Improving Scientific Inquiry through Physical Computing

Sandra Schulz
Humboldt-Universität zu Berlin
Department of Computer Science
Unter den Linden 6, 10099 Berlin, Germany
saschulz@informatik.hu-berlin.de

ABSTRACT

Physical Computing is used to improve computer science competences in school. For this purpose numerous devices and tools for earning knowledge exist, but only with few didactic concepts. Theoretically, there are a lot of overlaps between physical computing and scientific inquiry. The aim of my research is to learn from other sciences to improve physical computing in computer science education. It appears that computer science skills and especially scientific inquiry skills can be improved in this context. Thus we learn more about student's problems in computer science and can find supporting mechanisms.

CCS Concepts

•Social and professional topics → K-12 education; •Computer systems organization → Embedded and cyber-physical systems; *Robotics;*

Keywords

Physical Computing, Scientific Inquiry, Computer Science Education, STEM Education

1. PROGRAM CONTEXT

I am a doctoral candidate advised by Prof. Dr. Niels Pinkwart. Since spring 2015 I conduct research and participate in a structured doctoral program at Humboldt-Universität zu Berlin. This program is called "ProMINTion", which is aimed at STEM education (MINT is the German equivalent for the English STEM). Integrating computer science in STEM teaching subjects is innovative for empirical learning and teaching research in Germany.

Until now I did literature research and pilot studies related to my research questions. I will conduct a further pilot study in summer 2016 to start the main studies in spring 2017 and finish my dissertation in the same year. A more detailed summary of my research is included in section 6.

ICER '16 September 08-12, 2016, Melbourne, VIC, Australia

ACM ISBN 978-1-4503-4449-4/16/09.

DOI: http://dx.doi.org/10.1145/2960310.2960352

2. CONTEXT AND MOTIVATION

Scientific inquiry (SI) is a subset of the general problem solving theory. An often used description to explain what computer scientists are actually doing is problem solving. It is obvious that SI skills and ways to gain them are necessary in computer science education, but only little research has been done in this field. To use physical computing (PhC) in schools concrete didactic concepts need to be researched. PhC is increasingly used to improve computer science skills in different topics like programming or algorithmic thinking. It appears also to be suitable for STEM education. The positive influence of PhC on motivation and skills sets the goal for a wider use with a theoretical grounded concept.

3. BACKGROUND & RELATED WORK

SI is well-researched and developing inquiry skills is demanded by numerous organizations and researchers as a key competence [4] independent of domains. The process is divided in the phases: (observation,) hypothesis, inference, test, and feedback. Several passes of this cycle and potentially even in a different order are common [1]. Results also exist which concern student's problems [6] (e.g. drawing conclusions based on experimental data). Some guidelines for supporting these deficits are provided as well. Physical computing is defined by O'Sullivan and Igoe as "[it] is about creating a conversation between the physical world and the virtual world of the computer" [3][p. xix]. It is realized using sensors, actuators, and processing with microcontroller. Concrete devices are robots, Arduinos etc. The use of PhC is increasing in schools and other learning environments. The most popular goal is to improve computer science competences. Okita observed the process of evaluating outcomes in robotic activities and did find difficulties too [2] – in this case for PhC. She linked to problem solving and states that robotics provide a special (recursive) feedback. Problems during hands-on activities in computer science need to be observed in detail, and the development of supporting techniques to compare real-world outcomes and the virtual program is desirable. The educational view on PhC is quite new in computer science education and could improve PhC and the connection to STEM. It appears to be an overlap between the structure and the process of SI and PhC, but it is not investigated.

4. STATEMENT OF THESIS/PROBLEM

PhC has the potential to improve competences in computer science and natural sciences as well. SI holds a strong

theoretical base and practical experience, which could be adapted for computer science education to provide a theoretical based concept. It is a core hypothesis of my research, that computer science students can improve their inquiry skills using PhC.
To investigate this problem, several problems need to be addressed. These include measurement instruments, a theoretical PhC model to develop an educational PhC model, and to find similarities to scientific inquiry literature. It is necessary to figure out specific hurdles computer science students have during PhC activities. If these are also similar to scientific inquiry, supporting mechanisms can be adapted for computer science education.

5. RESEARCH GOALS & METHODS

The first research question includes a theoretical comparison of scientific inquiry with the PhC process. Therefore a model for the PhC process is necessary. This theoretical base is then used to find critical parts of the process, which need to be supported, and to anticipate further problems for computer science and STEM education. The second research question focuses on different levels of problems provided by PhC. It encompasses a devision of the predefined levels: hardware, software, and environment. If we know more about concrete problems and errors, we can support the transition between performance and – that is where the greatest challenge lies – evaluation. Identifying is just as important as handling them. We need concrete ways to overcome these problems. My research questions are:

- Q 1 What are the challenges and what is the benefit of using physical computing as a scientific inquiry working technique? Do the similarities of the processes even support the theory that PhC is a working technique in scientific inquiry?
- Q 2 Which problem sources and errors can occur in the PhC process? What is appropriate for debugging or troubleshooting?
- Q 3 What type of support do students need to improve inquiry skills and in more specific which methodological supports for typical problems in the evaluation phase, e.g. matching input and outcomes?

Methodologically I expand my literature review in order to find evidence for Q 1. After finishing that, I will continue recording videos of students during computer science tasks in PhC without inquiry instructions, to observe the "natural" PhC process. Therefore and to tackle Q 2 the students are requested to work in pairs of two to discuss their problems and to find a solution together. Analyzing their discussions I will get deeper insights of the cognitive processes and problem solving strategies of the students. In a qualitative analysis I code concrete problems and group these by their characteristics and by their occurrence. For Q 3 a support shall be created and integrated into this experimental setting. Because of previous results a methodological aid for the evaluation phase appears to be most required. This could either be a simple structuring of the working process to an inquiry process or a worksheet. This worksheet should be an instrument, which supports the evaluation of the observed outcomes and handling problems. To compare the influence of scientific inquiry components on inquiry skills, a closing interview will be conducted in addition to the qualitative analysis of the videos.

6. DISSERTATION STATUS

Within the last year I conducted two pilot-studies regarding to different research questions. The first of which was exploratory in nature: to figure out the effort for science learning during physical computing (PhC) activities [5]. We did find initial evidence PhC devices can improve STEM competences. I analyzed the PhC process described in the literature to conduct a theoretical comparison of SI and PhC process. In pilot-studies in spring 2016 I investigated if PhC is suitable for inquiry learning. Therefore I included scientific inquiry (SI) components to improve inquiry skills (paper status: submitted). Students at the age of 14 to 17 got the task to solve a specific problem in PhC activities. During summer 2016 I plan to conduct further pilot-studies related to Q 3. For this I will design an instrument which supports students inquiry during PhC activities. The instrument will be tested in a qualitative study. My dissertation contains the theoretical base and first results for Q 1 and first indications for Q 2, which need to be confirmed in further studies. In spring 2017 I will conduct main studies and complete the dissertation until the end of the year. In the doctoral consortium I would like to discus preliminary results, get a feedback to my methodology and the supporting instrument.

7. EXPECTED CONTRIBUTIONS

Exploring these problems provides a strong base for PhC and gaining competences in computer science. I will establish a SI method, which is suitable for computer science education, and test the effectiveness in research studies. A side product will be the design of SI material for computer science lessons. This is directly connected to inquiry learning in PhC and improves SI skills. I will build a base for an interdisciplinary STEM education with PhC.

8. REFERENCES

[1] R. W. Bybee. Scientific inquiry, student learning, and the science curriculum. *Learning science and the science of learning*, pages 25–35, 2002.

[2] S. Y. Okita. The relative merits of transparency: Investigating situations that support the use of robotics in developing student learning adaptability across virtual and physical computing platforms. *British Journal of Educational Technology*, 45(5):844–862, 2014.

[3] D. O'Sullivan and T. Igoe. *Physical computing: sensing and controlling the physical world with computers.* Course Technology Press, 2004.

[4] J. W. Pellegrino, M. R. Wilson, J. A. Koenig, A. S. Beatty, et al. *Developing assessments for the next generation science standards.* National Academies Press, 2014.

[5] S. Schulz and N. Pinkwart. Physical computing in stem education. In *Proceedings of the Workshop in Primary and Secondary Computing Education*, WiPSCE '15, pages 134–135, New York, NY, USA, 2015. ACM.

[6] C. Zimmerman. The development of scientific thinking skills in elementary and middle school. *Developmental Review*, 27(2):172–223, 2007.