrial and Manufacturing Systems, Agricultural and Biosystems Engineering, and Aerospace Engineering. We invited the instructors to semi-structured interviews to understand their perceived affordances and challenges of using the TEACHActive model and their recommendations for future implementations.

Results

Results from the semi-structured interviews revealed instructors' perceived affordances and challenges of TEACHActive implementation. Instructors' perceived affordances and challenges were highlighted under three main themes: (a) automated feedback, (b) self-reflection, and (c) progression.

TEACHActive displays automated feedback

Participating engineering instructors found the TEACHActive model to be useful in displaying automated feedback and detecting moments of their teaching practices that they could not recall otherwise. All instructors highlighted that TEACHActive's automated feedback makes it easier for them to check and visualize their class sessions at a glance. Results from the first implementation revealed that instructors had different perceptions about meaningful metrics depending on their classroom context and the planned activities. For example, while two instructors identified speech as the most useful metric to provide automated feedback about the changes in activity during their classroom sessions, one instructor highlighted hand raises to be the most useful metric, and another one highlighted the movement patterns displayed through a heat map to be the most effective. The dashboard and its metrics were iterated based on feedback from the instructors. For example, in the first prototype, student engagement was displayed as a pie chart aligning with the ICAP framework: interactive, constructive, active, and passive (Chi & Wylie, 2014). However, based on instructors' feedback, this was not perceived as a meaningful display; therefore, we changed the display to include a scatter plot of hand raises, instructor speech, and student speech. Figure 1 illustrates TEACHActive dashboard prototype iterations.

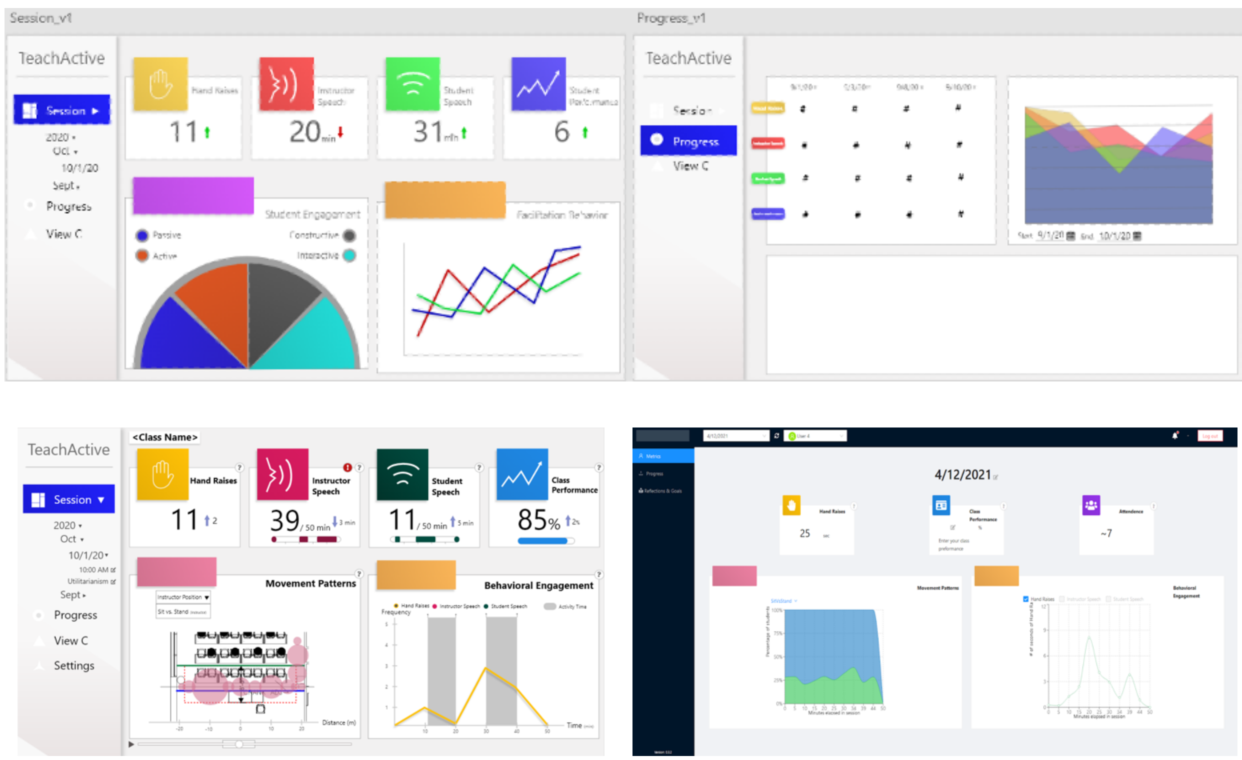

Figure 1. TEACHActive dashboard prototype iterations

TEACHActive promotes self-reflection

During the interviews, instructors shared that the classroom analytics provided on the TEACHActive dashboard promoted their self-reflection and provided opportunities to facilitate feedback on their future teaching. TEACHActive was perceived to facilitate their reflective practice by gaining a better overview of the in-class activities, reflecting on their facilitation strategies and setting goals to address pedagogical changes in their next sessions. Instructors highlighted self-reflection as a significant outcome from participating in the TEACHActive model. For example, they shared that the time-stamped moments during which they can detect hand raises were valuable as they allowed them to reflect on their class time. The dashboard integrated a reflection window that included reflection prompts based on instructors' feedback. Instructors complete reflection prompts after checking their classroom analytics for the session.

TEACHActive highlights progression between sessions

TEACHActive model displays the comparison and progression of metrics between sessions. During the interviews, instructors highlighted the importance of comparing metrics and checking their progress and changes from one session to another. They emphasized the importance of looking into what is driving these changes. All instructors perceived the progression display to complement the session display as they highlighted that the session display might not be as indicative without a comparison between sessions.

Perceived challenges

A number of challenges were also experienced during the first implementation of TEACHActive with a cohort of instructors in the Spring 2021 semester when COVID-19 restrictions took place at the university. Because the system implementation required data collection from face-to-face classrooms, it was critical to ensure that the system deployment and the data collection followed the new classroom teaching and research protocols. Instructor recruitment was another challenging factor due to the continuous unprecedented changes in-class teaching formats, available classrooms, and new regulations introduced for classroom capacities. These challenges were addressed through continuous communication, collaboration, and coordination between the research team and the university's classroom scheduling, audiovisual, information technology services, and units.

Conclusion

TEACHActive is designed as a comprehensive professional development that is uniquely situated within the growing literature on data-driven reflective teaching practice, multi-modal classroom analytics, and professional development. Despite research showing the significant impact of professional development on transformative classroom pedagogy (Felder & Brent, 2010; Lattuca et al., 2014), very few studies have focused on the effectiveness of data-driven models with engineering educators and published studies. This paper presents the results of the prototyping phase of a larger DBIR research project that aims to expand our understanding of the impact of a classroom-analytics-driven model on instructors' reflective practice and classroom engagement. The paper presents the TEACHActive model with its components and the new dashboard that was tested during the first iteration. Future iterations will test and iterate the system and the dashboard with a larger number of instructors recruited from different career stages and departments. This work can contribute to the acceleration of instructors' evidence-based decision-making for the success of their students in classrooms.

Acknowledgements

This research is supported in part by National Science Foundation under Grant no. 2021118. The opinions, findings, and conclusions or recommendations expressed are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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