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An Analysis of User Engagement in Relation to Computing Workshop Activities

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ABSTRACT

Computing is now one of the fastest growing fields of employment, with a large bias placed on developing Science, Technology, Engineering, and Mathematics (STEM) education in schools. However, due to the fast pace of technology development, it is increasingly difficult for schools to keep up with the latest computing methodologies. A possible solution is the use of university outreach programmes, whereby local universities can provide training workshops on areas that can be challenging for schools to implement. This can be problematic, as there is a perceived lack of interest in the methods used to interact with secondary school pupils on a university level.

This paper introduces a week long ‘Easter Computing School’, comprising of five workshop sessions on different topics. These sessions were analysed in terms of user engagement, to better understand aspects that are important to secondary school pupils. It was found that a combination of theory and interactive workshop sessions can provide the highest levels of engagement and their use is encouraged in future workshop design.

Categories and Subject Descriptors

Computers and Education~General.

Human-centered computing~Usability testing, Human-centered computing~Interface design prototyping, Social and professional topics~Computational science and engineering education.

General Terms

Measurement, Design, Experimentation, and Human Factors.

Keywords

Summer school, user engagement, outreach.

1. INTRODUCTION

As the development of digital technology increases, there is a growing demand for graduates within the computing sector in Scotland. In order to meet this requirement, higher educational institutions are placing an increasing importance in attracting students to Science, Technology, Engineering, and Mathematics (STEM) subjects in the coming years. However, school-based computing education can be limited due to increasing financial constraints and disparities in teacher knowledge between schools. Initiatives exist that are attempting to overcome this shortfall [5]. The provision of outreach programmes to local schools and communities is becoming more prominent in universities. The aim of these programmes is therefore to develop interest in computing as an educational field and to promote the potential for future employment in this area.

A series of computing workshops was developed and held along with exam revision sessions to engage local school pupils in varying aspects of computing. These were held during Scottish Easter school holidays and marketed to local schools and university applicants as an ‘Easter Computing School’. Workshops were a mix of educational and experiential sessions, taking place over a five-day period. Staff, postgraduate and undergraduate students delivered workshops in order to expose participants to a wide range of academic experience. Feedback from these sessions was gathered focusing on individuals’ user engagement levels. This was divided into factors relating to user-focussed attention, perceived usability, aesthetics, durability, novelty, and involvement. Analysis was conducted to evaluate the success of the workshops in terms of user engagement, compared to the student’s experience of high school computing classes.

2. RELATED WORK

In some cases, there is a lack of interest in computing within schools. This is due to a lack of effective role models, a lack of familiarity with computing fields, and negative perceptions of computing as being “nerdy” [4, 9]. However, there is a clear need for students to become better skilled in computing, with an

increasing demand from employers for computing science skills [2]. Across the UK, and particularly in Scotland, there are many more jobs available than university graduates in the field of computing [15]. However, many school-aged students have a poor understanding of what a career in computing can involve [18].

Outreach activities are often used as a method for universities to encourage a broader participation in computer science higher education [11]. This provides potential students, and the wider community, with valuable exposure to the resources and expertise that the university can offer [7]. The most successful of these allow the community to meet “real world” experts from both academia and industry [19], in order to provide role models.

It is noted that outreach activities that reduce or avoid the need to program provide an effective and scalable way to introduce concepts in computing science [2]. Computer Science Unplugged¹ is an online resource for teaching materials that can be used by teachers and tutors. Alongside activities, suggestions are made of how to integrate them into the school curriculum. This is valuable, as curriculum content can vary greatly between schools, even within one geographical region, due to resources and teacher knowledge. The focus of Computer Science Unplugged activities is to ensure that learning can take place away from computers to increase interaction between participants. Students are engaged in “computational thinking” [17], independently of developing their knowledge of programming languages. Therefore, students with knowledge of different languages can participate in the same session. A similar program, CS Inside [6] also provides lessons for teachers, introducing computing science concepts using everyday technologies as exemplars. This ensures that the lesson is directly applicable to the students, and that they can see the immediate value in the topic. The use of everyday technology also reinforces the relevance of this field of study. The aim of this paper is to report on outreach workshops held at a Scottish university as part of an Easter School.

3. METHODOLOGY

The aim of this work is to examine how the experiences of school age pupils in a variety of workshop sessions compares to their experiences of computing education in a standard computing classroom. Five workshop sessions were organized and pupil experience measured through self-reported questionnaires. This data was collected in order to compare their perceived experiences from a standard computing classroom environment.

3.1 Experimental Variables

Participant user experience (measured through a self-reported questionnaire [12]) was used as a dependent metric. Workshop activity (Arduino, Prototyping, Internet usability, and Mathematics in Games) and standard class engagement was used as independent metrics.

3.2 Participants

A total of 12 participants (10 male, 2 female) participated in this work. Participants were all aged 14-17 and were students of local high schools, studying computing at SQA Higher and Advanced Higher levels [16].

3.3 Materials and Equipment

3.3.1 Workshop Activities

Workshops, and accompanying revision sessions, were promoted as an ‘Easter Computing School’, which ran for five consecutive days. One workshop and one revision session was held each day with a break for lunch. Posters were sent to local schools in the surrounding areas and were displayed in the computing department or pupil social areas. In addition, emails were sent to all applicants to the university who were studying computing as one of their chosen school subjects. This wider promotion ensured that pupils who would benefit from the revision sessions were individually informed, while offering the workshop activities more broadly within local secondary schools.

The aim of these sessions was to provide local school pupils with additional revision opportunities prior to sitting their SQA exams. The results of these exams, in most cases, will have a direct impact on the individual’s course and location of study in higher education. Having a local secondary school teacher run the revision class ensured direct knowledge of the school curriculum. Staff, postgraduate and undergraduate students ran the workshops from the School of Computing, with a wide range of educational and industry experience. The interdisciplinary nature of the workshops meant that little or no computing experience was necessary to complete them.

The remainder of this section introduces the workshop sessions, giving details on the topics covered and the activities undertaken.

Arduino Workshop - Arduino is an open source platform used to create interactive objects and environments. Arduino boards are cheap to purchase (starting at £20 (\$30)) and are programmed using open source software. The Arduino board can sense the environment and user interactions by receiving inputs from sensors such as buttons, and can affect the environment by controlling actuators such as LED lights, buzzers and motors. Despite the low cost of each board, multiple purchases are required, as well as knowledge of the topic. As a result, many school pupils are not exposed to microcontrollers in schools.

Participants were invited to explore the world of microcontrollers through a series of activities involving LEDs and potentiometers (a variable resistor, e.g. used as volume control knobs). The tasks included a ‘Hello World’ program, creating a set of traffic lights and controlling multiple LEDs using a potentiometer. Participants explored the creation of electronic circuits, were encouraged to use modular programming techniques, and to consider future developers by commenting code.

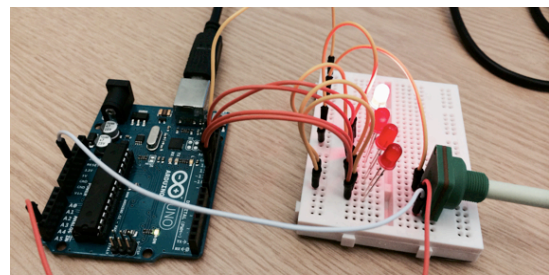


Figure 1 The Final Output of Arduino Workshop - 4 LEDs Controlled by a Potentiometer

Internet Usability Workshop - One key aspect in computing is to develop an understanding into problems that can be faced by the end user when designing digital services. This workshop was intended to examine the importance of Internet Usability

¹ <http://www.csunplugged.org>

guidelines and their implementation in modern websites. This session was split into three separate components: (i) The collection of usability guidelines from online sources, allowing students to understand the large variety of usability issues that exist in designing digital services; (ii) A usability analysis of several live websites, intended to allow students to examine if the implementation of usability guidelines would either enhance or detract from the user experience of navigating through a live website; (iii) The creation and adaptation of simple websites with a focus on the usability of navigation options.

Figure 2 demonstrates some of the potential adaptations that users could make to websites in order to change the physical appearance of the page, while keeping the content of the page the same.



Figure 2 Website Usability Adaptions

Prototyping Workshop - Prototyping is a powerful tool used in research and industry to conceptualise products in a very visual way. Participants explored the concept of prototyping, learning about the steps involved in creating a prototype, and how prototyping is used in industry today. Students designed, created and presented a prototype wearable technology from scratch. Materials such as clothing, marker pens, and additional paper were provided. Participants were encouraged to keep in mind the reasoning behind all of their decisions; it was not enough to simply state the design of their products, but instead they had to be able to explain how they came to make the decisions that informed these designs. Blue-sky thinking was encouraged throughout the prototyping process, to foster the creation of interesting and novel ideas.

Mathematics in Games Workshop - Both board games and computer games involve mathematics at some level or another; Monopoly, for example, teaches basic concepts such as addition, subtraction, negative numbers, and compound interest. As such, games provide an accessible platform for teaching students about mathematics and programming. In this workshop, participants were introduced to a number of concepts including understanding that theory and mathematics underpin most games. The workshop explores the concept of perfect information (when the behaviour of a player causes the best possible outcome for that player, regardless of an opponent's response) can how this combines with algorithms to create a solved game [13, 1].

Participants completed series of activities, culminating in a task to create an algorithm to play Connect 4 perfectly. In a Connect 4 tournament participants used their algorithms in order to win.

3.3.2 User Experience Questionnaire

A questionnaire measuring participant user experience was used during the workshop sessions. Based on work by O'Brien and Tom [12], questions were adapted to relate to a more generic

'activity' rather than the 'shopping task' used in their work. This work is one of the currently recognised academic sources for measuring user engagement and justifies its use in this case.

The questionnaire consisted of 32 questions, administered on a forced 6-point Likert scale option (*Strongly Disagree, Disagree, Somewhat Disagree, Somewhat Agree, Agree, Strongly Agree, n/a*). This option was used instead of a standard 7-Point scale in order to make participants more likely to give answers on one of the two sides of the scale. Participants were given printed copies of the questionnaire to complete.

Exploratory Principal Component Analysis conducted by O'Brien and Toms concluded that this questionnaire could be split into six separate factors. These, along with a brief explanation into their composition are detailed below:

- **Focused Attention**, 7 questions. This factor is a measure examining users perception of time passing and their ability to recall what was happening out with the current task being created. It is a measure of individuals' ability to concentrate on one single task and not being distracted by any others [10].
- **Perceived Usability**, 8 questions. This factor was used to understand the emotive state of participants throughout a task, with questions examining feelings such as frustration, confusion, and annoyance. In simpler terms, this is described as individuals' perceived effort in completing a seminar workshop.
- **Aesthetics**, 5 questions. This factor is used to measure the visual attractiveness of the task being completed and the overall appearance of any materials used.
- **Endurability**, 5 questions. The endurability factor is used as a measure of workshop success and, to a degree, participants' likelihood to recommend the activity to others. Again, this uses the definition set out by O'Brien and Toms, stating that endurability is "the likelihood to remember things that we have enjoyed and a desire to do again an activity that has been fun" [14].
- **Novelty**, 3 questions. The three questions used in the novelty factor relate to the curiosity felt by participants during a workshop, and also their interest in the task.
- **Involvement**, 4 questions. This factor was used to understand the interest felt by participants throughout the seminar workshop activities. The questions used in this factor focused on the fun, feelings of involvement and the overall interest levels of participants.

3.3.3 Additional Feedback Questionnaire

After the week of workshops was completed, participants were contacted by email and invited to complete an online feedback questionnaire. Participants were invited to comment on which sessions they enjoyed most and least, providing justification for this also.

3.4 Procedure

Workshop activities and revision sessions were organised within the University of Dundee. As part of these workshops, pupils were given *two user experience questionnaires*, the first of these (measuring their standard computer class engagement) was given at the start of the week and the second (measuring their engagement in an individual summer school workshop) was given at the end of each workshop session.

3.5 Analysis

The purpose of analysis is to provide a comparison between pupils' perceived experiences in a standard computing class and that of the four separate education workshop sessions.

Due to the small sample sizes, null hypothesis statistics testing (NHST) is not used due to the low power that would be achieved. Instead, analysis is based on an interpretation in the differences in the six engagement levels across the four workshop activities. This is accomplished through examining the mean and standard deviation levels of baseline and workshop activities. A higher value is indicative of greater engagement. In addition, Cohen's *d* value acts as a comparative statistic. Cohen's *d* value is a measure of effect size. Analysis was conducted using R [20].

Quantitative analysis is further explained through an interpretation of qualitative responses gathered from the *Additional Feedback Questionnaire*.

4. RESULTS

Due to the small sample sizes, analysis is based on an interpretation in the differences in the six engagement levels across the workshops by examining the mean and standard deviation levels of baseline and workshop activities.

4.1 Arduino Workshop

The Arduino workshop was organized for the first day of the Easter School and had a total of 4 attendees. Pupils reported that this workshop was more visually attractive than a standard computing class (*aesthetics*) ($d=.72$). However, they were also less likely to remember aspects of the workshop that were enjoyed (*endurability*) ($d=-.96$) than if they were participating in a school-based computing class.

Table 1 Arduino Workshop Results

	Baseline		Arduino		d
	M	SD	M	SD	
Focused Attention	4.14	0.48	4.18	1.11	.04
Perceived Usability	5.50	1.04	5.75	0.32	.30
Aesthetics	5.17	0.69	5.67	0.27	.72
Endurability	5.30	0.84	4.60	0.23	-.96
Novelty	5.20	0.99	5.25	0.96	.05
Involvement	4.44	0.36	4.50	0.20	.12

4.2 Internet Usability Workshop

The Internet Usability workshop was organized for the second day of the Easter School and had a total of 6 attendees. Pupils reported that concentrating on a single task during this workshop was more difficult than a standard computing class ($d=-1.08$). However, they also reported that they felt more involved in this session and had higher levels of overall interest ($d=1.85$).

Table 2 Internet Usability Results

	Baseline		Int. Usability		d
	M	SD	M	SD	
Focused Attention	4.98	1.06	3.76	1.46	-1.08
Perceived Usability	5.94	1.02	5.67	0.88	-.28
Aesthetics	5.67	0.92	5.56	0.82	-.12

Endurability	5.77	0.93	5.87	0.72	.11
Novelty	5.80	0.94	5.80	0.59	-.08
Involvement	4.38	0.67	4.38	0.65	1.85

4.3 Prototyping Workshop

The Prototyping workshop occurred on the third day of the summer school and had a total of 4 attendees. Again, this workshop was more visually attractive than a standard computing class ($d=1.07$), as well as having greater endurability of perceived usability. Participants found it more difficult to concentrate on the task ($d=-.53$).

Table 3 Prototyping Results

	Baseline		Prototyping		d
	M	SD	M	SD	
Focused Attention	4.57	0.80	4.00	1.52	-.53
Perceived Usability	5.58	1.07	6.67	0.32	1.3
Aesthetics	5.33	0.82	6.22	0.57	1.07
Endurability	5.35	0.81	6.27	0.54	1.12
Novelty	5.50	0.93	6.07	0.66	.64
Involvement	4.34	0.39	4.79	0.87	.56

4.4 Mathematics in Games Workshop

The Mathematics workshop was the fourth session and had a total of 6 attendees. All measures showed higher ratings than a standard computing class. Large differences were seen in the aesthetics ($d=1.41$) and involvement ($d=1.61$). In addition, the perceived usability ($d=.31$), endurability ($d=.42$), and novelty ($d=.50$) between baseline and workshop sessions all showed a medium effect.

Table 4 Mathematics in Games Results

	Baseline		Maths		d
	M	SD	M	SD	
Focused Attention	4.5	1.44	4.71	1.35	.18
Perceived Usability	5.72	1.00	6.00	0.58	.31
Aesthetics	5.33	1.03	6.5	0.33	1.41
Endurability	5.73	0.97	6.10	0.53	.42
Novelty	5.43	1.08	5.90	0.64	.50
Involvement	4.25	0.60	4.25	0.45	1.64

5. DISCUSSION

This study set out with the aim of assessing the differences that exist in levels of user engagement between a standard computing class environment and four university-based workshops. Prior studies have noted the importance of outreach activities such as this in creating exposure to the expertise that universities have to offer. Analysis therefore focused on six different aspects of user engagement.

5.1 Workshop Discussion

In the first workshop session, the open sourced Arduino platform was introduced to students. This was used to explore several

aspects relating to the hardware of computing and focused on the control and manipulation of a simple LED array. The results for this session indicated that pupils experienced higher levels of aesthetic appeal and lower levels of durability in this workshop compared to their standard computing class. Surprisingly, very little difference was seen in the focused attention and novelty factors reported by pupils when comparing between these two tasks. From this, it is possible to conceive that the use of an emerging technology, such as Arduino, can improve the learning experience of pupils while keeping levels of focused attention and novelty relatively similar. The trade off between task complexity measured by *endurability* and task visual appeal measured by *aesthetics*, while not predicted, is an interesting point to note.

The second workshop session focused on the concept of Internet Usability, allowing students to conduct their own usability analysis of websites before creating their own sites using these principles. It is interesting to note that in this workshop, participants reported involvement was higher than a standard computing class, while user focused attention was lower. All other measures (except perceived usability) had effect sizes lower than 0.2, showing to be lower than Cohen's criterion for a *small* effect. This workshop session placed a significant bias on student self learning, with pupils being firstly asked to research a topic before applying any information that they had found. Due to the complex nature of research skills, it is not surprising that pupils untrained in this area found it difficult to maintain high levels of attention during this task. Higher levels of user involvement is put down to the interactive elements used when pupils were asked to create their own websites at the end of the workshop session.

The third workshop focused on the development of pupils' prototyping skills with an emphasis on wearable technologies. The feedback questionnaires from this session indicated that pupils experienced higher levels of perceived usability, aesthetic appeal and durability when compared to their standard computing class. Similar to the above workshop, the environment in this workshop was different to that of students' previous experiences. This is likely to have contributed to reduced focused attention levels. This combination of findings provides support for the use of highly interactive session in computing teaching, showing that a combination of academic rigour and blue-sky thinking can improve the engagement of pupils.

The final educational workshop focused on the use of mathematics in gaming, examining how this occurs in both computer and board games. Results from this session showed increases in aesthetic appeal and user involvement, with these both having Cohen's *d* levels indicating over 68% of non-overlap. All other aspects of user engagement was shown to have increased, with perceived usability, durability, and novelty all showing to have effect sizes between small and medium according to Cohen's criterion. In general, therefore, it seems that by introducing students to computing principles and then reinforcing this learning through interactive sessions, levels of user engagement can increase across all factors. This has important implications for developing future workshop sessions, with the combination of theory and interactivity showing to have the largest increase in engagement among pupils.

5.2 Overall Discussion

Of the four educational workshops conducted, Mathematics in Games was the only workshop in which differences between the workshop session and a standard computing classroom were all in favour of the workshop session. This workshop also had the highest average effect size calculated across all 6 categories ($d =$

0.74). This increase indicates that the participants were most engaged with this workshop. However, this is in contrast with participant reports that Prototyping was their favourite workshop. While Prototyping had largely positive engagement levels, perceived usability and durability were the highest scoring. Therefore, student engagement may be defined using a subset of these engagement levels.

The level of focused attention showed only small increases in the Arduino and Mathematics in Games workshops. A medium reduction in focused attention was seen in the Prototyping workshop and a large reduction in the Internet Usability workshop. These reductions are likely due to the environment of the workshops being considerably different to a typical classroom setting. These workshops were student-led, whereby sessions were facilitated by tutors rather than focusing on taught content. In addition, the skills being explored in these workshops required subjective consideration of the subject matter.

The Internet Usability workshop was the only workshop that showed lower levels of perceived usability than the classroom. The complex subjective and research skills needed for Internet Usability may have resulted in this reduction. Participants reported in the post-questionnaire that they found this workshop the most difficult, as concept of usability was not something that they had not previously encountered.

Participants reported higher levels of task visual attractiveness compared to their standard computing class in all workshop sessions apart from Internet Usability. A possible reason for this focuses on the content of this workshop where a focus, in part, was placed on poor design in order to provide a comparison with successful and usable websites. This inclusion of "bad" sites may have impacted on the reported aesthetics level.

Participant feedback for the Arduino workshop rated it as "one of the more fun kinds of computing" but also acknowledged that "it was pretty easy". One participant noted that he was familiar with the workshop, as he had previous experience with the platform.

The novelty level for Prototyping was highest of the workshops. Participant reports that the workshop was "different from usual lessons" are attributed to the practical and interactive content. While this novelty may have contributed to reduced focused attention, it appears to be a key element of engagement.

The involvement ratings reported by pupils in the workshop sessions all had higher levels than that of their standard computing class. Of these, Internet Usability ($d = 1.85$) and Mathematics in Games ($d = 1.64$) were particularly large. While this may be attributable to the small participant numbers, it is encouraging to note that these workshops particularly piqued the curiosity and interest of the participants. Future events might consider the format of these workshops, which comprised combinations of theoretical and practical learning. In addition, regarding the Internet Usability workshop, although the workshop had the lowest level of focused attention, participants showed the highest level of involvement, suggesting that the difficulties were motivating rather than challenging their interest.

5.3 Limitations and Future Work

Results from this study are encouraging, but are limited to the context of this series of workshops. Small participant numbers meant that results could not be widely generalized and NHST could not be conducted. Additionally, different students participated in the four workshops, making it difficult to draw comparisons between each session. Due to the small participant numbers in each workshop session, large changes may be seen

due to the reported engagement levels of one participant. Furthermore, there is a greater teacher to pupil ratio than could be expected in schools, which may have contributed to large differences seen.

Future engagement with computing classes in school should be conducted to determine the longer-term effects of the workshops on student engagement.

6. CONCLUSIONS

This paper has reported on a series of workshop activities that were used in conjunction with revision sessions as part of a computing outreach program at the University of Dundee. The purpose of this work was to examine if levels of user engagement for pupils is different across these workshop activities when compared to their previous computing education at school.

The results of this have indicated that the use of interactive workshop sessions can increase the aesthetics, involvement, and durability experienced by pupils when participating in these sessions. It was also found that in general the focused attention and perceived usability could be increased when focusing on theory-based aspects in this style of workshops. Taken together, these results are aligned with previous work showing that a combination of theoretical principles being reinforced by interactive learning can increase all aspects of user engagement for pupils, may be an area deserving more attention in the future.

The current findings add to a growing body of literature on the use of outreach programs, focusing on the benefits that these can bring to school pupils when participating in computer science higher education. Further investigation into user engagement in relation to classroom and workshop activities would allow for these findings to be validated, generalised, and, moreover, provide further reasoning for the importance of outreach workshops as part of a Universities Agenda.

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