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# Describing Computer Science Education Research: An Academic Process View

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**Abstract**

Changing circumstances within universities involve the adoption of innovative teaching models and the incorporation of advanced technologies. The integration of new technologies into computer science (CS) and Information Technology (IT) educational programs is frequently accompanied by research aimed at comprehending and enhancing teaching and learning experience. The assessment of the potential of emerging technologies and their incorporation into teacher education has become increasingly significant. Unfortunately, numerous studies conducted by researchers in CS and IT education have faced criticism for their ad hoc experimental methodologies and insufficient research rigor. This paper promotes the establishment of an applied research framework for educational research to improve the development, implementation, and understanding of educational innovations within scientific fields. In order to develop a framework, we have conducted a review of some of the research activities in CS education to extract and analyze the underlying principles that contribute to a valuable investigation of an educational context. Developing a framework for applied research can help to ensure that studies of educational contexts are more complete. This is valuable as it helps other researchers to understand the context of the study so that they can interpret the results and decide how the findings might be relevant to their own courses. Such guidelines can also serve as a basis for teacher education programmes concerned with course design and assessment of teaching practice.

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## Introduction

Research focused on innovation in educational processes within the field of computer science (CS) is becoming increasingly vital as educators seek to comprehend the mechanisms of learning. A significant portion of this research revolves around addressing variations of the following inquiry:

> *How do students achieve an understanding of concepts and develop the capability to apply these concepts along with technical and practical skills in computer science? Furthermore, what structural changes should be implemented in future educational environments to enhance the overall effectiveness of the learning experience?*

Studies that gather and analyze data to provide insights into the effects of innovative course implementations are notably scarce in conferences and journals targeted at CS academics. Instead, many educators tend to focus on narrating their course contexts and teaching methodologies in a largely anecdotal fashion. This trend in publication has led to a perception among many practicing educators that domain-specific educational research, particularly in areas like computer science, lacks seriousness and relevance.

Education is a multifaceted endeavor that encompasses various components, including personnel, tools, technologies, learning theories, and assessment methods, among others. The intricate interconnections among these components are often challenging to articulate. Establishing a clear framework to guide domain-specific educational research activities appears to be a crucial next step for research in CS education. The benefit of such a model lies in its capacity to undergo scrutiny, evaluation, and refinement. A primary objective of this research framework should be to maintain flexibility while aiding researchers in integrating methodologies from diverse fields such as sociology and pedagogical theory. Consequently, the framework proposed here promotes the notion that the choice of research methods should be critically examined, ensuring that the advantages and disadvantages of various approaches are clearly articulated. Explicit guidelines and a well-defined research framework are essential for advancing this field. The subsequent sections of this paper are organized as follows. The initial section examines relevant research efforts and underscores the necessity of implementing a robust research framework in applied education research. This is succeeded by a section that delineates our interpretation of rigorous applied research within the educational context. Through this discourse, we aim to highlight several key elements that we consider essential to researcher-focused research endeavors. A visual depiction of a researcher-centric perspective on applied educational research will then be introduced and elucidated. The paper concludes with a discussion of our findings, objectives, and future research intentions.

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**Related Work**

Computer Science (CS) education research is recognized as established, yet it remains in a developmental stage. This assertion is supported by various studies, including those conducted by Daniels et al. [9], Holmboe as reported in [11], and discussions held at the ACM SIGCSE conference [10, 8]. Some researchers have addressed the need to enhance the skills and competencies of individuals interested in learning about techniques and methodologies pertinent to CS education research [17]. Additionally, a broader examination of how academics perceive their discipline and their practices within it [15, 3] is relevant in providing context for our work.

Related literature on overarching models and the research practices and cultures within higher education can be found in the works of Prosser and Trigwell [16], Becher [3], and Pescolido [15]. However, these studies do not specifically cater to academic researchers aiming to comprehend CS education research as a multidisciplinary field. Ahlgren [1] has raised important questions regarding the focus on studies that enhance the general understanding of teaching and learning processes and techniques. He categorizes three types of studies that can yield valuable data for investigating educational processes. Nevertheless, this work does not adequately define a comprehensive research methodology; instead, it emphasizes particular types of experiments that the author believes are effective in generating useful data.

Other significant contributions to the characterization of educational research activities include constructivism [6] and action research [19, 14]. The action research model described by Newman [14] is relevant but remains more general and abstract than the practical framework we propose. While constructivism plays a crucial role in modeling the processes through which students develop understanding and has been advocated within the CS education research context [4], it does not offer the comprehensive framework for applied CS education research that we seek. Rather, it represents one of the pedagogical theories we aim to integrate.

**A STRUCTURED APPROACH**

The theoretical underpinnings for exploring educational contexts and processes within established pedagogical theory often present a perspective on educational processes and research methodologies that may not be readily applicable or accessible to practitioners in computer science education. To address this issue, it is essential to create research methodologies that are more intuitive for researchers and tailored to facilitate comprehensive studies of educational environments in the field of computer science. This approach would help to connect practical teaching methods with advanced educational theories. There are two primary advantages to this strategy. Firstly, it simplifies the explanation of the significance of

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educational research within scientific disciplines. Secondly, a well-defined research method or framework—taking to the "scientific method" in applied education—will enhance the recognition of computer science education research as a legitimate and important area of scholarly inquiry.

## AN EDUCATIONAL RESEARCH MODEL

The design and development of study contexts in educational methodologies for computer science can be explored through the lens of applying and modifying established theoretical models found in educational theory literature. Potential frameworks for educational study design include those proposed by Langerth et al. and Holmboe et al. However, the straightforward application of these methodologies to the design of studies in computer science education presents challenges. A significant portion of the difficulty arises from the general and theoretical nature of these frameworks, which often complicates their practical implementation. We aim to define an applied framework by pinpointing the essential components of the educational environment and the educational research process, viewed from a researcher-centric standpoint. This forms the implicit research meta-structure that underpins the design and presentation of studies focused on teaching evaluation and innovation within the field of Computer Science. The objective of the descriptive research model we have developed is to provide a practical perspective on the educational research process, emphasizing the elements that are most crucial to the teacher/researcher in computer science, or potentially in any scientific discipline.

Utilizing this model enables researchers in Computer Science Education to create more comprehensive studies of educational contexts. The diagram presented in figure 1 illustrates a researcher-centric perspective of the teaching and research environment where subject and topicbased studies occur. It delineates the relationships among technologies, students, teachers, and researchers within the framework of investigating educational innovation and improvement. The diagram should be interpreted from top to bottom, with the course cloud representing the focal point of activity. Activities related to the course can be categorized into two main areas: influences and evaluation/research.

### Course Influences

The influences on a course are categorized into three main types: tools, stakeholders, and educational theory. By tools, we refer to the instruments and technologies employed to implement various aspects of the course environment. Various tools include course websites,

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laptops, computer-based educational products, and wireless networking. Stakeholders refer to the community that influences the content, structure, and methodology employed in course design. This category also encompasses implicit elements of the course context, such as the expectations held by administrators, faculty, students, and teaching assistants regarding the course. Teaching staff, regardless of their backgrounds, possess their own pedagogical ideas, which may be either implicit or explicit. The educational theories that underpin efforts to create an effective learning experience for students—whether implicit or explicit—are encapsulated within the education theory framework. The tools, techniques, expectations of students and staff, and pedagogical approaches all significantly impact a course and contribute to defining its context. The specific implementation of a course is illustrated by the bold arrow connecting the course cloud to a rounded box that signifies a particular course instance.

**APPLYING OF THE MODEL**

To illustrate the practical application of the model, consider a study conducted in an introductory computer programming course. The instructor has observed a recurring issue where students frequently conflate the concepts of alternation (choice) and looping. This observation prompts the instructor to investigate how students develop their understanding of these concepts and the internal models they form regarding them. The course utilizes desktop computers linked to a UNIX server that operates the GNU GCC compiler, and students are encouraged to install RedHat Linux on their personal computers, provided they have access to one at home. The stakeholder group for this course is extensive, as it serves as the foundational programming course for all degree programs, with the Department actively participating in the formulation of the curriculum and teaching methods. The teaching strategy has been established by the Departmental Committee and remains unchanged by the instructor. The student body comprises individuals from diverse ethnic and cultural backgrounds, with their prior educational experiences limited to institutions where attendance was mandatory. The educational approach follows a traditional model, incorporating lectures to introduce concepts, followed by tutorials that present and discuss conceptual solutions to practical programming challenges, and laboratories where students are expected to write programs based on the ideas explored in tutorials. All lecture content is pre-prepared using PowerPoint presentations and delivered in a lecture hall accommodating 500 students.

The primary focus of this study is to explore "What models do students develop as they strive to comprehend the functioning of alternation and loop constructs in an imperative programming language?" By characterizing these models, we may gain insights into why many students mistakenly believe that an alternation construct functions as a looping mechanism. Our lecturer has opted for a study methodology known as phenomenography. This

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approach aims to articulate the various ways in which learners experience concepts, utilizing qualitative data gathered through interviews with a representative sample of the student population. The selection of this methodology not only dictates the type of data we will collect (interviews) but also significantly influences the framework employed to organize that data and derive insights regarding students' comprehension of the course content related to loops and alternation.

Subsequent research can leverage the findings from this initial study as a foundational reference, exploring how the introduction of new elements within the learning environment affects the understanding models that students construct. For instance, the lecturer may incorporate additional practical programming tasks into the laboratory sessions, necessitating that students develop programs utilizing loops and alternation. Alternatively, the introduction of Java applets during lectures, along with the provision of these applets as online revision tools, could facilitate interactive visualizations that illustrate the distinctions between looping and alternation.

## CONCLUSIONS

The framework we have outlined represents an initial step in an essential dialogue regarding the nature of structured investigations within computer science education. Our objective is to clarify the significance of educational research, as well as the methodologies for data collection and interpretation. This endeavor aims to deepen the understanding of domain-specific educational research and to broaden the applicability of particular studies, enabling their findings to be utilized across various courses and fields. The advantages of our approach include the refinement of educational research techniques and the generation of practical insights that can influence teaching practices and teacher education. Furthermore, it fosters the creation of innovative curricula and teaching strategies for future computer science and information technology courses. The anticipated outcomes not only promise to enhance teaching practices and teacher training but also contribute to the foundational principles of educational research within the computer science community. This initiative seeks to bolster the research profile and rigor associated with computer science education, facilitating the evolution of this emerging field into a well-established discipline, complete with the necessary research culture, resources, and interdisciplinary knowledge to support high-standard scholarship.

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