Improving Undergraduate STEM Education by Integrating Natural Language Processing with Mobile Technologies

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The degree and quality of interaction between students and instructors are critical factors for students' engagement, retention, and learning outcomes across domains. This is especially true for the introductory STEM courses at the undergraduate level, since these courses are generally taught in lecture halls due to the large number of student enrollments. Recent developments in educational technology such as MOOCs and financial troubles in universities make it safe to predict that the class size problem will only get worse. So, how can we modify the passive nature of lectures and increase the interaction while actively involving both students and instructors in the learning process in these circumstances? The strategy pursued in our project was to integrate Natural Language Processing (NLP) with a mobile application that prompts students to reflect as well as provide immediate and continuous feedback to instructors about the difficulties that their students encounter. By enhancing the student reflection and instructor feedback cycle with technology-enhanced learning tools, our project investigated three research questions: RQ1) role of students' reflection and instructor's feedback on students' retention and learning outcomes; RQ2) effectiveness and reliability of NLP to summarize written responses in a meaningful way; and RQ3) value and design of mobile technologies to improve retention and learning.

We first designed an instruction model, called the reflection and feedback cycle, which integrates two core learning sciences concepts, reflection and feedback, prompts students to reflect on confusing concepts, and provides immediate and continuous feedback to instructors about the difficulties that their students encounter. To support this model, we developed a mobile learning system, CourseMIRROR (i.e. Mobile In-situ Reflections and Review with Optimized Rubrics, http://www.coursemirror.com), as well as the server-side infrastructure to implement the reflection and feedback cycle effectively in large courses (Luo, Fan, Menekse, Wang, & Litman, 2015; Fan, Luo, Menekse, Wang, & Litman, 2015). CourseMIRROR supports major mobile platforms such as iOS and Android, and is also accessible to PCs and other mobile platforms via web interfaces. The CourseMIRROR application prompts students to write and submit their reflections on confusing concepts and problems at the end of each class (and after the class) for an entire semester by using their own devices (smartphones, tablets, or PCs). CourseMIRROR uses NLP algorithms to provide relevant and coherent summaries of student reflections for each lecture by clustering them based on the common themes (Luo & Litman, 2015). These summaries allow users to understand the difficulties and misunderstandings that their students (or peers) encountered from the lecture. A recent enhancement of CourseMIRROR uses NLP to automatically assess reflection quality (Luo & Litman, 2016), which in turn is used by the mobile app to visualize the reflection quality and provide instant feedback to motivate students to complete sustainable and insightful reflections. CourseMIRROR has been deployed in eight university-level courses involving a total of 330 students to date.

With respect to RQ1 and RQ3, results of an *in vivo* study in an engineering statistics class showed that learning outcomes for students using CourseMIRROR were significantly improved over time compared to baseline data (Menekse et al., in preparation). For RQ2, NLP evaluation techniques demonstrated that the new summarization algorithms developed for this project (Luo & Litman, 2015; Luo, Liu, Liu, & Litman 2016) outperformed existing alternatives. In a 60-participant lab study, we found that NLP enhanced instant reflection quality feedback can significantly improve both the engagement of students and the quality of reflections. Finally, survey results demonstrated positive student perceptions for CourseMIRROR (RQ3). The team is continuing the CourseMIRROR collaboration, with external funding applications planned.

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[1] Graduate Student Researchers Xiangmin Fan and Wencan Luo (both from Computer Science) were also critical members of the research team.

Publications:

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- Luo, W., Fan, X., Menekse, M., Wang, J., Litman, D., Enhancing Instructor-Student and Student-Student Interactions with Mobile Interfaces and Summarization, Demo Paper, Conference of North American Association for Computational Linguistics (NAACL HLT 2015), Denver, CO, May 30 – June 5, 2015.
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