Combining Machine Learning and Learning Analytics to Provide Personalized, Adaptive Scaffolding

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Abstract: This work aims to propose a methodological framework to provide personalized and adaptive scaffolding to students who engage with computer-supported learning activities. Bridging the gap between pedagogical theories and established practice, my particular aim is to answer the following research questions: what makes scaffolding more beneficial for some students than others, why do some students give up even when supported, how can we prevent dropouts and turn them into successful learning episodes? My goal is to explore how theoretical frameworks on scaffolding can guide computational models in order to address student needs. My research hypothesis is that we can use Learning Analytics to model students' cognitive state and to predict whether the student is in the Zone of Proximal Development. Based on the prediction, we can plan how to provide scaffolding based on the principles of Contingent Tutoring.

Goals of research

The main goal of my research is to study how we can combine computational models informed by learning analytics (LA) with established pedagogical theories in order to provide personalized and adaptive scaffolding to students, targeting their specific needs. In particular, I am working on a project that aims to provide personalized guidance and feedback to students by adapting scaffolding to their background knowledge and cognitive state[1]. To that end, I propose the use of machine learning in order to design models to assess students' knowledge and cognitive state with respect to students' prior practice. To monitor prior practice, I propose the use of computational learning analytics (LA). To maintain the most up-to-date representation of students' knowledge and cognitive state, student models will be dynamically updated during students' practice. In order to provide guidance and feedback with respect to student's specific needs, I follow the Vygotskian construct of the Zone of Proximal Development (ZPD) (Vygotsky, 1978) and adapt scaffolding with respect to the principles of Contingent Tutoring (Wood, 2001).

Background

The adoption of technology in education has led to the development and adoption of new tools and methods to support learning and teaching. These tools and methods provide us with the unique opportunity to employ cutting-edge computational approaches for addressing fundamental pedagogical challenges that remain open: how to adaptively guide students and how to provide appropriate scaffolding to facilitate learning and to improve the learning outcome. Empirical research suggests that the learning analytics methods currently used to provide feedback are not based on established pedagogical strategies for instruction and scaffolding. On the contrary, they are commonly data-driven and have limited theoretical grounding (Gašević, Dawson, & Siemens, 2015). The lack of theoretical grounding can lead to providing inappropriate support that fails the purpose of scaffolding and inhibits learning instead of enabling it: for example, providing the wrong amount of support (too much or too little), providing support at the wrong time (too late or too soon) or even providing the wrong kind of support (giving away the answer to a question when eliciting would be beneficial). The open challenge is to bridge the gap between pedagogical theories and practice when it comes to scaffolding.

My research hypothesis is that we can use learning analytics to design student models that will describe the student's knowledge and cognitive state, thus generalizing cognitive student models used in Intelligent Tutoring Systems (Corbett, Koedinger, & Anderson, 1997). The output of such student models can be used as a proxy to assess whether the student is - or, is not - in the ZPD. The core rationale is that if the student model cannot predict with acceptable accuracy whether a student will answer a question correctly, then it might be the case that the student is in the ZPD. Based on the student model's outcome - that is, whether the student is in the ZPD, above the ZPD, or below the ZPD - we can further plan the teaching strategy: what tasks to assign to the student, whether the student needs scaffolding and what kind of scaffolding is appropriate. This rationale - known as the "Grey Area" approach - has been previously studied in the context of Intelligent Tutoring Systems (Chounta, Albacete, Jordan, Katz, & McLaren, 2017; Chounta, McLaren, Albacete, Jordan, & Katz, 2017). Here, I aim to extend and

[1] https://www.etis.ee/Portal/Projects/Display/bb291d41-e11d-4667-b374-8a801015e374?lang=ENG

generalize its use to learning activities orchestrated by Learning Management Systems and Collaborative Learning environments in Higher Education.

Methodology

For this research, I will follow a mixed-methods approach, combining qualitative (focus groups, observations, surveys) and quantitative (machine-learning, social network analysis, sequential pattern mining, time series analysis) research methods. The research and development work will take place over four work-packages during the course of four years. The project follows an iterative methodology by adopting a design-implementation-evaluation circle (Figure 1) in order to confirm that findings from different work-packages and outcomes from various methodologies will be combined and cross-validated.

The outcome of this research will include the methodological framework for personalized scaffolding and a Learning Analytics taxonomy for informing research with respect to the significance of various learning analytics in assessing student's knowledge enriched with machine-learning cognitive models. Additionally, I will communicate the findings of the evaluation phase in the format of "lessons-learned" and use them as guidelines for future work.

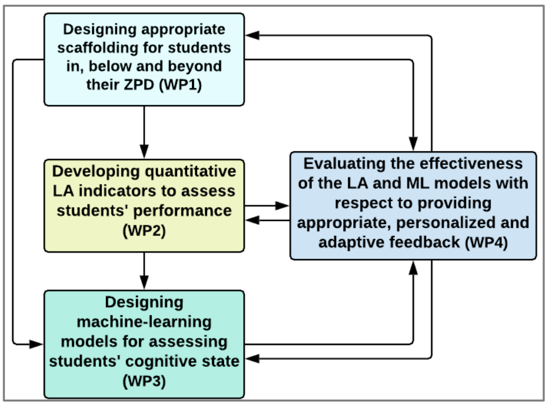

Figure 1. Method of Research

Expected contributions

To the best of my knowledge, this is a novel approach for providing scaffolding in technology-enhanced learning environments. Existing learning analytics approaches that aim to provide scaffolding rely on rubrics and empirical rules that attempt to explain how student activity relates to student performance. The novelty of this contribution is twofold: 1. Using machine-learning cognitive models in order to dynamically assess student's knowledge state; 2. Adapting scaffolding with respect to the cognitive model's output based on the principles of pedagogical theories, namely the ZPD and Contingent Tutoring. A key broader impact of this work is that it can support complex pedagogical decision-making necessary for providing effective scaffolding. Once the proposed approach has been developed and vetted through efficacy testing it can be widely used in various contexts, such as online courses, MOOCs and collaborative learning environments. Furthermore, I envision that this approach will impact how we design learning material and learning activities, taking into account students' characteristics and needs. The project could also contribute to the ever-present assistance dilemma (Koedinger & Aleven, 2007)—that is, the challenge of providing the right amount of help to the student so that the student is challenged but not frustrated.

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