Computational thinking with Girlguiding

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Abstract

This paper presents the findings of a joint project with Girlguiding UK to design activities to promote computational thinking. The purpose of the project was to enable many girls to learn key computational thinking concepts from inclusive, high-quality materials. We produced low cost, low tech computational thinking activities to be used in Girlguiding meetings, supported by adult volunteers who may not possess computing expertise. Our pedagogical focus centred on developing enjoyable collaborative activities for girls and women aged 5-25 to facilitate learning about the flow of control, decomposition, structured information, sorting, and encoding information. In this paper, we report the findings from an evaluation of the material with 483 girls to evaluate the suitability of the materials from the perspective of learners and leaders. The materials were regarded as suitable by Girlguiding in the sense that the girls found them to be enjoyable and challenging, while the leaders found them to be adaptable and offering scope for leadership opportunities. We also consider implications about the large scale roll-out of computer science education materials within informal learning environments, in partnership with a voluntary organisation. There are inherent challenges associated with including computer science education as part of the wider experiences offered by a youth organisation, particularly because of the lack of computational expertise among volunteers. However, partnership working between computer science education researchers and voluntary organisations offers a route to bring computing to a wider variety of learners in a supportive setting, as well as opportunities for researchers to learn more about inclusive educational practices.

Introduction

In the last decade, there has been international recognition that computer science (CS) education should improve to enable young people to master core computational concepts, and participate fully as creators in a digital society (Margolis & Goode, 2016; The Royal Society, 2012). At the same time, there is a pressing need to increase diversity within the IT

profession, for example by encouraging more young women to become interested in technology careers. In the UK, a House of Commons Select Committee report on Digital Skills called for initiatives to encourage more women into the technology industry, as currently only 30% or less of the IT workforce is female (The Select Committee on Digital Skills, 2015). Lack of female participation in the IT profession is not a problem unique to the UK - similar rates of participation can be found in the US, Canada, New Zealand, Australia and some other parts of the EU (Vitores & Gil-Juárez, 2016).

There have been considerable efforts to encourage girls to become interested in computer science (for a review of intervention strategies, see (Miliszewska & Moore, 2010)). Companies, governments, third-sector organisations and university academics have designed a variety of interventions[1] to promote computer science careers (Hunter & Boersen, 2017) and teach introductory CS concepts to girls, often in informal educational settings such as online programmes, summer camps or after school clubs (Hulsey et al., 2014; Thomas et al., 2017). While such programmes are designed with the best of intentions, the lack of diversity in CS and related STEM disciplines is a highly complex problem and interventions are often ineffective (MacDonald, 2014a). Over the past few decades, various solutions to address gender issues have been proposed within CS which have met with varying levels of success (Tech Partnership, 2016). Even carefully designed intervention programmes focussing on school girls have not changed girls' career interests in computing (e.g. Lang, Fisher, Craig, & Forgasz, 2015). The *People Like Me* campaign (MacDonald, 2014b) makes the case that short-term or one-off interventions are unlikely to have the desired effect, and that consistency is required. The campaign focuses on the message that "girls need to be able to self-identify that 'science is for people like me'." (p7). This paper describes a set of materials which were designed to introduce computer science (CS) concepts to members of Girlguiding in the UK. Girlguiding has been a strong voice in campaigns for gender equality. Their 'Girls Matter' campaign targeted MPs, schools and the media, and their 'Girls Can' merchandise encouraged girls to have a positive mindset about their abilities. Girlguiding's mission states that "We want all girls across the UK to have the space and opportunities they need to thrive, grow and give back to their communities… We give girls a space just for them. This means girls feel free to be themselves. We won't tell them an activity is 'for boys'"[2]. Given that there is a link in the literature between the low representation of women in the field and masculine culture, girls' low self-efficacy and lack of early experiences in computer science (Cheryan et al., 2016), the supportive and positive environment of Girlguiding meetings seemed suitable for introductions to computing. Including introductory CS activities as part of Girlguiding meetings across the age range (5-25 years) is one way to reinforce to girls, from a diverse range of backgrounds, that computing is for people like them.

In this paper, we consider questions from two different perspectives. To answer the first question, we evaluated the suitability of the materials from the perspective of our partners in Girlguiding*: Q1. To what extent do girls and leaders find the activities to be suitable (in the sense that they are enjoyable, challenging, adaptable and offer scope for leadership*

[1] Such as https://girlswhocode.com, http://www.geekgurldiaries.co.uk, http://www.blackgirlscode.com, https://coderdojo.com/girlsinitiative/, https://learning.thetechpartnership.com/mod/page/view.php?id=462

[2] https://www.girlguiding.org.uk/about-us/what-makes-guiding-special/our-mission/

opportunities) within the informal learning context of Girlguiding units?
To answer the second question, we reflected on this case study of partnership working from our point of view as computer science education researchers: *Q2. What lessons can computer science education researchers learn about the large scale roll-out of computer science education materials to informal learning environments, in partnership with a voluntary organisation?*

Computational thinking and unplugged approaches

Much effort has been directed into finding appropriate ways to bring computing concepts to diverse groups of learners, particularly since Jeanette Wing's landmark work on computational thinking and why it is important to all members of society (Wing, 2006). Wing wrote that "computational thinking involves solving problems, designing systems, and understanding human behaviour, by drawing on the concepts fundamental to computer science" (p. 33) (Wing, 2006). Computational thinking (CT) is the mental orientation to convert the problem into solutions (Denning, 2009). In other words, CT is a problem-solving process (Barr & Stephenson, 2011). It draws on the concepts and methodologies of computing to address problems in a broad range of subjects (Qin, 2009). In a review of the computational thinking literature, Grover and Pea identify the following commonly accepted elements which make up computation thinking: abstractions and pattern generalizations (including models and simulations); systematic processing of information; symbol systems and representations; algorithmic notions of the flow of control; structured problem decomposition (modularizing); iterative, recursive, and parallel thinking; conditional logic; efficiency and performance constraints; and debugging and systematic error detection (Grover & Pea, 2013). We designed the materials for Girlguiding learners with reference to these elements.

Using unplugged methods enables students to nurture CT skills without the computer. This approach to teaching computing concepts, using constructivist activities with the absence of a computer, has been well-acknowledged both in classroom environments (Conde et al., 2017; Dorling & White, 2015; Giordano & Maiorana, 2014) and after-school / outreach programs (Curzon, 2014; Guenaga et al., 2017; Pollock et al., 2015). Computing education should not focus only on technical skills, but also encourage soft-skills development as a critical element of problem-solving ability. As Missiroli and colleagues (Missiroli et al., 2017) point out, educators should not only promote coding skills and provide knowledge, but also give collaboration and teamwork skills to deal with difficult problems which are too hard to be solved individually. Sondakh (2019) acknowledges that soft-skills such as problem-solving, teamwork, communication and collaboration are essential skills required in computational education.

Research into game development and girls (Carmichael, 2008) suggested that the CT unplugged activities designed many years ago by Bell et al (Bell, Bensemann, and Witten, 2005) were "one of the most valuable resources for group activities" and went on to state "Computer Science Unplugged is a collection of activities designed to teach the fundamentals of computer science without requiring a computer. Because they're independent of any particular hardware or software, unplugged activities can be used anywhere, and the ideas they contain will never go out of date." (ibid.,p109)). Fees et al note the advantages of low cost for unplugged activities in CS: "these activities can often be

implemented with little or no cost, with resources that are easy to obtain, and the materials are more portable than computer hardware – all relevant considerations since many schools involved have limited resources"(Fees, Da Rosa, Durkin, Murray, & Moran, 2018;p3). These practical considerations are particularly relevant to Girlguiding units which generally have small budgets.

Why women do not currently participate in computing careers

There is no reason to believe that women are cognitively less capable of practising computer science than men. Indeed, women consistently outperform men in gaining higher undergraduate degree classifications in CS across the UK university sector (Equality Challenge Unit, 2017). In an international multi-institution study of 693 CS students, the female students had higher end of year pass rates than male students (Quille et al., 2017). When women do choose computer science, they do well.

The factors which drive women's choices when considering computer science careers partly depend on the other choices available and what is culturally expected or desirable; stereotypes about women in science generally vary across ethnicity, cultures and countries (Miller et al., 2015). Intersections between gender and race are an important consideration because "women of non-European descent are even more under-represented in the global IT workforce than their peers of European descent" (Scott, Martin, et al., 2017). Although there is a lack of female participation in CS in some countries, this is not a worldwide pattern. In India, IT careers are seen as "women-friendly" while in Malaysia, IT is a female-dominated profession (Vitores & Gil-Juárez, 2016). Participation also appears to vary according to time period as well as geography; in previous times, computing careers have been more popular among women, such as in the 1970s and 1980s in the US (Thomson, 2019).

Previous research about the gender gap in STEM indicates that an individual's attitudes toward math, self-assessments, math and science achievement and experiences of gender socialization contribute to STEM career choices (Han, 2016). Recent comparative analysis of the literature about recruiting women into STEM (in the US where the study took place) has fruitfully contrasted findings in STEM disciplines where recruiting female students is not problematic (maths, biology and chemistry) with those which do have gender imbalances at undergraduate level (computer science, physics and engineering) (Cheryan et al., 2016). Factors that contribute to lower levels of female participation appear to be *lack of early experiences in the subject*, the *gender gap in self-efficacy* and *masculine cultures* to which women feel they do not belong.

Lack of early experiences in computing

Children become "gender detectives" at an early age, beginning to categorise objects and activities as "for" boys or "for" girls as young as two years old (Fine, 2010). They do this by picking up cues from the world around them and observing the interactions which form the backdrop of their daily lives. If they live in an environment where computing activities are more commonly performed by males (in books, TV shows, in nursery schools or at home),

then an association that technology is “for” men may begin. Cultural perceptions (e.g. in the UK or US) that males perform better in CS produces a negative stereotype, although the differences in performance are negligible as discussed above. Kermarrec recognised that school children are most likely to be influenced by stereotypes, and by the time they reach University, it is harder to change views that have been formed (Kermarrec, 2014). Meelissen and Drent suggest there are non-academic factors which affect an individual’s view on computing such as digital availability in the home (although presumably, this will continue to decrease over time as personal digital device ownership increases), parental influence, and the overall gender bias towards men in computing (Meelissen & Drent, 2008). Wang et al’s more recent study of the factors which influenced college students to study CS confirmed that family, peer and other influencers such as teachers had a role to play in students’ choices (Wang et al., 2015).

It has been highlighted that earlier intervention methods may be necessary to help improve numbers of women in CS (Klawe et al., 2009). Klawe et al suggest that potentially, efforts at a secondary school level may be too late to help improve the situation and encourage more girls into CS-related subjects.
Cheryan and colleagues highlight that children in the US are less likely to have early educational experiences in computer science than in more mainstream STEM subjects like chemistry (Cheryan et al., 2016). They identified that there are fewer computer science course offerings, and less freedom to choose computing within the timetable at high schools than other STEM subjects. Note that this pattern will vary across countries – for example in England since 2014, CS has been embedded in the curriculum for 5-year-olds upwards. Children are gaining early experiences of CS at primary school which is likely beneficial, although the freedom to choose computing as a subject is restricted (to all genders) in some schools due to a lack of qualified teachers (Royal Society, 2017).

The impact of the opinions of others on girls’ sense of possibility is reflected in the finding from previous work by Girlguiding that, “some of girls’ views become more gendered as they get older and progress through the education system – for example, younger girls see computing as equally for both boys and girls but as girls get older, they are more likely to say computing is ‘more for boys’.” (Girlguiding UK, 2017;11); 30% of girls aged 11-16 think computing is more for boys.” (ibid, p13).

Gender gaps in self-efficacy

Educators and researchers have sought to identify the challenges within secondary school education that could contribute to the dwindling numbers of women engaging in computing. For example, an analysis of the 2006 PISA data from 49 countries highlighted that when asked about their future, male secondary school pupils expected to enter STEM subject-based careers, whereas young women expected to enter industries such as healthcare and life sciences (Han, 2016). In a survey of girls' attitudes, Girlguiding UK found that a sizeable proportion of girls (29%) believe that girls do not tend to enjoy STEM subjects as much as boys and that 52% of 11-21-year-old girls and women agreed that STEM subjects have the image of being more “for” boys (Girlguiding, 2016a).

Previous qualitative findings from focus groups in the US suggest that differences in STEM career outcome expectations may be partly linked to a decrease in self-esteem and performance concerns in STEM subjects as a girl progresses through secondary school

(Shoffner et al., 2015). Indeed, the lack of self-efficacy in female computing students has been highlighted as a key issue by numerous researchers (e.g. Meelissen & Drent, 2008; Quille et al., 2017; Shoffner et al., 2015). In contrast, in a recent study by Girlguiding, 70% of girls aged 7-10; 78% aged 11-16 and 80% of 17-21 surveyed (n.1906) reported feeling "confident in tech skills" (Girlguiding 2017, p16). For example, 50% aged 11-21 know how to set up a website or blog (Girlguiding 2017, p14).

Given this set of factors, it would appear that early educational computing experiences within a supportive environment might give girls a chance to build self-efficacy in the subject and encourage them to study it further. It is currently unclear whether a girls-only environment is effective in encouraging girls to pursue careers in computer science. Evidence indicates that single-sex schooling does not improve academic performance or attitude (Pahlke & Hyde, 2016) and indeed Cheryan and colleagues suggest that gender-mixed learning environments might be better for girls in the long run because they give girls a better sense of what their eventual working environment will be like (Cheryan et al., 2016). However, even as we advocate for computer science education, we should not lose sight of the wider challenges faced by girls and young women. Qualitative research about the mental health of girls and young women in the UK points to the need for supportive spaces where girls do not feel the pressures of everyday sexism and harassment (Girlguiding, 2016b). Learning opportunities in a positive environment which offers respite from the pervasive micro-aggressions experienced by girls and ethnic minorities in mixed school environments (Grossman & Porche, 2014) may be welcome.

Masculine cultures

The masculine culture that surrounds computing, education and work has been characterised as a "chilly environment" where women need metaphoric "sweaters" (Vitores & Gil-Juárez, 2016). The emerging evidence about toxic workplaces in the tech industry suggests that this metaphor might be underplaying the scale and nature of the problem. It is not merely that women and underrepresented minority groups are subject to *unconscious* bias within the computing industry; they encounter outright discrimination, hostility and harassment. Concerning fair pay, men in the UK high-tech sector earn 25% more than women – considerably higher than the 18% gender pay gap in other sectors (Charman et al., 2016). A recent survey of 2000 employees who had chosen to leave US technology companies in 2017 found that 37% considered unfairness to be a factor in their decision (Scott, Kapor Klein, et al., 2017). Women of all backgrounds experienced significantly more unfairness than men, although unrepresented men of colour were most likely to leave because of this. This survey indicates that employees were more likely to leave technology companies because of unfairness than non-technology companies. Experiences of unfairness included stereotyping, bullying, being passed over for promotion, poor leadership, and others taking credit for work. One in ten women who left tech companies reported experiencing sexual harassment before they left; unwanted sexual attention is almost twice as prevalent in the tech industry as in other workplaces.

Everyday sexism and sexual harassment were much discussed in 2017, in the media, social media and face-to-face conversations. The power of the #MeToo movement is that it draws attention to the previously unacknowledged, but deeply felt, inequalities in societies across

the world. Now that women and girls have more access to and higher awareness of news reporting and personal accounts of workplace discrimination and harassment, it is likely that the results of surveys such as these will further damage the reputation of the computing industry as a positive working environment for women. Perhaps it is time to pause; for academics to refocus their current efforts to persuade women to alter their negative perceptions of the tech industry by convincing them that good opportunities await them there. Perhaps the problem lies not with women, but with the working environments that we are keen for them to join.

Girl Guide project partnership

In this project, we worked together with Girlguiding UK to produce a range of activities on computational thinking for use in weekly unit meetings as part of their new programme framework.

This project was developed to produce high-quality educational materials to introduce members of Girlguiding to computational thinking (CT). Girlguiding has a membership of 553,000 in the UK alone, which enables the project to reach a substantial number of young people. Girls can take part in the organisation as Rainbows (aged 5-7), Brownies (aged 7-10), Guides (aged 10-14) and Seniors (aged 14-25).

In 2015 Girlguiding launched a five-year strategy called “Being our Best”. The aim was to develop a framework to work across all sections (Rainbows, Brownies, Guides and Seniors), to ensure a broader range of provision for girls and leaders that would address girls' current ambitions and expectations; a greater sense of balance of activities within a year, and progression over years. This included undertaking a significant review of their curriculum. The curriculum had been designed to have 6 strands: personal identity; express myself; being well; have adventures; take action; and, skills for my future. Three distinct products would facilitate engagement: dedicated resources for unit meetings; skills builders’ badges; and, interest badges. Activities developed on the theme of computational thinking was positioned as fitting into the revised materials for leaders and girls to use as part of unit meetings, which would also be part of the “skills builders” programme. Key requirements were that activities had to feel fun; feel different to school; and, enable differentiation between age groups/ sections. Additionally, there was a strategic focus from Girlguiding that resources should be inclusive and be able to support their broader intention to increase their presence in deprived communities. The structure of the curriculum for Girlguiding was recognised as avoiding the limitations on learning inadvertently created by school systems of curriculum and assessment. The non-linear, or non-hierarchical nature of what girls learn, and how, provided potentially fertile ground for inclusive pedagogical practice (Florian & Linklater, 2010) because the focus was on girls’ engagement and participation in particular activities, in addition to their demonstrating command of specific skills.

Materials are retailed by Girlguiding as a set of a range of laminated cards, with the expectation that for each unit meeting over the course of a year a different card would be selected. The new materials for all strands (referred to as *Innovate*) were launched in Summer 2018. From this point they were promoted to over 27 thousand Girlguiding units, reaching approximately 100 thousand volunteer leaders and over half a million girls. As of

December 2022, over 96,000 girls have completed Innovate activities.

Within the wider strategy, the project objectives were to develop sets of enjoyable, hands-on activities to teach computational thinking to members of the Girlguiding association during unit meetings (differentiated by age group); and to evaluate the activities among a subset of the units who volunteered to test new materials. The second author, a computing teacher and former guide leader wrote the content with advice from the other researchers on the team. Utilising an action research iteration style method, she tested and revised each activity with a group of volunteer young people in the computing club at the school where she taught. Girlguiding provided the overall graphic design and production of the template for the activities, feedback, access to girls to test the activities and the capacity to roll out widely as part of the new Girlguiding programme[3].

A key aspect of our work was to incorporate CT into developing girls' understanding of information and process in everyday life. Our approach focused on the developmental progression of the intellectual skills required to analyse problems and their solutions in terms of information and processes. We drew on the CSUnplugged work, which is an experiential learning approach to introducing fundamental concepts in computer science to children, using physical or pen and paper activities rather than a computer (Cortina, 2015). The activities are intended to be adaptable for diverse groups of children and are designed to be gender-neutral. The CSUnplugged materials were, therefore, a good source of ideas for the Girlguiding activities with the important difference that CSUnplugged is intended for use in schools by teachers.

Design requirements and constraints

The brief was to develop a series of six 'Skills Builder' group activities, spanning across the different levels of Girlguiding. While the level 1 activity would be aimed mainly at Rainbows, and the level 6 activity aimed mainly at Seniors, each of the six activities could be undertaken by girls in different sections. This was to cater for the diversity of Girlguiding membership, which varies widely within and between units.

The activities were to be presented on activity cards which are attractively illustrated laminated A4 cards. The activity cards were written for the girls rather than the adult readers, apart from an occasional "Notes to leader" advisory section. The activities were required to be facilitated by non-specialist volunteers with no assumed prior knowledge of CS, and these volunteers would not undertake training to deliver the activities. The girls were also assumed to have had no prior experience of computational thinking at school, and unpredictable previous experiences of computer science teaching as it is relatively new in the school curriculum. The activities needed to be accessible by a range of different ages of girls and by girls with different additional support needs.

Girlguiding requested that the activities be fun and different in tone and style from the types

[3] https://www.girlguiding.org.uk/making-guiding-happen/how-were-being-our-best/were-going-on-a-journey/unit-meeting-activities/

of activities the girls would encounter at school. The activities needed to be active, lively, with minimal writing or calculating. The activities were required to not involve technology or computers in any way, due to the lack of access to such resources, or facilities such as Wi-Fi, at Girlguiding venues. Resources used as part of the activities needed to be very low cost and readily available, such as basic stationery. The venues were likely to be sports halls and church halls, with no presumed access to outdoor spaces. The timescale for the activities needed to be undertaken within one meeting, generally within an hour. Subsequent unit meetings would most likely vary in their focus of activity, which meant that there was limited scope for immediate follow on activities that explore the topic further. Nevertheless, because the activities link to girls working for their badges, there is progression across the activities designed, evident in the description of materials (Table 1).

The researchers deliberately aimed to develop activities which might appeal to girls with a wide variety of interests, avoiding topics and themes stereotypically associated with young girls, reflecting the aims of Girlguiding's revised curriculum.

Description of materials

An overview of how each of the activities relates to the elements of computational thinking identified in Grover and Pea's review of computational thinking (Grover & Pea, 2013) is shown in Table 1. The activities for the younger learners (Gobots, Move and Shake) were designed to cover a smaller number of elements as an introduction to computational thinking, whereas the activities for the older learners (Arcade's Alive and Escape Rooms) were intended to be more complex and include practice in more of the computational thinking elements. Each activity was initially designed to be completed in under one hour, although the testers suggested alterations to this for particular activities as documented in the result section.

	Gobots	Move and Shake	It's on the cards	Binary Beads	Arcade's Alive	Escape Room
Abstractions and pattern generalizations (including models and simulations)			X			
The systematic processing of information	X	X	X		X	X
Symbol systems and representations				X		X
Algorithmic notions of the flow of control	X	X			X	X
Structured problem decomposition (modularizing)		X			X	X
Iterative, recursive, and parallel thinking		X			X	X
Conditional logic			X			

Efficiency and performance constraints			X			
Debugging and systematic error detection	X	X			X	X

Table 1. Computational thinking elements in each activity

1. Gobots

The Gobots activity was designed for the 5-7-year-old Rainbow group. It is an unplugged activity which focuses on following and issuing clear instructions. The children draw instructions on a series of sticky notes, using a set of four symbols (↑, ↓, ↶, ↷), which their friends then follow to navigate around obstacles in the room. The text linking the activity to concepts in computing reads "*We can tell robots and computers what to do by giving them instructions. Robots or computers only follow instructions; they can't think for themselves! If the instructions get mixed up, the robot or computer won't do what you want. These mistakes in computer instructions are called 'bugs'.*"

This is a familiar type of activity within computing education in the early years. It is analogous to physical computing activities which involves programming toy robots (such as Beebot) to navigate to a destination and other unplugged activities in which the learners instruct another human to perform a series of operations (such as Phil Bagge's jam sandwich activity[4]). The aspects of collaboration and communication make the activity potentially more challenging than programming a device requiring them to be metacognitively aware of the processes for both giving and following instructions.

2. Move and Shake

This activity is aimed at 7-10-year-old Brownies. The girls learn a dance and then decompose the dance into a series of moves represented as instructions on sticky notes. The instructions are written as body part objects (e.g. "left hand") paired with actions (e.g. "place on right hip"). Repeated instructions can be shown with arrows and numbers next to sticky notes. After writing down an existing dance sequence, the girls are asked to create instructions for a new dance and share them with another group.

The text which explains how the activity relates to computing is as follows "*What's dancing got to do with computers? A set of instructions put into an order (like your dance moves) are called 'algorithms'. Computers can't think for themselves they only follow instructions, so we give them algorithms so they know what to do. Someone who writes algorithms for computers is called a 'software developer'. When she's writing them she'll look for patterns of instructions that are the same and use a loop to repeat them - just like you might have done! This makes the instructions easier to read and write*."

This dancing activity also focuses on expressing instruction clearly, this time introducing a

[4] http://code-it.co.uk/unplugged/jamsandwich

wider set of instructions and the concept of iteration. It is similar to other computing education activities such as Barefoot Computing's Decomposition Unplugged lesson.

3. It's on the Cards

This trading card activity was designed for Brownies and Guides (age range 7-14) (see Figure 1). It is intended to introduce the concept of structured information and show how information can be sorted according to different attributes. The girls first play an existing Top Trumps card game (or similar) to understand how the principles behind the game work. There are many different themes of trading card packs, but they all consist of a set of cards. For example, each card represents a single character or animal and with numerical scores for a series of attributes (e.g. the dinosaur pack uses attributes including length, weight, killer rating, intelligence). A player proposes an attribute and her opponents consult the top of their card stack to find the numerical score for the specified attribute for that character. The player with the highest numerical value on that attribute gets her opponent's card and takes the next turn.

After trying out a premade game, the Brownies propose their theme for a new trading game and decide on the attributes. They make a card set, then practice sorting it according to different attributes. They then review and amend the trading card game rules and ask another group to playtest it.

The original text which explains how the activity relates to computing is as follows (this was subsequently edited following feedback).

"*In Computing Science it is important to be able to store information in a sensible way so we can find things quickly. A lot of electronic information is stored in a database, and many of the websites and web services we use are stored as databases (Google, Facebook, BBC.co.uk, Netflix, Amazon and Spotify are all big databases). The cards made by the Brownies are like a little database, although they're printed on card not stored on a computer. Each card is a record, collecting information on one thing like a film or a sports team. Every piece of information on the cards is called a field.*

Databases are most efficient when they are sorted in a logical order. It's not so important when there are only 20 or 30 records or cards, but it becomes really important when you think about the huge number of records stored by some companies. When a database is sorted into a logical order then you can find information a lot faster."

Sorting activities based on trading cards are used as an example in the Teach Computing Science curriculum guide for Early Years and Primary teachers in Scotland[5].

[5] www.teachcs.scot

Figure 1. Sample activity card

4. Binary Beads

This activity is intended for Guides (aged 10-14 years). The girls learn about ways to encode information and practice sending codes to each other, before using an ASCII to binary table to translate the letters of their name into binary. They then use two different colours of beads to represent the encoding of their name and make them into an accessory. The explanation for the activity reads: "*In Computing Science, a software developer will encode information in lots of different ways when she is working. She will plan out a program in English and then she will write in programming code such as Python, Java or Ruby. This will then be changed into binary, that computers can understand but humans can't read very well!"* (Note that we deliberately left out all the stages involved in compilation to keep the key message simple).

Significant to the rationale for this task is that the resources required by Girlguiding units were likely to be readily available. By changing the pedagogical intention, the traditional "crafting" was repositioned to facilitate a 21st-century objective.

Binary Beads is a computational crafting activity similar, for example, to Karen Petrie's binary loom bands task[6].

5. Arcade's Alive

This activity is designed for Guides and Seniors in the age range 14 – 25. The girls are asked

[6] https://www.youtube.com/watch?v=4Q3IUIgBOss

to design a real-life video game, with other guides acting as non-player characters. They must decide on the rules of the games, and a set of game objects and actions which can be performed on them. The rules are a series of conditions for the player, such as "If you reach the wall, then turn around 180 degrees." The girls also design rules to maintain the state of the game world using variables e.g. "If you hear a Guide shout 'lose a life!' then take one point away from the 'lives' variable." The activity aims to give the learners the experience of designing and debugging a set of interacting rules for a system, in an event-based model such as would be used in a children's programming language such as Scratch but using an unplugged approach. The unplugged aspect of the activity allows the learners to focus on a system without getting distracted by the syntax of a programming language.

The explanation relating the activity to computer science is as follows:

"*In Computing Science, a software developer will plan her program or game very carefully. It is important to figure out what each of the parts of the program will do, and how they interact. A prototype is an early model of a game or program which a developer will use to test her new ideas. Testing is important at each stage of development as a developer will need to make sure that people like playing her game and that it isn't too easy or hard.*"

6. Escape Room

This activity is for the Seniors section (aged 14-25). Escape Rooms are themed interactive puzzle games, often run by commercial organisations in a dedicated venue, although there are also downloadable Escape Room instruction packs which can be tried at home. The aim of the game is for a team of people to complete a series of challenges (such as logic puzzles or decryption exercises) set within a fantasy narrative framework before a time limit expires. In this activity, the girls are asked to think of a theme and a set of puzzles for an escape room of their own, create all the materials and then ask a group of friends to try it. An example theme/narrative suggested in the instruction card is "*Escape Tent: Your Guide Leader is the best in the world…. except for camp cooking. She's awful at cooking camp meals. Tonight, she's going to cook chilli with her special top-secret Ingredient X. All the other patrols have ganged up on your patrol and have trapped you in the store tent. You will only be allowed out if you manage to steal the mystery yucky ingredient from its ultra-secure storage and prevent everyone from eating a horrible meal.*"

There are various connections to computer science in this activity. For example, the participants could devise puzzles which are related to aspects of computing such as decoding messages from binary/ASCII. It also requires the designer to think of a sequence of activities which the player must complete to achieve an end goal. This is similar to the Arcade's Alive activity, but it is more complex because Escape Room players can generally choose to tackle the tasks in any order, or in parallel (if playing in a team). The designer must, therefore, reason about the dependencies of each task, and decide to what extent strict ordering should be enforced – should the players complete sub-task a) before sub-task b), or can they be completed in any order? Ordering can be enforced by giving the player a physical object (such as a key) or a piece of information (such as a password) when they complete one subtask and requiring that object or information to complete the next task in the sequence. The text on the activity card connects the task to computer science in the

following way:

"*When we try to solve problems in Computing Science, such as creating a mobile app or designing a computer game, we first break down the problem into smaller chunks that are easier to solve. This is called 'decomposition'.*

When a software engineer plans a computer program, she will first work out the inputs and outputs for each section of the program. For example, if the developer is making an app to make secret codes, the section of her program that encrypts the message will need an input of the message in English, and it will output the secret coded message."

Evaluation

Evaluation focus

The purpose of this evaluation is to illuminate the issues which arise when CS education researchers work with partner organisations to produce and disseminate educational materials. As the materials were informed by existing unplugged approaches to computational thinking which is a well-established technique within computer science education, we chose not to focus our evaluation on learning outcomes relating to computational thinking. Rather than consider whether this particular instantiation of an unplugged approach helped to promote computational thinking in an ideal setting, we decided to explore wider issues of whether this approach to computer science education would be acceptable to learners and educators in a messy real-world setting. This is an important aspect to evaluate because computer science education research is at its most valuable when it impacts young people in learning environments which they encounter as part of their everyday lives. In answer to question 1, descriptive quantitative and qualitative results which evaluate the suitability of the materials are reported in the Results section.

To promote computer science education, researchers often enter partnerships with educational policymakers and delivery organisations which have wider agendas and priorities of their own. In this case, the partner organisation was engaged in a much broader process of educational change of which our agenda of computer science education was a small aspect. Girlguiding offers rich informal learning experiences to girls, but as a charitable organisation largely staffed by volunteers it has constraints on the training opportunities offered to leaders which are likely to impact on educational quality. Part of the evaluation, therefore, was to discover how feasible it is for non-expert volunteers to deliver computer science education based on a set of printed materials designed primarily for the learners themselves (question 2). In the Discussion and Reflection section, we further reflect on the leaders' perspective from the evaluation, considered in juxtaposition with the learners' views, insights from the literature, educational policy and current practice in schools.

Participants

A total of 483 child participants from 38 units tried the activities, as part of a wider pilot testing exercise run by Girlguiding to evaluate the new materials across multiple topics. The

questions and sampling methods were chosen and executed by Girlguiding who then shared the data with the research team. Units volunteered to take part in an evaluation of new materials, and were randomly allocated to try an activity. The subset of volunteer units who evaluated the suite of Innovate materials tested only one computational thinking activity each. It is worthy of note that the units in the testing pool were directed to test particular activities, which does not reflect the pedagogical choice that is typical of the leaders and girls for most Girlguiding unit meetings. The unit leaders who undertook to test the materials did not receive training about the content of the computational thinking activities before delivering them, as this would also be the case when the materials became mainstream.

Unit leaders used the activity cards as an activity in a normal unit session. At least one other adult was present, as is Girlguiding policy, but data was not collected on how many leaders helped run each activity. After the activity, they were requested to ask the girls a series of questions about the activity as shown in Table 2. The leaders asked the questions verbally and wrote down responses which were given with shows of hands and spoken comments. For example, the leader would read out a question with the potential answers such as "How clear were the instructions. Hands up if you think they were not clear… now hands up if they were just clear enough…" while counting the hands raised in response to each option. The leader was also instructed to ask open-ended follow-up questions such as "What would make the instructions easier to understand? Please tell us if there were any steps you didn't understand" and write down the girls' comments. After the session, one leader to represent each unit entered the girls' responses into a web form, and also answered the online question set shown in Table 3 from the perspective of the leaders.

Data collection

Girlguiding summarized the feedback and prioritized the participants' suggestions for changes to the material. The target scores which Girlguiding aimed to achieve for each question across all their activities are shown in the rightmost columns of Table 2 and Table 3. The research team and Girlguiding collaborated to implement these changes as far as possible before the final copies were sent to a graphic designer. The final versions of the cards are now available for unit leaders to purchase on the Girlguiding website[7].

	Question	**Response options**	**Girlguiding target**
1	Overall how much did you enjoy the activity?	5 point scale. 1= I didn't enjoy it , 3 = it was OK, 5 = I really enjoyed it.	Scores between 3.5 and 5
2	Overall, how challenging did you find the activity?	5 point scale. 1 = too hard, 3 = just right, 5 = too easy.	Scores between 2.5 and 3.5

[7] Innovate skill builder activities available at http://www.girlguidingshop.co.uk

3	Looking at the 'Aim of activity' and 'What you'll get out of it' on the front of the card – were these met?	5 point scale. 1 =yes, 3 = somewhat, 5 = no	Scores between 1 and 2
4	Please explain your answer or tell us if you got anything else out of the activity;	Open-ended	
5	How clear were the instructions? Did they make sense?	5 point scale. 1 = not clear, 3 = just clear enough, 5 = very clear	Scores between 4 and 5
6	What would make the instructions easier to understand? Please tell us if there were any steps you didn't understand.	Open-ended	
7	Were you able to play a part in running or leading the activity?	1 = yes, 2 = somewhat, 3 = no	Scores between 1 and 2
8	What would make it easier for you to lead some of the activity yourself?	Open-ended	
9	Is there a way we can improve the activity not covered in the previous questions?	Open-ended	
10	Is there anything else you want to tell us about the activity?	Open-ended	

Table 2. Evaluation questions for girls

	Question text	**Response options**	**Girlguiding target**
1	Overall, how challenging did the girls find the activity?	5 point scale. 1 = impossible	Scores between 2.5 and 3.5
2	How clear were the instructions?	5 point scale. 1 = unclear	Scores between 4 and 5
3	How could the instructions be made clearer?	Open-ended	
4	Were there any particular steps which you feel could be clearer?	Open-ended	
5	Looking at the 'Aim of activity and 'What you'll get out of it' on the front of the card – were these met?	5 point scale. 1 = no	Scores between 4 and 5
6	Please explain your answer.	Open-ended	
7	Was it easy to adapt the activity to meet the	5 point scale. 1 =	Scores between

	needs and requirements of all girls?	no.	2 and 3
8	Please explain your answer.	Open-ended	
9	Were the girls able to take a leadership role during the activity?	5 point scale. 1 = no	Scores between 2 and 3
10	What would make it easier for the girls to lead some of the activity?	Open-ended	
11	Is there a way we can improve the activity not covered by the previous questions?	Open-ended	
12	Is there anything else you would like to tell us about the activity?	Open-ended	

Table 3. Evaluation questions for unit leaders.

	Name of activity	Number of units which tried materials	Number of participants	Average time to do activity (minutes)
Stage 1 Rainbows	Gobots	6	107	44
Stage 2 Brownies	Move and shake	6	118	37
Stage 3 Brownies and Guides	It's on the cards	10	135	28
Stage 4 Guides	Binary beads	6	53	65
Stage 5 Guides and Seniors	Arcade's alive	6	44	45
Stage 6	Escape room	4	26	67

Seniors				

Table 4. Evaluation participants for each activity

Analysis methodology

The mean scores were calculated for learners and leaders for each activity for the rating scale questions (1,2,5,7 and 9) and compared to the target score set by Girlguiding.

Thematic analysis of the open-ended questions (3,4,6,8,10,11 and 12) was conducted using NVivo (Hayes, 2000). The first author familiarised herself with the data by reading through the open-ended comments. She then worked through the answers to each question in turn, coding the content according to the initial themes, and identifying emergent themes. The themes were checked by the co-authors. The analysis was partially deductive, based around initial themes pre-identified as goals of Girlguiding: challenge, adaptivity and the potential for leadership (questions 1, 8, 9 and 10) and improvements to the clarity of the material (Questions 3,4 and 11). Additionally, themes relating to enjoyment and computer science content of the materials emerged from the open-ended comments (often in answers to questions to 3, 4, and 12). Analysis of the leaders' comments indicated underlying attitudes and knowledge about computer science and the girls' abilities which are reported in the Results section under the relevant theme. We reflect further on the attitudes and knowledge of the leaders in the Discussion and Reflections section when considering the answer the Question 2 about the ways in which researchers can work in partnership with voluntary organisations.

Results

Quantitative scores

The mean scores for each question and the Girlguiding targets are shown in Table 5.

	Enjoyment	Challenge		Aims met		Clarity		Girls as leaders		Adaptivity
	Girls	*Girls*	*Leaders*	*Girls*	*Leaders*	*Girls*	*Leaders*	*Girls*	*Leaders*	*Leaders*
Gobots	2.9	2.3	1.5	2.3	2.2	3.0	2.7	**1.8**	**2.0**	1.7
Move and shake	**3.7**	**2.8**	2.2	**1.5**	3.7	2.8	2.5	**1.6**	**2.3**	**2.5**
It's on the cards	**4.0**	**3.2**	**3.0**	**1.4**	3.7	3.5	3.2	**1.5**	**2.5**	**2.6**
Binary beads	**3.5**	**3.3**	**2.8**	**1.7**	3.3	3.1	2.8	**1.9**	**2.7**	**2.3**
Arcade's alive	**3.7**	**3.5**	**3.3**	**1.8**	**4.2**	3.8	3.8	**1.5**	**2.8**	**2.2**
Escape room	3.0	**2.8**	**2.8**	**1.2**	**4.5**	**4.2**	3.5	**1.7**	**3.0**	**2.3**

Table 5. Participants' evaluations of activities (average scores). Bold text indicates activities which met Girlguiding targets.

In terms of enjoyment, four of the activities met Girlguiding's target (3.5- 5) – *Move and Shake*, *It's on the Cards*, *Binary Beads* and *Arcade's Alive*. *Escape room* and *Gobots* were rated on average as 'OK' (around 3). Five of the six activities met the target challenge rating (according to the girls themselves), while *Gobots* was very slightly out-with the target range at 2.3. In all activities, the leaders estimated the challenge for the girls to be higher than the girls' perceptions. According to the leaders' views, *Gobots* and *Move and Shake* were too hard. The girls thought that the aims were met for five of the six activities, with *Gobots* slightly outside the target. In contrast, for the leaders, two of the activities met the aims, three met the aims "somewhat", and *Gobots* did not. Only the *Escape Room* task met the Girlguiding target of over 4 for clarity (from the girls' point of view) although all but the *Move and Shake* activity were considered to be "just clear enough" or better. Again, the leaders gave consistently lower ratings for clarity, with the ratings ranging in the 2-3 band. Both the girls and the unit leaders considered that the activities offered opportunities for leadership roles, meeting the Girlguiding targets. All but the *Gobots* activity met the Girlguiding targets of being easy to adapt for unit leaders.

Qualitative feedback

The leaders and girls offered considerable feedback on the materials, much of which was related to minor editorial or graphic design issues or suggestions relating to activity timing. These comments were used to revise the materials before publication.

In general, the feedback was mixed depending on the textual feedback. As one Brownie put it "we are not all the same, what is fun for one is not fun for others." The same activity (*Binary beads*) was described as "fun and creative while being enjoyable for all...very snazzy" by one group, while another group pleaded "Don't inflict it on other Guides please". As another illustration of the power of personal preference, a Guide leader said "When testing a previous challenge one of the guides said if this was what the new programme was going to be like she would leave guides. After testing this she loved it and said she would stay!". The *It's in the* Cards Activity was best received, attracting positive comments such as "Enjoyable", "Exciting", "Mindblowing", "Unicorn-y", "Excellent", and no negative comments. The *Gobots* activity had the most negative feedback, particularly from the leaders. This was mostly because it was considered too challenging for the age group, as described below.

Girlguiding has a focus on developing leadership skills in the girls. The activities designed for the older girls (*Escape room* and *Arcade's alive*) worked well in this respect e.g. a guide leader who tried *Arcade's alive* wrote "the girls took charge from the beginning as soon as they heard the word 'computer'. They all worked as a team and everyone's views and opinions were taken into account". Although one group of seniors requested "options for how we can run this more independently", the younger girls did not always want to be in a leadership role. One Brownie said "I didn't want to lead", but that she might when she was older, a pattern noted by a unit leader who said that the older girls tended to naturally take a leadership role. Some of the activities for Brownies enabled the girls to lead, but this was less common for the Rainbows. One reason for this was the challenging nature of the

activity; another reason may be that the Rainbow leaders did not consider it appropriate. For example, one Rainbow leader wrote: “In our unit (we are in a deprived area and have to deal with a lot of behaviour issues) we tend to lead activities for the girls, as the girls cannot run activities for themselves”.

The analysis below focuses on substantive issues which can inform the design of other computer science materials for informal learning settings in the future.

Computer Science content

The feedback from the Rainbow unit leaders on the *Gobots* activity was that “it was difficult to get the Rainbows to understand the concept of giving step by step instructions”. One noted that “some of the older girls could vaguely get the idea of what they were doing if they were led through each stage one on one by an adult. However, with a group of 19 girls = 10 pairs, we didn't have 10 adults to walk them through it and essentially 'dumb it down' enough for the 5 and 6-year-olds to grasp within the time frame." This problem was exacerbated by the children's difficulty with executing the instructions to be sequenced, and their developing literacy (see below). The leaders and girls had difficulty relating the activity to concepts in computing: "The girls learnt how to give instructions, but I don't think it helped them understand how computers work or how to fix problems. Possibly as we did not have enough time to go into that much details, unfortunately", "The Rainbows couldn't relate to a computer. They seemed to understand following instructions but not how it related. They lost interest half-way through as they didn't understand."

Feedback about *Move and Shake* suggests that there is an age dimension to linking computing with the activities*:* "most of our unit are only 7 so they totally missed the link with computers. They needed prompting each step by the leaders. The older girls got a lot from it." Another leader said, "I got it, but talking to the girls afterwards it clicked with a few but seemed a bit abstract to what they had been doing". With this particular activity, the separation of object and action caused some confusion: “They didn't understand about putting the object on one post-it and the action on another. They wanted to write the whole action for each move on the same post-it.”

There were also queries about how *It’s in the cards* related to computing concepts: "We felt this could be two activities. One that concentrates on a computer database and one that makes a card game. For the first activity, it would be easy to get the girls to create a database of information about themselves e.g. height, age, school year, six, eye colour, hair colour etc and then get them to organise themselves as quickly as possible into different orders which was the aim and outcome stated in this activity. A second activity could be creating your own trump card game in groups and then playing”. Another unit leader said: “Are you faster that [sic] a computer? Brownie age have no concept of this idea. The girls need to have an understanding about excel. We don’t use computers at Brownies neither excel at school so they cannot link to this topic.” In addition, the database aspect of the activity was thought by one unit leader to be off-putting: "Not sure the link between computer database and ‘Top Trumps’ was understood. The Brownies liked the idea of making a game that they could then play again, but lost some interest when it started talking about databases etc - one girl said ‘this is like school, why do we have to do it here? ’” The

Move and Shake activity was also noted to have been covered at school by some girls: "This is very similar to a Barefoot computing activity so take care to not make it too much like the computing curriculum for primary schools."

Similarly, there was feedback about *Binary Beads* which pointed out that the children had already done binary at school and so they considered it to be boring: "A lot of the girls have covered binary in school so it wasn't fun for them. I appreciate the attempt to inspire them for computer science but surely it could be made more exciting? My group also hate crafts and felt it was too crafty." The last sentence of this comment illustrates that while many Girlguiding activities in the past have focused on crafts, it is not universally liked by girls. In contrast, there was also positive feedback about the computing content of Binary Beads: "[the girls] produced feedback indicating they felt they had achieved these [the aims]. We also had a parent tell us that they thought this was a very good activity and that their daughter understood what binary code was".

There was some appetite for additional activities with computing content. A Guide leader commenting on *Arcade's Alive* said: "I think this would also be useful to show the various ways that coding could be used in the real world so that they realise it is not just a 'fun' activity but actually has a purpose and they could pursue this as a career." "The girls felt it was relevant to today's society. One group took a little over the 60 mins. It would be easy to take this further by coding their ideas into a game on the computer after trying it by walk through". A unit leader wrote about the positive experience her group had with the *Arcade's Alive* activity and how it has inspired further computing learning for one guide: "One guide, who goes to an after school computer club is going to have a go at making the game… This activity was brilliant and we spent the evening laughing. It really captured their imaginations."

Challenge

The *Gobots* activity was considered to be too difficult by all the leaders. The difficulty lay not so much with the computer science content of sequencing, but with the underlying instructions which were to be sequenced. A Rainbow leader wrote "The girls struggled to grasp the concept of the simplest of commands - like turn 1/4 or turn left or right. Most of the girls could not work out their left and right, and even when told they couldn't remember for when they had to make a set of instructions." The Rainbow's developing literacy was another issue; the leaders recommended minimizing the amount of reading and writing required as some of the girls "struggle to write their own name".

Arcade's Alive was considered to be too easy by one Senior group "This type of activity may suit some senior section units but it is something they cover in a much early stage of school life so they felt it would be more suitable for guide age". Note that this activity was originally planned to be for the younger age group and was changed to be aimed at the older age group by Girlguiding. However, the difficulty level of this activity will vary greatly depending on the computer game chosen or planned by the girls.

The other activities were generally regarded to have appropriate levels of challenge for the intended age groups. The girls' disinclination to read and write during unit meetings was a

theme, either because it was difficult for the younger girls or because it was associated with school. For some, activities which seemed too structured were off-putting. A guide leader commented that "they felt it was too structured an activity they like to be more relaxed in the meeting environment as they have enough structure in school". Some seniors commented that they weren't motivated to finish an activity after a day at school or college.

There were several comments from unit leaders about how the girls who had no prior experience or understanding of the domain from which the example was drawn would find the activities more challenging. For example, concerning *Arcade's Alive*, a leader noted: "Some girls don't play the range of computer games, they play on their phones and some play Sims games (for example), so the girls who do play computer games got frustrated trying to explain it. I do not play computer games but it would have benefited me to do so beforehand." Similarly, it was thought that having previously participated in an Escape Room would be advantageous.

Adaptations and demands on leader's pedagogy

The unit leaders' responses indicate that they were willing and able to adapt the materials to the needs of the girls in their units. When she noticed that the younger Rainbows were struggling with Gobot, a unit leader "became the Robot and the girls took it in turns to direct me through the maze and I followed their instructions (even when I knew it wasn't going to work) they helped each other to solve the problem and come up with a different movement/direction." A Guide leader gave thought how to make the activity inclusive: "I have two special needs girls. By working in a team, the girls were included in the planning", and another took care to adapt the formatting of the ASCII table in *Binary Beads* in advance for a dyslexic Brownie. Other leaders changed the activities to use stationery resources that were available to them.

Some leaders also offered suggestions for extensions to the *Binary Beads* activity such as "You could do it as a larger size activity where they could spell things out for each other on a skipping rope for example, in a big group" and "We added an extra activity - we used a pack of ordinary cards (shuffled) and shared them out equally amongst the group. They then had to put the cards down in order to create 4 suit piles starting with the Ace and ending with the King. It helped them understand the process of a computer comparing information and putting it in order".

Actions taken to improve the materials

Girlguiding, who described the evaluation feedback as "very positive', decided to publish all of the activities after another round of edits. Many of the changes involved minor changes to the wording, re-ordering of content, and the introduction of pictures and other graphic design elements.

The *Gobots* activity was shortened to a 30-minute activity, and the instructions were constrained so that the girls were told to give instructions for the Gobot to get across the room and avoid obstacles. A prompt to put an elastic band on the left wrist as a mnemonic was inserted into the instructions.

Move and Shake was also shortened to 30 minutes, and the separation of object and action was removed. More context about databases was introduced to *It's in the Cards*. An additional cypher activity was introduced to *Binary Beads* to make it more active, and the task was changed to decoding someone else's bracelet instead of making a new one. Example puzzles were added to *Escape Room* to give the Seniors ideas, and the activity was split over two sessions to give the girls more time to complete it. *Arcade's Alive* remained unchanged apart from minor edits.

Suitability of the materials: summary

Q1: To what extent do girls and leaders find the activities to be suitable (in the sense that they are enjoyable, challenging, adaptable and offer scope for leadership opportunities) within the informal learning context of Girlguiding units?

The evaluation of the materials was intended to gather feedback to improve them for final publication. The findings, although not definitive at this stage, may be of interest to others who wish to introduce computing concepts to girls in an enjoyable and accessible way. The combination of the materials in the Girlguiding context shows some promise in addressing the factors which Cheryan and colleagues implicated in low participation of women in computer science (Cheryan et al., 2016). The activities enable girls to have early experiences of computational thinking (starting at 5 years old), without the potentially discouraging effects of a masculine environment in a way which could build self-efficacy towards computing.

Although further work would be required to examine self-efficacy of the Girlguiding members in the longer term, there are positive signs. The girls generally enjoyed the activities and considered them to be appropriately challenging; both requirements for the development of self-efficacy. The activities were successful in their attempt to encourage the girls to take a leadership role, which also could build self-efficacy and autonomy for future encounters in mixed environments. This opportunity to develop materials for Girlguiding is a small, but hopefully significant, step towards beginning to create new spaces for girls to exercise their skills in computational thinking. As the leaders considered that the materials were suitable for adaption to the needs of particular learners, there is scope for the activities to be used within an inclusive approach which can enable all learners to thrive. The unplugged approach on which the materials are based is not just applicable for girls, but can be used when everyone learns all together.

Limitations

One of the limitations of this study is how feedback was gathered from the girls at the end of the unit meeting. As they did not have access to computers and Girlguiding deliberately keep writing activities to a minimum, the leaders wrote summaries of the girls' verbal answers afterwards. As a result, some of the answers may have been recorded incorrectly or lost. There may be a social desirability response as a result of collecting responses by a show of hands; the girls may be less honest when asked to reveal their views as part of a group.

This method was used as a trade-off in collecting data from girls under resource and time constraints. Additionally, Girlguiding does not collect demographic/socio-economic information about their members or participants in the survey so this information is not available to aid interpretation of results.

Discussion and reflection: Lessons for researchers for future partnership work

Q2: What lessons can computer science education researchers learn about the large scale roll-out of computer science education materials to informal learning environments, in partnership with a voluntary organisation?

Designing computer science education materials to be delivered through highly constrained printed materials by non-expert volunteers is extremely challenging. The materials must not only cater for learners with diverse interests and prior knowledge but also be suitable for delivery by leaders with different educational backgrounds and computer science content knowledge.
A strength of working with Girlguiding is that their focus is on providing positive environments for girls; Girlguiding volunteers are committed to and skilled in supporting the engagement and development of girls. They are likely to be less skilled at teaching computer science concepts, as discussed below, and are likely to require additional training to develop their domain and pedagogical content knowledge. However, there may be much which computer scientists can learn from organisations such as Girlguiding about creating environments which are not "chilly" (or indeed discriminatory, unfair or hostile).
The general approach of working with partner organisations which have deep understanding of the needs of particular demographic groups (e.g. underserved communities, or neurodiverse learners) could be fruitful to make CS Education more inclusive.

Avoiding duplication between informal and formal learning environments will become increasingly problematic

The results of the evaluation highlight emerging issues about how computing learning in informal settings relates to the formal school curriculum. Within England and Wales (where the study took place), computing has been embedded in the curriculum since 2014. Children at Key Stage 1 (roughly ages 5-7) should "understand what algorithms are, how they are implemented as programs on digital devices, and that programs execute by following precise and unambiguous instructions". They should be able to "create and debug simple programs". From this point of view, the original *Gobot* activity was a suitable unplugged activity which is consistent with these objectives, and yet the leaders considered it to be too challenging for the 5-7-year-old Rainbows. There are three reasons why this could be the case in an informal learning setting. Firstly, the age range is wider in a Rainbows unit than in a typical primary school classroom so the leaders are working with some children who are beginning to be able to grasp the computing concepts but need more support, alongside other children who are already confident in these topics. Also, the children may come from different schools and classes with a variety of approaches to building the foundational skills required for the activity. Thirdly, the leaders are volunteers who have not participated in formal teacher education, and could consequently be less skilled at supporting learning than class teachers.

They do not spend as much time with the children as teachers each week and are unlikely to have the context of what each child has learned already across the curriculum. The National Curriculum in England and Wales includes geometric concepts of position and movement which underlie the *Gobots* activity for Year 1 learners. Leaders would be unlikely to know which girls are already secure with these concepts (or indeed the concept of algorithms from the computing curriculum), or how to support them in developing their understanding. These factors explain why the *Gobots* activity was particularly hard to support.

The Royal Society has characterised computing education in the UK as "fragile and patchy", identifying the need for teachers to participate in more continued professional learning in this area. Some of the girls had already encountered computing concepts such as binary or databases or had taken part in similar unplugged activities at school. The participants in this study did not want to do activities with Girlguiding which seemed too much like school. The original intention of this project was to provide an introduction to computing concepts to this group of learners in an informal learning setting partly because it is not yet firmly embedded in schools and we believe that girls should have opportunities to learn about computing. As computational thinking and computing in general gradually enter mainstream schooling internationally, providers of computing materials for informal educational settings will need to consider the issue of how to design materials which do not duplicate school work. This will be challenging, particularly for settings with constrained design briefs for materials such as this one. In the future, it may be that a certain amount of computational background can be assumed to have been adequately covered in school and that activities for informal learning settings can be designed to augment or deepen existing knowledge or cover interesting side topics rather than introduce concepts.

Volunteer leaders differ in terms of content knowledge, pedagogical experience and biases

Further research is required to explore some of the challenges highlighted by this study, relating to a pedagogical focus on developing opportunities in teaching computational thinking. Some of the functional and strategic difficulties indicated by the leaders may reflect limitations in their knowledge and understanding of how core concepts such as giving instructions relate to computer science.

There appears to be a disconnect reflected in both the results of the participants' evaluation of activities and the Girlguiding (2017) girls' attitudes survey between the perception of the girls and leaders about the "difficulty" of tasks/ the girls' capacity to engage. While some of this difference could be accounted for in terms of the leaders simply not being familiar with girls' prior experiences, knowledge and understanding, the evidence suggests that we should also hold in mind the powerful influence of stereotyping and limiting mindset that is highlighted by girls as problematic when engaging with computer science and STEM subjects in school. For example, in our findings, in all activities, the leaders estimated the challenge for the girls to be higher than the girls' perceptions.

Reflecting on this outcome in light of the research reviewed at the beginning of this paper, for example, Lang, et al's (2015) finding that even carefully designed intervention programmes have not changed girls' career interests towards computing re-directs our

attention to additional areas of challenge. Enhancing girls' engagement in computer science is not simply a matter of undermining gender stereotyping. There are also pedagogical challenges. The argument presented here can be aligned with a persistent challenge for inclusive education: where limitations on learning are falsely attributed to belonging to learners ("Our girls are not capable."). The implication is that significant progress in extending participation in computer science will not be achieved until the mind-sets of the teachers and leaders changes.

The volunteer leaders' views reflect a range of different backgrounds and computing experiences. This potentially made it hard for some to understand the underlying purpose of a computing activity. This is evident in the comments about databases and spreadsheets in particular. Some leaders interpreted computing to be about using software applications, rather than the intellectual discipline of computer science, a problem which was identified in a Royal Society report in the UK (Furber, 2012). Lack of technical self-efficacy and knowledge in instructors has previously been identified as a problem in computer science interventions for girls, even with qualified teachers (Lang et al., 2015). Unplugged activities often use physical metaphors to explain processes which are executed digitally. People who are unfamiliar with the digital version of the processes may be unsure of the connection with the real-world activities, particularly because noting underlying patterns which connect similar processes requires the capacity for abstraction, which is in itself a target skill to be developed in computational thinking.

One possible solution would be to offer (or require) additional training for leaders to help them to prepare to deliver the materials. However, this is unfeasible within a large organisation (Girlguiding has 100,000 volunteers) where the volunteers may deliver hundreds of different activities on a broad range of topics. Training time is very valuable and is likely to be devoted to the highest priorities of the organisation rather than any individual topic. The organisation considers their "five essentials" for adult leaders to be "working together in small groups, encouraging self-government and decision making, a balanced and varied programme which is girl-led, caring for the individual, and sharing a commitment to a common standard".[8] Short online videos to accompany the activity cards aimed at leaders who are looking for additional support to help them prepare to deliver a computing topic would be beneficial.
Another possible avenue would be to create a partnership between Girlguiding and volunteers in the computing industry (perhaps organised through an organisation such as ACM). This would enable girls in Girlguiding to benefit from the computational expertise of the computing industry volunteers, and the volunteers to benefit from working with Girlguiding leaders about how to promote supportive and positive environments for women. Existing Girlguiding volunteer leaders would also learn about computing topics by working with industry volunteers.

[8] https://www.girlguiding.org.uk/making-guiding-happen/programme-and-activities/the-five-essentials/

One-off sessions should lead to sustained learning

One-off activities may have limited value. Computational thinking is an approach to tackling problems, rather than a series of facts. It requires time and sustained effort to develop. Some participants in this study found it hard to see the connection between the activity and computing, which is not surprising given the word count constraints on the instructional text on the activity cards. Even with fewer constraints on the materials, it would be hard to develop a deep understanding of the connection between the unplugged metaphors and the target digital process in a single activity. One could argue that the learner requires experience and understanding of both the metaphorical process and the computational version of it before they grasp the connection. Otherwise, they have to take it on trust that such a connection exists which may lead to scepticism about the value of the unplugged activity, especially if the adults supporting the activity are also unaware of the connection.

In future work, we would like to collaborate with Girlguiding to design a set of optional in-depth materials for girls to study to gain badges or other awards. Such a course would have a mixture of plugged and unplugged activities and would focus on explaining how the unplugged metaphor relates to digital processes.

Learning from Girlguiding

Many CS educators are committed to addressing inequalities within computing. Often this is manifested in projects which encourage girls to study computing and consider it as a career. There is no doubt that the technology industry would benefit from the increased participation of women but does an individual woman benefit from participating in the technology industry? There is currently reason to doubt this, given the data on the gender pay gap and emerging evidence about harassment and discrimination in the industry. A fruitful area of research should, therefore, focus on how we can create respectful and safe environments in which diverse groups of young people can thrive as they learn computer science. There is much to learn from organisations like Girlguiding on this topic. Based on consultation work with girls, the organisation is committed to working towards a more respectful world "where people don't make fun of, hurt, or leave out others just because they're different, or because they're girls. One where we're able to express ourselves, both online and off, and feel safe when we do. And one where everyone understands the importance of being kind to each other: online, at school, wherever we are."[9] Girlguiding builds a safe and respectful environment for girls and helps them to develop for the future in various ways. They offer unit activities and badges across a broad range of topics to help girls develop skills in areas such as digital learning and STEM, as well as wider personal development topics such as developing personal identity, leadership and building confidence. However, the organisation does not stop at just upskilling individuals; it also attends to group interactions. Girlguiding purposefully develops each member's understanding and commitment to equality so that everyone knows how to support others in safe spaces and no-one feels the "odd one out". Girls are taught how to listen, negotiate, work and make decisions together, and respect the opinions of others. Furthermore, they

[9] From https://www.girlguiding.org.uk/girls-making-change/future-girl/respect-makers/

consult with girls who have the opportunity to influence decision-making at all levels of the organisation. Finally, the organisation undertakes to advocate on the behalf of girls to ensure their voices are heard on a wider stage (such as through publishing reports, media engagement and lobbying). It would be worthwhile to invest in research which focuses on interventions which improve hostile computer science environments. As well as thinking about how we can change girls' minds about studying computing, we could also think about how to change the minds and behaviours of those who undermine girls as they contribute to computer science. Teaching all computer science learners about listening to others, respecting their viewpoints and creating safe spaces for everyone to contribute would have great benefits for the technology industry in future years. If we are serious about increasing diversity in computer science, these values should underpin all of the teaching materials which we develop, should be embodied in all of our pedagogical classroom approaches and should be habitual in our professional practices.

This project did not focus on how to design materials to encourage *girls* to study computing, but rather considered how to design materials suitable for a wide range of *people* with diverse sets of interests. Although some of the materials were based on activities which Girlguiding have traditionally valued (e.g. dancing or crafts) as anticipated, the girls themselves did not universally enjoy these aspects. We encourage other educators to develop sets of diverse materials which draw on different skill sets and spark or deepen interests in a variety of topic areas. We should not assume that the best or only way to reach a target group is by relating computation to topics which are culturally stereotyped to be acceptable (in the UK for example stereotypes would be that girls will respond well to princesses, but boys will only like football). There are wide differences in preferences *within* gender groupings as well as between genders. As one of our participants wisely observed "We are not all the same. What is fun for one is not fun for others."

Conclusions

We produced low cost, low tech computational thinking activities to be used in Girlguiding meetings, to introduce girls to computing concepts in informal, supportive learning environments. The materials were regarded as suitable by Girlguiding in the sense that the girls found them to be enjoyable and challenging, while the leaders found them to be adaptable and offering scope for leadership opportunities. Researchers who are considering partnerships with educational organisations or charities may benefit from the following summary recommendations arising from the evaluation and reflection presented in this paper:

- Consider the skills of the adults who work with the young people: is it realistic to expect them to know or learn about computational thinking?
- Learn inclusive practices from partner organisations which excel at fostering positive, supportive environments for everyone;
- Monitor the local curriculum and current school practices about computational thinking to avoid duplication between informal and formal learning;
- Where possible, develop materials in sequences rather than for single one-off sessions;

- Develop materials which will be of interest to a wide range of people with diverse interests, rather than girls in particular.

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