To build or not to build: Quantifying the value of strategic implementation projects that do not reflect professional development practices

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ABSTRACT

To deal with a shortage of computer scientists, industry is challenging the traditional view that students need a deep theoretical knowledge of computer systems. Some believe that time spent on assignments that do not reflect technical/development practices would be better used building practical skills. This is at odds with the pedagogical strategy of building mental models through students’ implementation of tools and libraries that would otherwise be used as off-the-shelf components. Although project-based learning is a well-studied area, there is little to no literature that studies the link between these programming activities and the target cognitive processes. Researchers must understand the advantages and disadvantages of these types of projects in building the correct mental models and any transfer learning it enables.

In this Birds of a Feather, we seek to create a working group of academics and professionals that are interested in an evidence-based understanding rather than reliance upon anecdotes. This group will look at the strategic implementation projects and how well they achieve their linked learning outcomes. This working group will discuss how to empirically define the value of these activities and gain a better understanding of how they affect a student’s cognitive processes.

CCS CONCEPTS

• Social and professional topics → Computer science education.

KEYWORDS

computer science education, constructivism, professional practice, project-based learning

1 SIGNIFICANCE AND RELEVANCE OF THE TOPIC

There is a push from industry to move undergraduate computer science towards a competency-based curriculum where students show mastery of professional/technical skills[2]. Since professionals never reinvent the “technology” wheel, competencies would focus on the usage, not building, of optimized and pretested libraries and tools that provide most of the building blocks that comprise a software system.

Academia is concerned that such training does not create transferable knowledge. It is thought that a focus on the theory better enables students to quickly understand a wider range of tools and languages throughout their careers. Subsequently, an understanding of computer functioning, from the architecture level to the mechanisms commonly used for resource management, data storage, and user interfaces, seems to be required for the appropriate and efficient use of libraries and tools.

Mental models are the understanding and knowledge of how a system functions, and can be constructed through experiencing things and reflecting on those experiences[1]. Coursework is often augmented with implementation projects aimed at coding components and programs that are already available in existing libraries and tools. The intended role of these projects is to build an accurate mental model of the functioning of the related computer component. Operating systems (process management, memory management, and schedulers), data structures (hash tables and red-black trees), programming languages (compilers), networking (protocol stacks), and graphics (ray tracers) are examples of classes with such projects.

The reality is that most students will be required to use libraries and will not be allowed to create custom implementations. Is the time spent on implementation projects well spent? Are these implementation assignments important in achieving learning outcomes and building transferable mental models? Although there is some
work on mental models in introductory programming and SQL\cite{5,6}, there is an opportunity to collect and evaluate empirical data regarding the efficacy and trade-offs around such practices.

This Birds of a Feather will bring together a community that has a vested interest in quantifying the value of the strategic implementation projects. A short-term outcome of this session would be to identify academics that would like to contribute their strategic implementation project practices to an article for the 2023 Computer Science Curricula Companion Volume of Curricular Practices.

Long-term, it is important to quantify the usefulness of such assignments and to explore the trade-off between time spent on purely pedagogical practices and time spent on building technical skills such as debugging and problem-solving. Participants will participate in a discussion around the formulation of research questions and data collection.

## 2 EXPECTED AUDIENCE

We expect to attract: 1) Members of the ACM/IEEE-CS/AAAI Committee on mental models in introductory programming and SQL\cite{5,6}, 2) Academics that teach upper division computer science courses, 3) Researchers that focus on project-based learning and mental models computer science, and 4) Professionals/hiring managers that evaluate the skills of new graduates

## 3 DISCUSSION LEADER(S)

Additional discussion leaders: Sherif G. Aly, American University; Brett Becker, University College Dublin; Marisa Exter, Purdue University; Michael Goldweber, Xavier University; Michael Oudshoorn, High Point University; Marcelo Pias, Federal University of Rio Grande (FURG); Christian Servin, El Paso Community College; Titus Winters, Google Inc; Qiao Xiang, Xiamen University

## 4 EXPERTISE OF DISCUSSION LEADER(S)

Not all the expertise for discussion leaders is presented due to space. Monica Anderson (Assoc Professor, The University of Alabama) Her previous research in computer science education studied self-efficacy improvements using robotics and the implications of teaching introductory programming using command line tools.

Marisa Exter, PhD, is an associate professor of Learning Design and Technology in Purdue University’s department of Curriculum and Instruction, and has a BS and MS in computer science and a PhD in instructional systems technology/instructional design and employment history in software design and development. Her research interests include computing education, design education, competency-based education, and transdisciplinary education.

Mikey Goldweber (Professor and Chair, Computer Science, Xavier University, Cincinnati, OH) In addition to teaching both OS and Databases for over 30 years, He is coauthor of the uMPS system emulator along with the Kaya and PANDOS semester-long, undergraduate, operating systems projects.

Michael Oudshoorn (Dean of Engineering, High Point University, North Carolina) He has taught computer science courses, focusing on programming languages and their implementation for over 35 years and has a strong interest in teaching pedagogy.

Marcelo Pias (Assistant Professor, FURG Brazil) His research interests comprise systems design and validation, including wireless sensors and embedded AI systems. He is also interested in understanding the long-term impact on students who learn principles and concepts from simplified implementations yet fully functional operating systems (e.g. Unix V6, x6 system implementation).

Titus Winters (Principal Engineer, Google) with broad influence over design and best practices for C++, as well as educational concerns for tens of thousands of Googlers.

Qiao Xiang (Xiamen University) teaching covers the design principles, algorithmic foundations and system building blocks of large-scale systems, spanning from cyber-physical systems to wide-area networks and data center networks.

## 5 PROPOSED ACTIVITY DURING BOF

To engage the largest community, we propose a hybrid format. We will start with an introduction to a common vocabulary on learning theories (e.g. behaviorism, cognitivism, constructivism)[4], pedagogical models, and educational research methods[3].

The collaborative tool Mural will be used to facilitate the meeting and engage both local and virtual attendees. The first activity will be a data collection session where participants contribute to a list of strategic implementation projects that they assign or have completed (with an author if known). These projects will be collected on the Mural. The attendees will divide into break-out groups to choose the most important strategic implementation projects, why they are important; and the associated learning outcomes. They will discuss empirical data collection that can evaluate the strategic implementation projects for the desired outcome. We would use zoom breakouts for virtual participants. Each group will report on the top projects/motivations/learning outcomes and suggested empirical activities. Ideas and notes will be collected via Mural for projection to the group during report out and will be the notes for the session. At the end of the session, leaders will synthesize the next steps and will create a mailing list of interested attendees.

## REFERENCES


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