Personalized and Representational Scaffolding to Foster Teachers' Diagnostic and Intervention Skills in Debugging

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Abstract

Debugging situations require computer science teachers to diagnose students' programming difficulties under time pressure. However, diagnostic skills for debugging are rarely explicitly addressed in teacher education. This dissertation investigates how simulation-based learning environments with personalized representational scaffolding can foster teachers' diagnostic skills when analyzing students' debugging processes.

CCS Concepts

• **Social and professional topics → Computing education**.

Keywords

Debugging, teacher education, diagnostic skills, simulation-based learning

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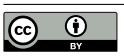
1 Context and Motivation

Debugging is a fundamental activity in programming, yet it poses substantial challenges for novice learners [9], in particular in K-12 settings. Students frequently struggle to identify and resolve programming errors and therefore rely heavily on their teachers' support during debugging situations [12]. Teachers must quickly diagnose the underlying causes of students' problems and select appropriate interventions that both resolve the issue and promote students' debugging skills [19].

Diagnosing such situations is a demanding professional task, particularly for novice teachers [3]. Diagnostic competence involves recognizing relevant cues in learning situations, interpreting them using professional knowledge, and making informed instructional decisions. Consequently, developing diagnostic skills is widely recognized as a key goal of teacher education.

Simulation-based learning has emerged as a promising approach to support the development of professional skills in teacher education. Simulations allow learners to repeatedly practice analyzing complex classroom situations in a controlled environment while maintaining essential features of authentic practice. A particularly promising mechanism for supporting learning in such environments is representational scaffolding. For example, simulations can highlight the salience of relevant cues or adjust the typicality of and complexity of practice situations [4]. Research suggests that such representational scaffolds enhance learning. In particular, adapting representational scaffolding to learners' prior knowledge [4] has been shown to enhance learning [5]. Despite these promising developments, research in computing education has only begun to explore how simulations and scaffolding can support teachers in diagnosing debugging situations.



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2 Background and Related Work

Research on debugging has documented common novices' errors that trigger debugging processes and reveal underlying misconceptions [13].

Evidence on teachers' diagnostic and intervention skills for supporting novice learners, however, remains fragmented. Individual studies have examined how teachers support students in physical computing tasks [7]. Scripted video vignettes have also been used to study experienced teachers' diagnostic processes in debugging through questionnaire-based qualitative data [19].

At the same time, simulation-based learning has been identified as a promising approach for supporting pre-service teachers' professional skills, such as diagnostic competence, in other K-12 subject domains [17].

To assess diagnostic activities within simulations, triangulating eye-tracking, screen recordings, and retrospective verbal reports has proven effective in self-regulated learning research [10]. Log data have been used to capture learner interactions and derive process indicators that inform adaptive support [2, 14, 15] . Eye-tracking has been applied to code comprehension, collaborative programming, and debugging [1, 6, 16] , offering insights into attention allocation that have been shown to reflect cognitive processes [8]. Complementing these traces, think-aloud protocols provide access to the reasoning behind observed behaviours [11, 18].

Using these data channels to synthesize possible interaction patterns, we can build on recent work suggesting that adaptive and personalized scaffolding, tailored to learners' interaction patterns and prior knowledge, is a promising approach for supporting learning processes in simulation environments [14].

3 Problem Statement and Hypothesis

Although debugging is a central aspect of programming education, teachers' diagnostic skills for debugging situations remain largely

underexplored and insufficiently addressed in teacher education programs. Existing research provides insights into programming errors, their causes, debugging strategies, and teacher interventions, yet little work has investigated how teachers learn to diagnose debugging situations, particularly within structured learning environments.

RQ: What are the effects of simulation-based learning environments with adaptive personalized scaffolding on teachers' diagnostic skills when diagnosing students' debugging difficulties?

H: The central hypothesis guiding this research is that simulation environments that combine theory-driven case design with scaffolding and personalized scaffolding can significantly improve teachers' diagnostic reasoning in debugging situations.

4 Research Goals

The overarching goal of this dissertation is to investigate how simulation-based learning environments can foster diagnostic and intervention skills in computer science teacher education. Debugging situations in K–12 computer science classrooms serve as the domain for examining these professional practices and are aligned with metacognitive strategies and support. In line with the SHARP framework, the project examines the effects of two forms of scaffolding for beginning teachers working with the simulation: personalized representational scaffolding (highlighting diagnostically relevant cues) and learning process scaffolding (dashboards providing metacognitive prompts).

5 Research Methods

The dissertation project adopts a mixed-methods research design combining conceptual framework development, multimodal process analysis, and experimental evaluation. First, simulation cases representing realistic debugging situations are developed for teacher training. Second, teachers' diagnostic processes are analyzed using a multimodal approach, including eye-tracking, interaction logs, and retrospective think-aloud protocols. This approach allows capturing teachers' attention allocation, interaction behaviour, and reasoning processes during diagnosis. Third, these data are used to identify patterns in diagnostic reasoning and to design (personalized) scaffolding mechanisms that guide teachers' diagnostic activities during simulations. Finally, experimental studies evaluate the effects of scaffolding and personalized scaffolding on diagnostic performance and diagnostic processes.

6 Current and Expected Contributions

This dissertation contributes to computing education research and teacher education in several ways. First, it advances theoretical understanding of how teachers diagnose students' debugging difficulties by investigating diagnostic reasoning processes in simulation-based environments. Second, it introduces a structured approach to designing debugging cases for teacher training through the ECDM framework. Third, the research develops and evaluates (personalized) scaffolding mechanisms for simulation-based teacher training, including adaptive scaffolding based on learners' diagnostic behaviour. Finally, the project provides empirical insights into how personalized support can foster teachers' diagnostic skills in debugging situations, contributing to improved teacher preparation in computer science education.

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