The Effect of CS Unplugged on Middle-School Students' Views of CS

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ABSTRACT
Many students hold incorrect views of what computer science (CS) is, and they have negative attitudes towards the field. In order to address these difficulties, a series of learning activities called *Computer Science Unplugged* was developed by Bell et al. [3]. These activities expose young people to central concepts in CS in an entertaining way, without requiring a computer. Using questionnaires and interviews, we examined the effect of the activities on middle-school students' views of CS, specifically, on their views of: (a) the nature of CS; (b) the characteristics of computer scientists and work in CS; (c) the variety of employment in CS. The results indicate that—although the students generally understood what CS is—they perceived the computer as the essence of CS and not primarily as a tool, contrary to the intention of the CS Unplugged activities. We suggest additions to the activities intended to increase the change in the views of CS that students have.

Categories and Subject Descriptors
K.3.2 [**Computers and Education**]: Computer and Information Science Education – *computer science education*

General Terms
Human Factors

Keywords
Computer Science Unplugged, attitudes, views, K-12 instruction

1. INTRODUCTION
During recent years there has been a decline in the number of high-school and college students choosing to study computer science (CS) [6, 9]. Some of the reasons are the students' negative attitudes and views about the field; it is perceived as boring and tedious, requiring workers to spend many hours in front of the computer. In order to address these difficulties, a set of 20 activities called *Computer Science Unplugged* was developed by Tim Bell and his colleagues at the University of Canterbury in New Zealand [3]. These activities are intended to expose young people and students (from elementary school through college) to central concepts in computer science in an entertaining and challenging way, *without requiring a computer.*

ITiCSE'09, July 6–9, 2009, Paris, France.

CS Unplugged contains activities on different topics, such as how computers store information (the binary system and the representation of pictures as pixels), and algorithms (searching and sorting). Other interesting topics include cryptography and networks. The CS Unplugged activities demonstrate the above topics using teamwork, games, tricks, and other entertaining methods that require only the simplest equipment, primarily worksheets.

The goals of CS Unplugged are [Bell, personal communication]:

- Increase students' interest in CS;
- Students will perceive CS as more challenging, intellectually stimulating, and cooperative than they did before;
- Students will better understand what CS is and avoid confusing it with programming;
- Promote CS as a career for women.

In this paper we report on a research project that examined the effect of the participation in the CS Unplugged activities on students' views of CS.

Section 2 contains definitions of the terminology used in the paper, followed by a literature review on views of CS. The research methodology is described in Section 3 and the results in Section 4. Section 5 discusses the results and Section 6 contains our conclusions.

2. BACKGROUND
2.1 Terminology
Different researchers use different terms for the concepts *attitudes* and *views*. Some use *beliefs*, some *perceptions* and some *views*. To make a clear distinction between attitudes and views, we define the terminology that will be used in this article. Following Ajzen [1], we define *attitudes* as representing evaluations towards an "attitude object," in dimensions such as good-bad, harmful-beneficial, pleasant-unpleasant and likable-dislikable. *Views* are how students perceive something like CS, regardless of their evaluations of these perceptions.

2.2 Students' views and attitudes of CS
Cassel et al. [6] argue that the crisis in enrollments in CS does not stem from a single cause, but rather from many factors. They report on negative views about the nature and attractiveness of work in CS, doubts about the relevance of CS, and the low level of public understanding of the broader dimensions of CS. They

also claim that students are afraid of becoming isolated in an asocial job, and women and minorities think that jobs in CS lack diversity. Yardi and Bruckman [18] interviewed thirteen teenagers about their thoughts concerning CS. They found that the students perceived CS as antisocial and lacking creativity. They also found that students thought that CS is only for smart people.

Carter [5] examined the reasons that cause high-school students to choose not to major in CS. One of the reasons she found is that students had incorrect views of the field; furthermore, many of her subjects had no idea what CS majors learn. She found that students think that CS is about programming and involves just spending many hours in front of a computer.

Moormam and Johnson [15] found that high-school students perceived CS as appropriate for males only.

2.3 Attempts to change views and attitudes

There have been attempts to influence students' views and attitudes towards CS through the use of games and pedagogical software tools (in addition to CS Unplugged): Alice is a well known environment for developing programs that include 3D animations, Scratch is a 2D environment that can be used by young people for developing programs, and there are several others [12]. Magic shows have been used to demonstrate concepts in CS [8]. CS4fn [7] is a magazine for the general public that describes interesting and entertaining aspects of CS.

Some research has been done on the actual effect of these tools on students' attitudes towards CS: Alice was found to improve college students' attitudes towards CS [14]. Lambert [13] examined the effect of CS Unplugged on students' *interest* in CS (rather than their views on CS). She found that the students were more interested in CS after participating in CS Unplugged.

Galpin and Sanders [10] examined whether a change occurred in college students' views of CS following an introductory course at a South African university, but they found that most views were not changed. Wick [17] designed a first-day lecture for an introductory college-level course that was meant to affect students' views about programming. He found that the lecture helped the students to view programming as a problem-solving process, not just the creation of an artifact.

Researchers suggest that curriculum change should be more comprehensive in order to explicitly address issues of influencing students' views [18]. Redish and Hammer [16] succeeded in changing college's students' views on physics by developing a curriculum that explicitly used a vocabulary of the target views.

There is evidence that views of a target object may influence attitudes towards that object [2]. For example, Carter states that when freshmen are properly introduced to CS, they are more attracted to it [5]. The CS Unplugged activities are aimed at changing students' views on CS and, as a consequence, their attitudes towards CS.

3. METHODOLOGY

We looked for changes in the following views relating to CS:

(a) What is the nature of CS? Are computers only tools? Does CS involve theoretical thinking?

(b) What are the characteristics of a computer scientist and the nature of work in CS? This includes issues such as: gender equity, a computer scientist is not necessarily a "nerd," the importance of cooperation;

(c) What types of jobs are available in CS?

In addition, we studied whether students are able to identify relationships between the CS Unplugged activities and central concepts of CS.

3.1 Population

Our subjects were middle-school students; we chose this age group because during these years students begin to think about their future [11]. We found a school that agreed to offer the CS Unplugged activities to seventh and eighth grade students (N=13); they studied the activities in school immediately after school hours. The teacher was a recent CS graduate who was not a professional teacher. The students participated in eighteen out of twenty activities. Each activity lasted approximately two hours. All the students volunteered to participate in the activities and six volunteered to participate in interviews. We also gave a questionnaire to a population (N=81) of middle-school students who did not study the CS Unplugged activities.

3.2 Instruments

3.2.1 Questionnaire

We developed a questionnaire that was aimed at checking students' views on CS. This questionnaire was administered to the students before they participated in the CS Unplugged activities. Since this questionnaire did not address some important issues such as gender equity in CS, we developed an improved questionnaire (that included both views and attitudes) and gave it to a similar population (N=81) that did not study the CS Unplugged activities. The questionnaire consisted of 22 Likert-type statements, such as "Installing software is central in CS." The students were asked to score each statement on a scale from 1 (highly disagree) to 5 (highly agree).

3.2.2 Interviews

Towards the completion of the CS Unplugged activities, we interviewed six students. Our experience showed that children find it easier to express their thoughts when responding to pictures than when presented with verbal questions, so we showed them six pictures aimed at *triggering* an expression of their views (Figure 1). We asked them to evaluate on a scale from 1 (low) to 5 (high) the extent to which each picture is related to CS or to the work or worker in CS.

Students' views about *the nature of CS* and of *the work in CS* were examined by Pictures 1, 2 and 4, which were intended to trigger responses that CS also involves theoretical work and not only computers. Students' views about *the characteristics of a computer scientist* were examined by Pictures: 3—the computer-scientist is highly-educated; 2—the person in front of the computer is a man or a woman, 5—working as a computer scientist involves cooperation, 6—the computer-scientist is a nerd.

In addition, we asked the students directly about: (a) the difference between CS and computers; (b) whether the worker in CS is more likely to be a man or a woman; and (c) the jobs available in CS.

We observed that the relation of the CS Unplugged activity on map coloring to CS was not explicitly mentioned in the activity itself. (The instructions to the teacher do note that the activity

introduces the students to the idea of problems that may be too hard for the computer to solve in a reasonable time.) In order to examine whether students are capable to identify relationships between this activity and central ideas of CS, we asked them the following question: "What do you think is the relationship between this activity and CS?"

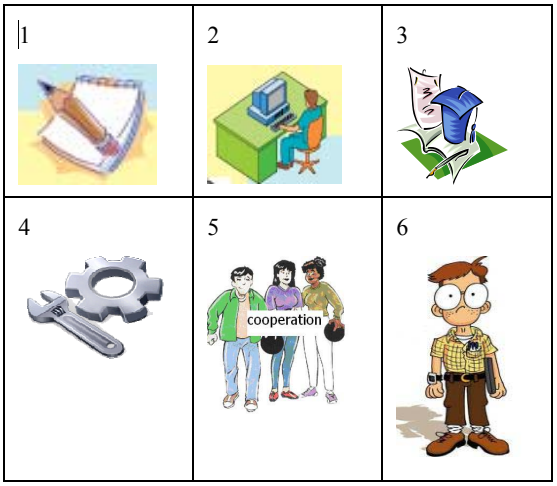

Figure 1. Pictures that were presented during the interviews.

We analyzed the data from the interviews and coded it according to the three categories of views (a), (b), (c) given at the beginning of this Section.

4. RESULTS

The questionnaire gave us an indication of the views and attitudes of students that did not participate in the CS Unplugged course (N=81). Table 1 shows the mean value given for six of the items that relate to views alone.

Table 1: Mean scores of the items.

Expression	Mean value	Standard deviation
Installing software is central in CS	4.2	1
Programming is central in CS	3.8	0.9
Someone who works in CS should be good at teamwork	3.3	1.1
Someone who works in CS is a nerd	4.3	1
Boys are better than girls at CS	4.1	1.4
Work in CS can be done without a computer	1.8	1

Students thought that installing software is very central in CS, even a bit more than programming. The students considered the need to cooperate in CS as neutral. The computer scientist is perceived as a male and a "nerd." Work in CS cannot be done without the computer.

We now turn to the analysis of the interviews that were conducted towards the completion of the activities.

4.1 The nature of CS and the work in CS

A primary objective of the CS Unplugged activities is to decrease the central position of the computer in CS and instead to present it as a tool. Five out of six students scored Picture 2 as highly related (4–5) to CS. When asked to explain their choice, the students answered that even though they did not use the computer during the CS Unplugged activities, work in CS does require a lot of use of the computer. For example, student O said:

> During the course [CS Unplugged activities] we studied about CS without using the computer. Before we studied the course we didn't think it was possible. We learned things about the computer that we didn't know before, without using a computer. … Working on the computer is not related to the course, but of course it is related to work in CS. In the course we learned about the computer which is the basis of CS. How could they CS is all about it [the computer].

S made the distinction between studying CS and work in CS as regards the use of the computer:

> The study of the software is without the computer. The work in CS is on the computer.

All the interviewees said that computers deal with the hardware and with using the computer, while CS is how the computer "thinks." L said:

> CS means how the computer thinks. The computer has a different way of thinking than a person, it uses zero and one. At the beginning I thought that CS means how to use the computer, but now I know that CS means how it [the computer] thinks.

while O said:

> The computer is actually a tool and CS teaches us how this tool works. How we do 1+1, how it takes billions of actions in less than a second. … CS is like a book with the knowledge of how the computer works.

Picture 1 was intended to trigger the students' views about the importance of theoretical work in CS that may be done using pen and paper. The picture failed to do so and we believe that this was because the intention of the picture was not clear enough.

When referring to Picture 4, we saw that the students had a variety of ideas about its meaning and therefore we were unable to draw conclusions from their answers.

It seems that the students knew the difference between CS and computers. Nevertheless, although the CS Unplugged activities were intended to emphasize the computer's role as a tool, many students perceived the computer as central aspect of work in CS itself.

4.2 Computer scientists

Gender equity

One of the objectives of the CS Unplugged activities was that the students will learn that females are equally capable of being computer scientists. All the interviewees were asked whether a worker in CS is more likely to be a man or a woman. We received contradictory answers. Two students said that usually there are men in the field; L said:

> In the picture [Picture 2] it looks more like a man. … Because of its look and also because men are more leaders and we [women] are trying to imitate them.

Two students said that both genders are equally likely to work in CS. O said:

> I think it makes no difference, because there are a lot of CS researchers that are either men or women.

C admitted that only after a second thought did she realize that both men and women can work in the field:

> I think it [the person in the picture] is a man. But maybe it makes no difference. … I don't know. I think it is a stereotype. I say it automatically, but if I think about it I will say that it can also be a woman technician. He or she is on the computer.

Cooperation

Another objective of the course is to influence the students to attribute to the computer scientist attributes such as cooperativeness. Four interviewees graded the picture of cooperation as highly related to workers in CS, but for two out of these four it came only as a second thought because of their partial understanding of the kind of work done in CS (as described further in 4.3). R for instance, claimed that:

> Computers don't need cooperation.

This answer was too superficial, so the interviewer asked the following question to probe deeper into R's understanding: Does the work in CS require cooperation? He changed his score to 5, saying:

> Cooperation is the most important thing. Everyone together can improve the ability of the computer.

Two students gave the picture of cooperation the value 3. S claimed that:

> It [cooperation] is not related so much. You are on the computer on your own. The worker in CS needs cooperation but not too much, not as in building where the worker really needs cooperation; otherwise there will be no building. The job in CS will be completed even if the worker doesn't cooperate.

The computer scientist as highly educated and as a nerd

Picture 6 was intended to trigger the students to say whether they view the computer scientist as a nerd. The picture failed to do so, because there was a range of ideas about who the person in the picture was. Therefore, since most students did not identify the person as a nerd, we refrained from asking about it directly so as not to influence the answers. The same occurred with Picture 3.

4. 3 Variety of jobs in CS

Every interview started by asking what jobs are there in CS. All students answered computer technician and four added programming. R said that the jobs available in CS are:

> Technicians, people who sell computer parts.

One of the students did not completely understand what programmers do; L said:

> The programmer uses the computer but different from a technician. The programmer fixes bugs on the computer and the technician fixes the computer's parts. I think that a programmer installs software on the computer. I don't know.

O mentioned computer researchers (!):

> There are software developers, computer researchers.

We see that the students did not have a wide range of careers available in CS. Furthermore, the careers they did know were mainly about working with computer itself.

4.4 CS Unplugged and concepts in CS

During the interviews (and without being explicitly asked) most of the students gave the binary system as an example related to CS, and were able to explain the relationship between the two. We then asked them about another activity (map coloring) whose connection to CS was less clear in our opinion. None of the students was able to give an answer that related to the intention of this activity, namely, the inability of the computer to solve some problems in a reasonable time. For example, L said:

> Wait, it's hard. How is it related? I have no idea. Ah! The computer tries to make processes as short as possible. The same thing was with this map, not to color it twice.

S thought about the connection between the graph coloring activity and CS for a while, and then gave an explanation:

> It has nothing to do with software itself. It's like a way of thinking how to solve problems, easy problems. You have to think of a way. This activity is like a riddle. This activity teaches us how to make things as easy and fast as possible. The same is with software. We want it to be the easiest and the most convenient.

5. DISCUSSION

From the initial questionnaire we obtained results that are consistent with the literature: students perceived the computer-scientist to be more likely to be male and a nerd; they thought that installing software and programming are very central in CS; their views regarding cooperation were neutral.

Even though one of the main goals of CS Unplugged is that CS is not just working on a computer, most of the students scored the computer as highly related to CS. But when specifically asked about the difference between CS and computers, all the interviewees showed a good understanding of the idea of CS. They all claimed that CS is the "brain" behind the computer, and that studying CS means studying how the computer "thinks." We suggest that the students understood the essential nature of CS, but that the immediate and automatic expressions of their views on the nature of CS were of a field dominated by computer use.

Another important goal of the course is to influence students so that they will consider studying CS in high school and college. We think that the CS Unplugged activities do not succeed in this goal because they do not provide the students with any knowledge of the career options available in the field (cf. [11] about trying to attract students to study engineering).It was clear from the interviews that students were not familiar with the wide range of careers in CS.

The results of this paper partially confirm findings that people perceive the computer scientist as more likely to be male [15]. Nevertheless, there was diversity in the students' answers

concerning gender equity in CS, for example, when one of them admitted that she automatically thinks about men in the field and only on second thought does she realize that women could also be computer scientists.

6. CONCLUSIONS

Changing students' views is not simple. Moreover, sometimes, instead of gaining new and improved views, undesired views appear [16]. We conclude that the CS Unplugged activities did start a process of changing the students' views, but that this process was partial.

It is possible that activities that deal directly with how the computer is constructed (such as the binary system) helped shape the new view of CS as the way the computer "thinks and works," and that this is the reason that the students mentioned binary numbers and not other activities during the interviews. Furthermore, we found that the students faced difficulties in identifying relationships between CS Unplugged activities and central ideas in CS.

According to the constructivist perspective on learning [4], acquisition of new knowledge involves building upon existing knowledge and views that the learners already have. Explicitly linking new information to them is essential to the success of an instructional program aimed at conceptual changes.

Our research leads us to suggest some additions and modifications to the CS Unplugged activities:

- The activities must be written with an awareness of students' prior knowledge and views on CS and built upon this pre-existing knowledge;
- The activities should be explicitly linked to central concepts in CS;
- Although not directly related to the activities, the range of careers in CS should be presented, especially those that do not require a computer.

We believe that these changes will materially improve the ability of CS Unplugged to achieve its goals.

In this paper we described a preliminary research that investigated the effect of participating in the CS Unplugged activities on students' views on CS. In the future we plan to expand our research in three dimensions: (a) we will widen the interviews to improve our understanding of the students' views on CS, (b) we will combine different methods to analyze the data , , and (c) we will examine the effect of participating in the CS Unplugged activities on students' attitudes to CS.

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