Enhancing Students' Critical Reflection on Smart Things Design Through an End-User Development Toolkit

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Abstract

We live in an increasingly connected society, and technology plays a vital part in it. The impact of its social transformation can be seen across many facets of everyday life, including how people relate to others and the environment, as well as how people perceive themselves, their needs and emotions. This assumption led researchers to investigate the need of educating young generations to a reflective attitude toward technology and its impact on society. This paper reports on a study with IoTgo, an end-user development design toolkit that helps young generations to become active protagonists in the design of inclusive smart things, reflecting deeply on the pros and cons of technology in use in their everyday life. Initial results of the study show how design with IoTgo toolkit can lead youth to critically reflect on the design and use of technology in the form of smart things.

Keywords

IoT, Toolkit, End Users, Inclusive Design, Prototyping and Programming

1. Introduction

In recent years, researchers have started investigating the negative effects which the excessive use of technology can have on people's well-being and social relations. Studies suggest that smart devices and social networks can in fact negatively impact attention [1, 2, 3], mental health [4, 5], and even the sense of connection with others or the surrounding environment [6, 7].

In response to such issues, researchers have begun to reconsider the role technology plays in their daily lives. This has resulted in a new focus of research on well-being, often referred to as *digital well-being*, which refers to the idea of *well-being of the human being within an information society* or, more generally, to the *influence that technologies have on the level of mental and social well-being of the individual* [8].

But digital well-being can also encompass increasing user awareness of not only the cons of technology but also of the multiple pros that adequate and responsible technology use can provide, e.g., inclusiveness. This goal is not immediate to be achieved, it needs a new mindset

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to be formed, and that can be done by educating the younger generation. As also argued by De Russis et al., educating people and bringing the notion of digital well-being into schools is necessary [9]. Designing technology with the younger generation, in particular, and reflecting through design with them can help promote such a critical stance [10].

2. Background

The use of appropriate design toolkits for young generations can engage them and foster their critical reflections on technology. Particularly, toolkits for the design of smart things enhanced with Internet of Things (IoT) technologies could encourage deeper reflection as IoT smart things and sensors that collect or exchange data on human behaviors have the potential to have a significant impact on social and individual digital well-being.

Numerous design toolkits employ cards and game boards to help end users ideate IoT-connected smart things [11, 12, 13]. In order to offer more flexibility, many of these toolkits are not tied to specific physical devices for input or output. However, while such a strategy aids in the open-ended generation of ideas, the risk is that end-users may generate ideas that are not feasible for implementation due to a lack of supporting electronic devices or the programming expertise required to create working prototypes [14, 15].

3. IoTgo phygital toolkit

In line with the goal of promoting responsible design education as a key to pursuing digital social well-being, this paper reports on a study conducted with a phygital toolkit, IoTgo, and the IoTgo method for designing with non-expert end-users. The method guides non-experts through the process of ideating, conceptualizing, programming, testing, and reflecting on the design of IoT-connected smart things. The toolkit helps the end users in quickly creating functioning prototypes of their ideas, leaving them more time for individual and group reflections on their design choices.

Being a phygital toolkit, IoTgo has various paper-based, software and hardware tools. The paper-based tools of IoTgo include decks of cards. These cards help users explore what smart things are meant for. For example challenge cards to explore the context with a challenging situation, persona card to see for whom the smart things is meant for, and for which environment (environment card), and what goals it has (missions card). Moreover, the card-based tools guide them to make things smart by means of physical inputs (e.g., tilt sensors) and outputs (e.g., LEDs), represented by input and output cards respectively, and by interconnecting them via peer-to-peer IoT communication.

The hardware and software tools of IoTgo include tools for supporting the programming of smart-thing ideas geared towards a specific design challenge. The generated programs follow specific programming patterns relevant to the physical nature of the smart things and are easy to follow and modify by non-experts.These tools include a physical scanner for IoTgo cards and a companion web app. Together, they automatically generate programs (available in Python, Javascript and Makecode) from the cards placed on the IoTgo boards. If needed, the web-app of IoTgo also enables its users to rapidly select different input and output combinations without

Figure 1: A student programming a Micro:bit using the end-user development toolkit: IoTgo

the physical scanner to generate programs. The generated programs can either be directly downloaded to hardware such as Micro:bits or modified in programming environments like MakeCode before downloading to Micro:bits. See Fig. 1.

4. The Study

The study was held in the computer room of the school and organized along three days in November 2021. Participants were from a class of 24, $17-18$ year-old students in the second last year (overall 12th grade of schooling) at a technical high school near Milan, Italy. The purpose of the study was to engage and make younger generation reflect through design. Teachers and researchers decided that the main design challenge, as specified in the IoTgo challenge card, should be social digital well-being with a focus on inclusiveness. Similarly, the class's school was chosen as the design context, and tasks for the design challenge were assigned to pairs of students at random. Instead, it was up to the students to choose something to make smart. Before starting the activity, students explored how different input and outputs work, and learned about smart things in general.

Data on participants' reflections on smart-thing design were collected as following. Each participant was given a post-questionnaire to measure their understanding of design for social digital well-being. It included the again-and-again survey originating from the Fun Toolkit [16], as well an open-format question that challenged participants to create new missions for creating new smart things. The toolkit itself contained several reflections lenses with questions from various perspectives such as relevance and safety. Thematic analysis was performed on the interview data with teachers in order to triangulate the other data regarding what reflections emerge from design for social digital well-being.

5. Initial Results

Except for two, the missions indicated by students in their questionnaire replies for future smart objects were all connected to social digital well-being. This result shows that the design experience for social digital well-being had an influence on the majority of participants, who chose to continue creating for the same goal even after the experience.

Except for one, all students responded to relevance and safety reflection questions, indicating the ability to critically think about such issues and to go beyond simple yes/no replies or rephrasing questions.

Each group was asked to share their smart things with the entire class, teachers, and researchers, as well as explain the motivations that guided their design, in terms of potential benefits for their persona. Although this activity was not originally planned, students took advantage of the opportunity to discuss the meaning of responsible design for social digital well-being with their classmates and teachers, emphasizing aspects that could have a positive or negative impact on individuals, society, or the environment.

6. Conclusion

This study focuses on the IoTgo phygital toolkit, which organizes design for a purpose for inexperienced designers or programmers, in accordance with the purpose-based approach recently recommended by Cunningham [17]. Tasks include empathizing, ideating and conceptualizing, programming and prototyping, and reflecting. This is accomplished it in a tangible way, using gaming boards, cards, and hardware and software resources.

The initial findings suggest that students were able to critically reflect on design for social digital well-being by following the instructions given in the IoTgo toolkit. They could consider it from various perspectives (relevance, safety), as well as through spontaneously emerging reflection topics (accessibility, universal usability, social engagement, green sustainability). The research presented in this paper may be of interest to a variety of communities. As the toolkit is modular, it is easy to adapt to different context and communities. In the past, the toolkit has been used with children, teens, teacher, and professional artists. In the most recent iteration, the participants were responsible for more than just generating ideas, conceptualizing solutions based on given patterns, and programming them. In fact, the IoTgo design allowed them to socially interact "for the social good", and critically reflect on smart technology for social digital well-being , and to consider how it can impact beyond individuals' own well-being, e.g., [18].

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