Tinkering in Scientific Education

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Abstract. In recent years in arts, technology and science there appears an increasing push to use technology and design in a more personal and autonomous context, integrated with the physical world. Creative platforms are developed that open up personal digital/physical technology to larger groups of novice tinkerers, allowing people to take control of technology and prototype solutions to personal problems and aims. Likewise, education benefits by providing students with tools and platforms to learn by doing and making. However, these advances lead to new challenges for scientific research and education, such as how to align the open-endedness of tinkering with more fixed education and research agendas. This is the first scientific workshop to identify and discuss such issues, and provide a platform for future collaboration and dissemination of results.

1 Scale of the Individual

Many of today's technology heroes and aficionados started their careers by what can be considered as *tinkering*. Bill Gates and Steve Jobs are well-known examples, surrounded by anecdotes of working in garages with small, enthusiastic teams, supposedly working under playful conditions. For many they exemplify what tinkering and grass-roots initiatives could lead to. But also the Wii Remote tinkering projects by Johnny Chung Lee (www.johnnylee.net), shown on Youtube.com, have captured and sparked the imagination of many.

At the level of today's technology consumer, there appears to be an increasing desire to interface our technological power-machines to the real physical world. And power-machines they are, our personal computers, tablets and smart phones – equipped with highly advanced man-machine interaction technologies, communication possibilities, location-determining hardware, acceleration sensors, and more. However, for all their strengths and possibilities, they do not offer the connectivity to the physical world around us that many dream of. No smart phone is currently on offer that drives itself around the house to play with the cat. No tablet is equipped with motors and sensors that make it suitable to steer a child's soap-box cart. No current iPhone models have a user-accessible digital thermometer to play with. And in a way, this is what we more-and-more expect our technology to do (well,

D. Reidsma, H. Katayose, and A. Nijholt (Eds.): ACE 2013, LNCS 8253, pp. 568–571, 2013.

perhaps not exactly this, but similar things) – to connect our computational devices to the physical world.

This desire to connect may have been always present, but there appears to be more of a push towards closing the gaps between human and technology, by leveraging technology in a more personal, private and autonomous manner, under control of the user.

As a result, tinkering with digital/physical computing systems has gained much attention over the last few years. For example the Wiring (www.wiring.org.co) and Arduino (www.arduino.cc) projects offer immensely popular tools for lower- to intermediate-level software and hardware tinkerers (e.g. [1],[2]), spawning thousands of interesting home-grown projects. Similar projects are Raspberry Pi (www.raspberrypi.org), MaKey MaKey (www.makeymakey.com) and, more in the creative coding domains, Processing (www.processing.org) and OpenFrameworks (www.openframeworks.cc).

These initiatives gave rise to low-cost rapid prototyping tools that offer rich, if not full functionality, while hiding complex underlying structures from the developer. The frequent open-source nature of the projects kindles what is in essence a community-like support structure, and the ongoing generation of example code and libraries. All this makes it possible for single medium-skilled developers to master complex (physical) digital prototyping tools.

> **Observation 1.** In recent years, (physical) digital prototyping was fitted to the scale of the individual. After years of increasing technological complexity in the systems around us, the right combination of technological abstraction and openness has re-enabled individuals to understand, own and prototype solutions to their own problems and aims.

2 Scientific Education

The adoption of digital/physical tinkering by individuals has had its effect on science and education. Scientists increasingly use publicly available low-cost digital prototyping systems to create measurement tools and other experimental devices (e.g. [3]). To witness, a Google Scholar (scholar.google.com) query for articles containing the word “Arduino” in their title, excluding legal document, patents and citations, yielded a result of 490 scholarly articles[1].

Naturally, developments in science and technology resonate in science education (e.g. [4],[5]) and scientific education (e.g. [6],[7]), although not all experiences are always positive. Tinkering is found in curricula worldwide, and students realized a plethora of projects that are disseminated via the web.

An example of successful tinkering by academic students that stands out in our opinion, is the Amplino project (www.amplino.org), in which students developed a low-cost Arduino-based polymerase chain reaction (*PCR*) diagnostic tool for malaria.

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1 Query result on September 2, 2013.

Naturally, not all student projects are as successful as the Amplino project. However, they nonetheless have educational value.

> **Observation 2.** Tinkering projects in education typically strive to teach various technical objectives such as programming skills, understanding of digital hardware, and rapid prototyping skills. Moreover, scientific education may benefit from the tinkering approach also by inducing playful interaction with scientific knowledge, exploration of a problem domain, and solution ownership by students.

Particular attention should be given to the role of educational tinkering within a research-oriented environment. Scientific research is a knowledge-driven activity, geared towards answering questions and generating new knowledge. Although exploration is an important force in science [8], typically scientific research is brought about through rigorous and methodical work, in which the exploratory and playful nature of tinkering has only limited place. The emphasis in science is typically on testing the validity of theories, hypotheses, methods, tools and other scientific end products, as opposed to providing the creative process and tools to discover and generate these. Furthermore, research agenda's may be based on timed delivery of knowledge products, something that does not evidently match the open-ended nature of tinkering. Finally, in research-based education, one may be uncertain how to evaluate the end results of tinkering – should evaluation be based on knowledge discovery, on work methodology, or on aspects of exploration?

> **Observation 3.** Aspects of tinkering in research-oriented education require special attention. Existing insights must be collected and further insight may be developed.

3 Current State and Future

It is the position of the authors that tinkering as a mode of knowledge production has great value, as acknowledged by the theme of the 10th International Conference on Advances in Computer Entertainment Technology (ACE 2013). Moreover we propose that this value extends into the realm of scientific education. As argued above, particular attention is required for implementing tinkering within research-oriented education. We are not aware of any initiatives to collectively deal with this topic.

> **Observation 4.** There exists an unfulfilled need to collect and share experiences, views, and thoughts about the future of tinkering in scientific education.

4 Workshop Objectives, Format and Output

The workshop "Tinkering in Scientific Education" aims at bringing together those who adopted tinkering as part of their scientific education, and those who wish to learn more about it. Participants share experiences, develop strategies and tackle problems, with the explicit goal of consolidating what is known and what is desired, and building a network for future collaboration.

Participants are encouraged to bring their own experiences and questions into the discussions. To this end, applicants are invited to fill in a short questionnaire prior to the workshop. After a plenary introduction and review of issues/questions posed by participants, separate issues are dealt with by sub-groups within short consecutive sessions. In a final plenary session, the results are aggregated and possible plans for future collaboration among participants can be discussed. If possible, the organizers will aggregate all material into (a) separate paper(s) to be published, consolidating the workshop results.

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