Effects of Physical Computing Workshops on Girls' Attitudes towards Computer Science

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ABSTRACT

Making is frequently utilised to promote disciplines such as computer science to new students. We investigated how Maker workshops on physical computing contribute to shaping girls' attitudes and perceptions towards computer science. We evaluated 25 physical computing workshops exclusively for girls aged 9-18 to explore potential changes of attitude towards computer science with pre and post surveys (n=135). Overall, the evaluation results show small effects for one third of items which may indicate that Maker workshops with physical computing material can support a balanced attitude towards diversity in the presence of and scope of computer science among girls.

CCS CONCEPTS

• Social and professional topics~Women

• Applied Computing~Education

KEYWORDS

Physical computing; Making; Computer Science; Girls.

1 Introduction, Background and Context

Making is associated with computer science (CS) and is used to creatively and informally stimulate more interest in STEM, especially technology. As women are underrepresented in CS and as stereotypes continue to persist [2], we conduct and evaluate Maker workshops for girls to make them more familiar with CS as part of a 3-year research project [12] aimed at motivating more girls to pursue a career in CS. In this context, we investigated *"how can physical computing Maker workshops contribute to shape girls' conceptions of and attitudes towards CS?"*

This paper refers to Making as a creative interdisciplinary construction activity with physical computing kits that comprise the design, construction and programming of smart objects with hardware kits, a desktop programming environment and crafting materials which allow creativity and personally meaningful projects.

Sheridan and Halverson define 'Making' as interdisciplinary hands-on activities at the intersection of arts, design, computer science and engineering [11]. According to Wagh et al., young Makers encounter and appropriate a variety of computational thinking practices in Making [13]. Rode et al. identified computational thinking as a core skill to Making [10]. Doing CS requires and involves — but is not limited to — computational thinking. Maker workshops are not only a way to arouse interest in IT, but also to the process of CS from formulating a problem, reviewing resources for solving it and iterative development of a solution (the artefact that is constructed and programmed) to presentation of the created object in a team [5]. Several studies have investigated students' attitudes towards CS, which are often characterised by stereotypes and a poor understanding of CS [7][6]. The image of CS as isolated and hardly connected with personal life remains. This improper image is more prevalent amongst girls and manifests itself between the ages of 13-15 [5].

The main focus of our study was not to evaluate the current attitudes, but rather whether the attitudes change through Maker workshops where CS-related activities such as hardware assembling, problem solving and programming are part of the process. 25 workshops with 221 female participants, conducted by 6 research institutions in three cities in Germany, were evaluated. Due to the different infrastructures of the partners, workshops varied in topic, technology, duration, participant age and type of access. All of the offered workshops comprised physical computing technologies, crafting materials to build smart objects and were guided by 2-3 tutors. Workshop curricula allowed creativity and personally meaningful projects in an informal learning environment with an iterative process of idea generation and design, constructing objects and hardware, programming and presenting results in teams of 2-3 students. Curricula were shared among project partners. Workshops had a duration of 8-28 hours (average 17h) during weekly sessions (9 workshops) or on consecutive days (16 workshops) with different access (17 with open access, 8 by school access). Workshops were offered in four age intervals covering 9-18 years (a mean age of 13 years, standard deviation 1.85). Half of the girls stated they had IT as elective subject in school. The topics comprised 'smart plant' (8

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workshops), 'smart cushion' (3), 'smart backpack' (2), 'light-up-flower' (2), 'smart room/house' (2), 'smart lights' (5), 'smart easter eggs' (1), 'colourful Easter baskets' (1), 'mBot' (1). 19 workshops used Arduino kits [1][8], 5 used Calliope [3] and one used mBot [9]. Six of the workshops also included 3D printing and vinyl or laser cutting in order to decorate or enhance objects.

2 Data Collection, Analysis and Results

Students completed a questionnaire at the beginning and at the end of each course. Participation in the survey was voluntary with written consent from both parents and participants. The questionnaire contained both quantitative and qualitative questions (not standard or validated). Answering questions was optional. We conducted an exploratory evaluation of 22 of these questions within the scope of this analysis. Quantitative questions had interval rating scales with sliders. The values of the sliders were mapped to a scale of 1-100. The questions can be split into two categories: (1) Questions regarding the image of male/female computer scientists (e.g. male/female computer scientists work on computers): agree or disagree using a one-sided slider (does not apply at all/applies fully). (2) Questions regarding the image of CS with two opposite statements with a two-sided slider (e.g. CS is easy/difficult). Both categories of the questions had a mixture of a normal and reversed scale. For the data analysis, we used a paired t-test. We assumed an alpha level of 0.05 to test the null hypothesis for statistical significance (one-tailed t-test). The data evaluated fulfilled the following three conditions: the participants were taking part for the first time, the specific questions were answered in both measures and both questionnaires had been overall completed. This resulted in a final sample size of n=135. The effect size was calculated according to Cohen's d [4].

computer science is ...:	T	p-val	dof	cohen-d
just anywhere/only in very specific fields	4.96	<0.01	126	0.40
similar to mathematics/quite different from math.	-3.72	<0.01	121	0.37
a male subject/a women's subject	-2.10	0.02	64	0.30
practical/theoretical	1.97	0.03	110	0.23
computer scientists are/do ...:	**T**	**p-val**	**dof**	**cohen-d**
programming	-3.70	<0.01	134	0.35
create a lot of new things	-2.16	0.02	133	0.22
must work well together in a team	3.27	<0.01	133	0.29

Table 1: Items with small effect size: question, t-value, p-value, degrees of freedom, Cohen's d.

We found small effects for 7 items of the questionnaire (table 1). Most interestingly in this context, CS was perceived as a more female subject than before (t(64)=-2.10, d=0.30, p=0.02) resulting in a more gender-balanced view (figure 1). Furthermore, CS was regarded as more ubiquitous than before (t(126)=4.96, d=0.40, p<0.00) (figure 1). We assume that by working with controllers, sensors and actuators, participants were able to recognise the scope of computer systems in their environment. Two questions had a connection to Making concerning the creation of innovation and collaboration. Although we have small effects concerning "computer scientists create a lot of new things" (t(133)=-2.16, d=0.22, p=0.02), there was less agreement to "computer scientists must work well together in teams" (t(133)=3.27, d=0.29, p<0.01) despite participants were working in teams.

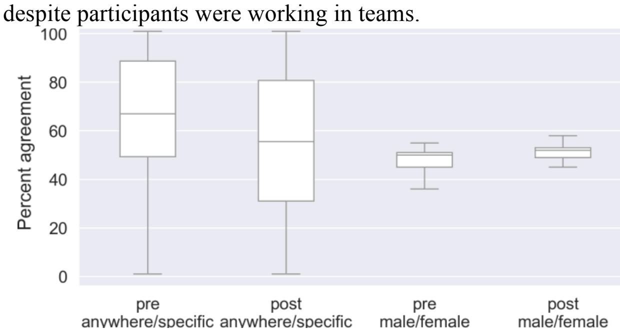

Figure 1: Box plots (pre/post) for questions 1 and 3 (table 1).

The survey included a qualitative question to give up to three associations with 'computer science'. Items (no. of associations in pre: 491, post: 513) were smoothed (typos, singular/plural), coded and categorised. The variety of words (smoothed) was 129 before and 131 after. Before workshops, the top three items were 'programming' (named by 42% of questionnaires), 'computer' (61%), 'technology' (32%). Afterwards, the top three were 'programming' (56%), 'computer' (46%), 'technology' (38%). The highest variations were found in 'programming' (+14% of quest.), 'kits' (+9%) and 'computers' (-15%). In the post survey, 4% mentioned non-technical workshop materials (plants and cushion). No Making-related activities such as gluing or crafting or other digital fabrication tools (e.g. 3D printers) were mentioned. We see this as a potential indication that most girls already had a basic conception about CS beforehand. Making did not add to wrong associations with CS but shifted their focus towards physical computing and programming.

A limitation of our study is the variety of workshops in terms of curricula, settings, participant demographics and a national context so that identifying influencing factors and generalisations are difficult.

3 Conclusion and Future Work

Our preliminary results contribute to digital fabrication in education by showing that Maker workshops with physical computing contribute to girls' attitudes towards CS regarding stereotypes, scope and presence of CS. However, if the goal of a Maker workshop is to promote a more comprehensive picture of CS, further investigation is required. As regards future work, we will evaluate the questionnaire's items and subsequently re-analyse the data with a mixed-method approach to pursue the effects among subgroups to identify potential impacting factors such as participant access. Furthermore, we shall plan a triangulation with qualitative workshop data.

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