Physical Computing as an Inquiry Working Technique

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ABSTRACT

Physical computing is receiving much attention in the shape of numerous variations of devices. This trend is apparent in computer science education from kindergarten to university. To improve the implementation of physical computing in secondary school I observe student's process of problem solving when they use physical computing devices. To successfully implement this in schools, it appears to be valuable to investigate problems that occur during the the process and to develop supporting material. These topics are the foci of my doctoral project and will be figured out with results from scientific inquiry. Particularly building on the experiment as an inquiry working technique.

CCS CONCEPTS

• **Social and professional topics → K-12 education**; • **Computer systems organization → Robotics**; *Robotic components*;

KEYWORDS

Computer Science Education; Physical Computing; Inquiry Learning

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1 PROGRAM CONTEXT

In January 2017 I started my 3rd year as a doctoral student at Humboldt-Universität zu Berlin in Germany. My advisor is Prof. Dr. Niels Pinkwart as the head of the "computer science education/computer science and society" chair. I am funded by a grant from Humboldt-ProMINT-Kolleg, an integrated STEM research group. It is also a structured doctoral program I am participating in and evaluating. Enabled by this colleague I went abroad for 3 months, starting in winter 2016 to conduct research at Carnegie Mellon University in Pittsburgh.
In the last two years I conducted an intensive literature review in computer science and natural science on concerning to this research area. Building on this, I explored the physical computing process through qualitative studies, and am analyzing data. Afterwards a design for the final studies needs to be developed in fall this year.

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2 CONTEXT AND MOTIVATION

The research on problem solving in natural sciences is well established and there are some supporting mechanisms which seems to be similar to problem solving in computer science. The experiment as an inquiry working technique is additionally very similar to the physical computing (PhC) process.
My motivation is twofold: 1) if it is possible to find evidence for the similarity of the scientific inquiry (SI) process and the PhC process, results from science can be adapted for computer science education (CS Ed). So we do not need to start from scratch in PhC research. 2) the research questions tackle hurdles for a successful implementation of PhC in school, and potentially in STEM subjects. This approach is aiming to enhance PhC research building on existing results.

3 BACKGROUND & RELATED WORK

In the literature, PhC is defined as "creating a conversation between the physical world and the virtual world of the computer" [4][p. xix]. The authors describe an interactive system consisting of sensors, actuators and a mircocontroller or mini computer, controlling received data and resulting aimed feedback. This is the case for example for Arduino mircocontrollers or robots.
From the science perspective, Klahr and Dunbar observed the scientific reasoning process (SDDS model), a base for following inquiry models [3]. The SDDS model contains to search in a hypothesis space and an experimental space. This means to first construct a hypothesis, test the hypothesis and draw conclusions based on data. The process is divided into phases and subphases, where the occurring order or integrity can vary. SI encompasses working techniques like experimentation and is known to be an important competence in science and needs to be improved [2].
The general idea of combining scientific inquiry (SI) and physical computing is not completely new, but not fully analyzed either. Blikstein [1] suggested a combination of the simulated and real world through PhC devices in an experimental setting. Therefore a robot programmed with LOGO like language was used for the intervention. He stated that with this approach models can be validated which leads to to a deeper understanding of scientific phenomena. Afterwards, Sullivan [7] pointed out that the necessary skills during robotics activities and scientific inquiry are similar. We can conclude that there is enormous potential in combining of both domains.

4 STATEMENT OF THESIS/PROBLEM

The results from literature lead us to the approach to investigate the deeper structure of PhC to compare the processes of PhC and SI. If both processes share substantial phases we probably can adapt findings from scientific inquiry research. This could be problems students have during the activity and also scaffolds for the process. PhC could be an interdisciplinary working technique to improve computer science and science skills.

5 RESEARCH GOALS & METHODS

To reach the goal to compare a science and a PhC process, the first hurdle was to construct a PhC process model, based on the limited literature.

An empirical analysis in a learning scenario was conducted to support and adapt the theoretical PhC process model (RQ1). According to results from SI, students have some problems to complete the SI process successfully. We will search for some of the common problems from SI in the PhC. The focus has been on the transition of performing a program to the evaluation of outcomes. In respect to the qualitative data, a preliminary categorization of occurring problems is figured out (RQ2, paper in preparation). The information about problems and investigating connected problem sources leads to RQ3. Building on this, an approach to support students during PhC activities will be developed.

One approach could be to open the "black box" of the PhC device and address the concrete problem sources, based on the components hardware, software and environment.

The research questions are:

- **RQ1** Do the similarities of the physical computing and scientific inquiry processes even support the theory that physical computing is a working technique in scientific inquiry? What are the similarities and differences?
- **RQ2** Which problems do students have to tackle and how can the problem sources be categorized?
- **RQ3** How effective is it to open the black box of a physical computing device in the evaluation phase to externalize the problem sources for students?

The 1st and 2nd research questions are (almost) tackled through qualitative studies. I recorded data from students working with LEGO Mindstorms robots and Arduinos. The students were video recorded while solving some tasks with the devices. The videos were transcribed and analyzed with a qualitative content analysis. A task with an Arduino could be to give different outputs regarding to the intensity of light in the environment. Using this data, I observed the process the students went through in solving PhC tasks. In the same data set student's problems became visible. Thereby I am already categorizing occurring problems and figure out appropriate hints for students how to tackle the problems.

Building on these hints I am considering to test them in a classroom setting. One methodological problem here is a lack in test instruments.

6 DISSERTATION STATUS

In 2015 I started with an exploratory study and reached preliminary results supporting the hypothesis that PhC tasks can be suitable to improve science learning as well as computer science competences [5]. I already tackled the first research question and published the results at a peer-reviewed conference [6]. An essential result is that the PhC process can be divided in the phases preparation, implementation, performance and evaluation, similar to SI. Both processes share an essential structure. As result of the conducted studies, there are results for the second research question and initial hints how to support the occurring problems students have. This time I am evaluating this data to give an answer regarding to RQ2. I plan to conduct further studies concerning RQ3. These will be designed in fall of 2017. After possible follow-up studies and the evaluation of gathered data, I plan to finish my doctoral studies in the mid of 2018.

I hope to get feedback from the ICER community regarding to the planned methods tackling the third research question. The most important issue is to find adequate indicators within qualitative video data to assess student learning. The participation in the conference would be important for me to receive some last hints before conducting final studies and finishing my dissertation. Additionally, I aspire to connect myself with the worldwide computer science education community.

7 EXPECTED CONTRIBUTIONS

By tackling my research questions I will provide a strong theoretical and empirical base for PhC through the connection of computer science and scientific inquiry. This creates a new facet of PhC research, that focuses on the concrete process and occurring problems during PhC tasks. This can effect the construction of new PhC devices and tasks, enabling an experimental approach in computer science in general.

Furthermore my research is directly influencing computer science education in school. An overview concerning occurring problems and suitable scaffolds will be constructed in my dissertation.

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