Supporting Elementary School Computer Science Learning with Interactive Spoken Dialogue Agents

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ABSTRACT

To meet the demand for young students learning computer science, computer science curricula for students in elementary school (ages 5-10) are emerging. With those curricula comes the question, *how do we gauge young students' computer science knowledge and practices?* This question presents many challenges, in part because no validated assessments exist for computer science in elementary school; written assessments are often not appropriate for this age group; and one-on-one assessment with teachers, a common practice for very young learners, presents challenges with respect to scalability and teacher preparation. To address these challenges, I propose to build an animated spoken dialogue agent that uses embedded assessment techniques to gather information on students' knowledge and practices. The data collected through this agent will help us understand how young children learn computer science, lead us to refine computer science curricula for young learners, and inform the development of adaptive individualized support for these students.

Categories and Subject Descriptors

K.3.2 [**Computers and Education**]: Computers and Information Science Education—*Computer Science Education*.

General Terms

Human Factors

Keywords

K-12, spoken dialogue agent, assessment

1. RESEARCH SITUATION

I am a second year Ph.D. student in Computer Science at North Carolina State University. I plan to complete my written preliminary examination by the end of this upcoming school year, propose my dissertation by the end of my third year, and graduate in May of 2018.

2. CONTEXT AND MOTIVATION

In recent years, the need to educate younger students in computer science has grown. With researchers eagerly working to educate elementary students in computer science [4, 5], we are now faced with a new question: *how do we gauge young students' computer science knowledge and practices?* With challenges related to students' reading and writing skills, limited teacher preparation and time, and the absence of standardized assessments for computer science, gauging students' understanding of computer science calls for a different approach. I propose to build a spoken dialogue agent whose persona is the same age and gender as a student, and interacts with the student using techniques shown to be effective for supporting learning and for gauging understanding. This agent will use embedded assessment techniques to gauge students' understanding of computer science concepts and practices.

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3. BACKGROUND & RELATED WORK

There are two highly relevant areas of related work. First, this section presents projects that have focused on assessing students' computer science knowledge at the elementary level. Second, I discuss two projects that have used interactive spoken dialogue agents with elementary school students in domains other than computing.

The Progression of Early Computational Thinking (PECT) model [9] is a framework created to assess and understand how elementary students think computationally. The framework, which is currently undergoing piloting and testing, assesses students' Scratch programs by taking into account the design patterns used and their level of sophistication.

Originally developed for older learners, the SOLO taxonomy is used to classify students' understanding of a given task [2]. It has been used to classify the programs of 4^{th} grade students, finding that students who did not perform well in school often created programs that showed a lesser understanding of computing and the problem structure of the tasks, while more high-performing students were able to complete the tasks presented to them [8].

Relatively little work with interactive dialogue agents has focused on elementary school students. Two systems, Marni [3] and the Reading Tutor [7], focused on reading skill, and Marni was later adapted to tutor science [10]. How to develop agents for computer science, and to leverage embedded assessment, remain open questions.

4. STATEMENT OF THESIS/PROBLEM

The proposed dissertation research addresses the problem of supporting and assessing elementary computer science learning. The proposed project will fall within the intersection of elementary computer science curriculum and assessment and interactive dialogue agents. I will build a spoken

dialogue agent that uses embedded assessment techniques to gauge young computer science students' understanding and support their learning.

5. RESEARCH GOALS & METHODS

The project's novel contributions will include embedded assessments about the problem solving process, not only on completed programs. Second, it will generate design principles for spoken dialogue agents that support computer science students in elementary school. Besides measuring students' knowledge and practices, the agent will be designed to gauge self-efficacy and attitude towards computer science throughout the course. The agent will be designed to appear similar in age to the students and converse with them as a peer.

My research question is: *how can elementary students' computer science learning, self-efficacy, and attitudes towards computer science be gauged using spoken dialogue and embedded assessments?* My project will proceed in a design-based fashion. Prototype versions of the dialogue agent will be used to support classroom studies. Data will be collected from these studies, including recordings of children's speech, the automatic speech recognizer's interpretation of the speech, and the system's response to the interpretations. The system will use embedded assessment techniques to prompt students to answer in a meaningful way. Identifying effective embedded assessment techniques will be one focus of the research. I will use the data I collected to evaluate the students' questions and responses as they engage in dialogue with the system.

6. DISSERTATION STATUS

I have just completed my first year as a Ph.D. student. I have worked closely with a partner elementary school to collaboratively design and refine two 4^{th} and 5^{th} grade computer science curricula on computational thinking, robotics, AI, computers in society, and programming. The design of the curricula drew upon CS Principles [1], Exploring CS [6], and the CSTA K-8 guidelines [4].

The 5^{th} grade class has been conducted four times. During each iteration of the class I collected videos of class participation, screen recordings of student programming, and artifacts such as conditional trees and storyboards. I also interviewed students at the beginning and end of the course regarding motivation for taking the class, previous experience, current attitude toward computer science, and attitude towards the class.

In the process of analyzing the data, I faced the challenge that has motivated my proposed dissertation: how to properly gauge students' knowledge, practices, attitudes, and self-efficacy. Additionally, while I believe that interviews are the most promising way to get some of the needed information, some students do not engage readily with a researcher during interviews, and I hypothesize that an animated dialogue agent will address this problem.

This summer, I will begin developing my app using Unity, as it can port to iOS, Android, and Windows devices. In the fall, I will pilot the app and make refinements based on the results. The piloting of the app will be built into the computer science course I designed as a weekly activity for the students to complete. The iterative piloting and refinement cycle will continue for the next year, after which the app will be deployed to collect data that will be analyzed to continue addressing my research questions.

I hope that participating in the doctoral consortium will help me to refine and focus my research question and hypotheses. I also hope to gain insight into the design of my app and studies, as well as gain knowledge that will help me when analyzing my data and validating the results.

7. EXPECTED CONTRIBUTIONS

The findings of my research hold the potential to improve the way young children learn computer science. The data gathered from the app will be used to improve and design elementary computer science courses and to inform future elementary computer science course designers. Finally, the app can become a tool for elementary computer science teachers to use to gauge their students' knowledge and practices, leaving more time for them to teach and guide students in learning the content. With this, I hope to bring computer science courses to more elementary schools and broaden interest and participation in computer science.

ACKNOWLEDGEMENTS This work is supported in part by the Wake County Public School System.

8. REFERENCES

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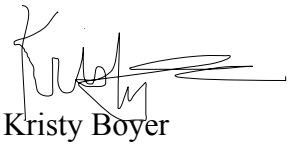
Dear Doctoral Consortium Organizers:

It is my pleasure to nominate Jennifer Tsan for participation in the ICER doctoral consortium. Jen is just finishing up her first year as a Ph.D. student. She has been my research assistant on a project to develop and refine a computer science curriculum for elementary school, a project funded by my local school district.

Jen has done excellent work in her first year, building a close collaboration with an elementary school teacher at our partner school, and interfacing with the principal and district administration as well. She is just beginning to clarify the focus of her dissertation research, and the doctoral consortium experience will be extremely valuable for her at this early stage in her studies.

Thank you for considering Jen for your doctoral consortium.

Sincerely,



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RESEARCH INTERESTS

Computer Science Education, Advanced Learning Technologies, Spoken Dialogue Systems.

EDUCATION

North Carolina State University, Raleigh, NC (2014 – Present)
Ph.D., Computer Science, Anticipated May 2018

West Chester University, West Chester, PA (2010 – 2014)
B.S. Computer Science
Computer Security Certificate
Summa Cum Laude

COURSEWORK

Database Management Systems	Spring 2015
Special Topic CSC – Spoken Dialogue Systems	Fall 2014
Principles of Computer Graphics	Fall 2014
Special Topics Education Research – Learning Sciences: Theories, Concepts, and Environments	Fall 2014

EXPERIENCE

Graduate Research Assistant (May 2014 – Present)
North Carolina State University
Currently working on a project to collaboratively design, implement, and improve elementary computer science curricula. Duties involve meeting with the team to plan and author the curricula, designing the research studies to measure effectiveness, observing the class and collecting data, and organizing, cleaning, and analyzing the data.

Computer Science Tutor (January 2013 – May 2014)
Learning Assistance and Research Center, West Chester University
Tutored undergraduates in CSC 110 (Introduction to Computer Programming), CSC 141 (Computer Science I), and CSC 142 (Computer Science II).

Robotics Mentor (October 2013 – April 2014)
American Helicopter Museum and Education Center
Planned and taught lessons on robotics and programming using the Vex Tumbler, Scribbler S2, Finch, and Scratch.

Undergraduate Research Assistant (June 2013 – August 2013)

University of Maryland
Performed a broad literature review on existing topologies in various fields outside of computer science. Worked with a team to design states for a state machine to analyze keystroke data gathered from honeypots. Categorized Linux commands to fit under the designed states and created analogies for the states to increase people's understanding of the significance of the work.

Undergraduate Research Assistant (May 2012 – July 2013)
Temple University
Conducted a literature review on Vehicular Ad-Hoc Networks (VANETs), attended symposia on various computer science topics, presented a poster at a poster session, and wrote a paper on VANETs.

PUBLICATIONS

Supporting K-5 Learners with Dialogue Systems. J. Tsan, and K.E. Boyer. To appear in: *Proceedings of the International Conference on Artificial Intelligence in Education - Doctoral Consortium*, Madrid, Spain, 2015.

PROFESSIONAL HONORS

2015 National Science Foundation (NSF) Graduate Research Fellowship Program Honorable Mention