Teacher Experiences of Learning Computing using a 21st Century Model of Computer Science Continuing Professional Development

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Abstract: Computer Science (CS) is a subject which is perceived as a difficult to learn and to teach. Building on previous work (Fisher et al., 2015), which explored post-primary school teacher reactions to a social constructivist Continuing Professional Development (CPD) Programme in CS, this paper explores the same teachers' experiences of learning CS during the workshops. The CS CPD workshops were delivered using the Bridge21 model of 21st century teaching and learning. This paper examines the extent to which the Bridge21 activity model proved effective in helping teachers learn computing knowledge and skills and explores teacher attitudes towards applying their new learning in the classroom. Nine workshops took place over the 2013/2014 academic year, resulting in 45 teaching hours and 110 teacher engagements. An exploratory case study approach informed data collection with comparative coding used to analyse results. Analysis indicates that peer-collaboration played an important role in assisting teachers develop computing knowledge and skills and that teachers intend to use the Bridge21 model to teach computing in their own classrooms.

1 INTRODUCTION

This study is situated within the context of 21st century education, where teachers are encouraged to use student-centred, technology-mediated teaching and learning strategies to help students develop 21st century skills (Walser, 2008). Technology-mediated learning experiences create rich contexts teachers can use with students to develop 21st century skills such as problems solving, team work and critical thinking (English and Sriraman, 2010). Problem solving activities used in a computing context enable students to put into practice digital and critical thinking skills.

Autonomous learning involves developing the confidence to apply learning strategies to solve complex problems (Boud, 1988). Teachers can empower students through facilitating technology mediated lessons which use problem solving as a way to help students develop problem solving strategies (Smyth and Banks, 2012). Technology-mediated, student-centred learning environments enable teachers to help students learn problem solving while also learning other 21st century skills such as critical thinking, digital expertise and collaborative working.

Teacher adoption of teaching methods designed to support 21st century learning coincides with the push by the European Commission to encourage schools to offer computer programming lessons in schools (EC, 2016). Against this backdrop the re-emergence of computing at secondary level across the United Kingdom (Brown et al., 2014), and within the Republic of Ireland (NCCA, 2014), has prompted CS educators to source Continuing Professional Development (CPD) in order to upskill themselves to meet the challenge of teaching CS.

The body of the paper is structured as follows. The literature review provides the rational which underpins the research questions and it is followed by an outline of the methodology used. The data analysis section describes the process used to code and interpret the data and the discussion section explores the study findings.

2 LITERATURE

Computer Science (CS) is perceived as a difficult subject to learn (Zendler et al., 2012), with computer programming perceived as being particularly difficult (Connell et al., 2015). Information Communication Technology (ICT) can play a key role in helping students access resources and are useful for helping

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students work through complex tasks (Brinda et al., 2009). Student-centred learning approaches use practical activities to help students develop key skills (Baeten et al., 2010) and when combined with ICT enables teachers to use problem solving as a way to encourage students to work through computing problems as a method of learning and understanding coding.

2.1 Teaching Coding in a 21St Century Style

Helping students learn computer programing or coding remains problematic (Connell et al., 2015) prompting teachers to seek assistance in designing innovative coding lessons. A 21st century approach to CS delivery, involving technology-mediated tasks structured around problem solving activities provides one possible solution, enabling students to develop a combination of social, technical and cognitive skills (Hazzan et al., 2014). Teacher CPD programmes using a 21st century approach enable teachers to obtain hands-on coding expertise in an environment designed to support technical knowledge sharing through peer collaboration (Bryant et al., 2006).

Exploring teachers' attitudes to CS CPD provides insight into what supports teachers need in order to teach computing in schools. This could range from assistance with developing content knowledge through guidance with developing particular skills to help to work through computing tasks all as part of building the confidence to teach computing (Harland and Kinder, 1997). This study sets out to explore teacher attitudes in terms of understanding what technical skills and computing knowledge teachers learned from attending the Bridge21 CS CPD programme.

2.2 Bridge21 CS CPD Programme

Bridge21 is a pragmatic model of 21st century teaching and learning that has been used extensively across a number of secondary schools in Ireland. It uses a team-based model to promote peer-learning in which the instructor orchestrates learning rather than focusing on delivery of content (Lawlor et al., 2010). It has been shown to encourage intrinsic motivation, promote the development of 21C skills, and to be suitable for delivering curriculum content (Lawlor et al., 2015, Johnston et al., 2015). The Bridge21 activity model outlines the structural elements necessary to delivery an effective 21C learning experience and is partially inspired by ideas on Design Thinking (Brown and Wyatt, 2010). It consists of seven steps around which learning activities can be designed: '*Set-up, Warm-up, Investigate, Plan, Create, Present and Reflect'*.

2.2.1 Computing Workshops

The Bridge21 CS CPD programme discussed in this paper consisted of six computing workshops. The first "Digital Media and 21C Teaching and Learning" was designed to introduce the Bridge21 model through a hands on technology mediated learning experience. The second workshop focused on "Problem Solving in the 21st Century"; the third offered an "Introduction to Programming through Animation using Scratch"; with workshop four covering "Intermediate Programming through Game Design using Scratch". Workshop five focused on "Advanced programming with Python", with six "Exploring Computer Systems with the Raspberry Pi" (Byrne et al., 2015).

2.2.2 Research Questions

Having already explored teacher reactions to the workshops (Fisher et al., 2015) this paper explores teacher learning through two research questions. Question one examined the extent to which the workshops proved effective in helping teachers learn computing knowledge and skills, while question two explored teacher attitudes towards applying their learning from the workshops in their own classrooms.

3 METHODOLOGY

The evaluation framework used to address the research questions was adapted from that of Kirkpatrick (1994). The Kirkpatrick framework has been used to evaluate educational phenomena across a number of contexts including evaluating teacher performance (Naugle et al., 2000) and measuring learning outcomes in teacher professional development programmes (Coldwell and Simkins, 2011). While Kirkpatrick is criticised for its deterministic structure (Kaufman et al., 1996, Holton, 1996, Bates, 2004) it has been adapted to evaluate Continuing Professional Development (CPD) for in-service teachers (Guskey, 2000) and it is this work that guides the design of methods used to evaluate teacher learning in this research.

3.1 Kirkpatrick Adaptation

Kirkpatrick operates over four levels. Level 1 explores participant reactions to a training intervention and Level 2 explores participant learning (specified as attitudes, skills and knowledge). Level 3 examines perceived changes in behaviour while Level 4 examines results in terms of changes made in the workplace as a result of the training.

The authors are in the process of rollout of the full Kirkpatrick framework to evaluate the delivery of the Bridge21 CS CPD programme over a three year period. Results from the administration of Level 1 Reaction Instruments are reporting positive reactions to the CS CPD workshops (Fisher et al., 2015) and that teachers intend using the Bridge21 model to enhance their subject teaching (Byrne et al., 2015). This paper focuses upon the perceptions of the participants with regard to their learning.

3.1.1 Level 2 – Learning Evaluation

This paper presents results gained from the administration of two data collection instruments. Each were at Kirkpatrick Level 2 and explored '*Skills*', '*Knowledge*' and '*Attitudes*'. The first instrument contained three open questions (Table 1).

Table 1: Bridge21-Individual Learning Form.

	Open Questions
1	WHAT - What happened during this workshop? What did you observe? What did you achieve? What did your colleagues achieve? What went well? What didn't go well?
2	NOW WHAT- How will you apply what you have learned today in your teaching? How will it help you develop your students' learning further? How will you develop your learning further? What information can you share with colleagues?
3	SO WHAT - What did you like / dislike about the workshop? How did you respond? How did you feel? Did you learn anything about yourself? Did you learn anything about your colleagues?

Question 1 was mapped to the category of '*Knowledge*'; question 2 was mapped to the category of '*Skills*'. Both items addressed research question 1. The 3rd question mapped to the '*Attitudes*' category, and addressed research question 2. The instrument was administered per participant, per workshop.

The second instrument contained five open questions (Table 2). Question 1 was mapped to the category of '*Knowledge*' and question 2 mapped to the category of '*Skills*', and together they addressed research question 1. Questions 3, 4 and 5 were all mapped to the category of '*Attitudes*', and addressed research question 2. This instrument was administered per team, per workshop.

Table 2: Bridge21-Team Learning Form.

	Open Questions
1	List 3 skills the team learned today.
2	List 3 skills the team would like to develop / improve on.
3	Overall, how would the team rate their performance?
4	Why does the team feel this way?
5	What was the team's best achievement today?

3.1.2 Data Gathering Procedures

Participants attended workshops on their own accord, thus samples were self-selecting. The authors provided an evaluation brief and issued participants with an ethics form at the start of each workshop. A total of N = 48 individual learning forms and N = 10 team learning forms were obtained from N = 110 attendees during the delivery of 9 workshops between October 2013 to May 2014. These numbers include responses from participants, whom attended more than one workshop.

4 DATA ANALYSIS

The authors acknowledge that the reconstruction of participant accounts are subject to author bias and present one of multiple readings. Moreover, the authors use quotations as primary data, cognisant of possible misreading's or unintended interpretations made from the remodelling of participant data (LeCompte and Goetz, 1982). Data presented for analysis consists of text responses to questions determined by the authors, in an attempt to shine light on phenomena described in the research questions. The following analysis may prove limited in supporting broader generalisations (Lewis et al., 2003), but instead attempts to render accounts accessible in a form that yields one reading with which to open further, more detailed conversations.

Text responses obtained from individual (Table 1) and team (Table 2) forms were transcribed, coded then stored in a searchable database. A total of N = 227 data base records were transcribed from hard copy individual and team learning forms. The authors used comparative coding to identify themes.

The qualitative data set comprised of individual and team responses. The authors used comparative or analytical coding (LeCompte and Schensul, 1999) to reduce the data set. This involved open coding across all records to look for similar concepts in the data (inductive coding cycle 1). Two further deductive coding cycles merged similar codes together, generating N = 6 sub themes. Table 3 illustrates the process used to reduce the data.

Table 3: Coding Process.

Total Data Records	227
Inductive Coding Cycle 1	125
Deductive Coding Cycle 1	56
Deductive Coding Cycle 2	30
Themes	6

The authors mapped each theme to one of Kirkpatrick's learning sub-categories of knowledge, skills and attitudes. While the authors acknowledge that code alignment is a subjective process (Goetz and LeCompte, 1981) the process of coding and theming, enabled the authors to look for and tease out and explore similarities and differences between themes.

4.1 Themes

Six themes emerged from comparative coding. Table 4 maps each theme to a learning category.

Table 4: Mapping Themes to Learning Categories.

Knowledge	Intrinsic Motivation
	Computing Comprehension
Skills	Computer Programming
	Hardware
Attitudes	Replicating Coding Activities
	Social Constructivist Learning

The themes 'intrinsic motivation' and 'computing comprehension' relate to *knowledge*; the themes 'computer programming' and 'hardware' relate to *skills* and both these themes address research question 1. The themes 'replicating coding activities' and 'social constructivist learning' relate to '*attitudes*' and speak to research question 2.

5 FINDINGS AND DISCUSSION

This section is organized as follows. Section 5.1 addresses research question 1 and examines the extent to which workshops proved effective in helping teachers learn computing knowledge and skills. The next section (5.2) explores teacher attitudes towards applying their learning in the context of teaching students coding. The concluding discussion (Section 6) revisits the research questions and describes the need for further research (Section 6.1).

5.1 Learning Computing Knowledge and Skills

This section explores participant experiences of learning computing, with particular focus on developing computer programming / coding content knowledge.

5.1.1 Knowledge

The workshops did enable participants to learn computing concepts. For example one participant reported obtaining a '*good, practical understanding of computer programming languages such as python*' while another participant commented that they too had learned '*how to use Raspberry Pi better, (and had developed a greater understanding) of the potential of what you can do'*. The same participant continued enthusiastically '*I want to know more about all of it'*. Teamwork played an important role in helping participants learn computing, captured in the following comment: '*I like being taken outside my comfort zone. I may not have skill set to do some of the computing tasks well, but I have a better understanding of what is involved and maybe prompted to learn more. (I also learned the) benefits of collaboration with other subject teachers'*. Working together created an opportunity for participants to share their learning with their peers.

5.1.2 Intrinsic Motivation

Working in a team played a key factor in helping participants stay motivated to complete tasks. One participant commented that '*group work is essential to keep yourself motivated when the programs are too complex for the individual'*. Another participant concurred with this statement, *'I liked the hands on element. Felt motivated as part of team collaboration to achieve objectives. I like to get things done, (and) I like defined roles with a team'*. Role division within teams also helped to keep teams on track: 'we *worked on a video and audio clip around a topic. Achieved objective using a variety of software programs and techniques. Great team, all motivated and stuck to the charter of rights, respectful of each other's differences'*. One reported that the learning model provided '*excellent steps for learning. I'm motivated to proceed with this process of using digital technology in classroom'*.

Team dynamics played also an important role in creating bonds and stay on track to complete tasks: '*we stuck to our (team) motto'! We achieved all the tasks; we worked well together'*. Team bonding also

Figure 1: Participants setting up a Controller.

helped participants succeed with difficult tasks such as *'completing the ambitious radar task'* which was a hardware configuration task completed as part of the Raspberry Pi workshop. Working in teams to solve complex computational problems also helped participants to gain in confidence, as demonstrated in the following comment: *'I worked well with my partner to complete tasks. Felt more confident and able to do tasks'*. Team working proved useful as a motivational tool, helping some participants achieve their goals, and in some cases exceeded them.

5.1.3 Computing Comprehension

Completing the tasks assigned required participants to develop problem solving skills: '*we worked as a team to create a project in Scratch. We noticed that there was a lot of trial and error involved. We all took on board new skills through our exploration. We felt a sense of accomplishment'*. However one participant expressed the need for '*more practice at tasks, building and improving basic skills'*. Learning activities also provided participants with a context in which to learn at their own pace; '*I learned how to program basic python tasks, and I felt that I could pass on that learning to others'*. Working together and sharing tacit knowledge played a pivotal role in helping participants develop the confidence to try out new tasks or to jump in and offer assistance. Indeed, the importance of peer-collaboration in the context of learning computer programming is evident in the following comment *'I liked the teamwork, learning from other people. I liked seeing the product of your work. I learnt that my knowledge is limited and I would like to learn more about programming'*.

5.1.4 Skills

Participants enjoyed experiencing the Bridge21 approach, involving '*Set-up, Warm-up, Investigate, Plan, Create, Present and Reflect'* as a method for learning computing skills. One participant reflected that they had learned *'about the bridge21 method. Observed (use of the Bridge21) method in action. (I also) achieved a very basic animation (and) the group went well to share skills'*. Another participant also enjoyed the combined approach: *'great learning achieved, networking digital knowledge. A lot of knowledge still to learn. Great capabilities in varying skills in colleagues in group'*. A further participant had also enjoyed a collaborative approach to learning computing *'I learnt that it is possible to use the same format, to take an unknown concept, research, storyboard, records and present in a short time and verify that learning has been achieved. With a group of strangers, and quickly recognise, skills, aptitude, have flexibility'*.

5.1.5 Computer Programming

Participants again reported that teamwork played an important factor in learning computer programming skills. One participant commented that, when learning programming *'team work can be very effective'*. Practical programing tasks also facilitated the *'learning and sharing of expertise'* which helped the same participant '*achieve coding a set of activities for animated characters in scratch. Teamwork went well (however I will) need more time to consolidate learning'*. The workshops used cross over activities to help participants make linkages between visual and text based programming languages: '*I learnt a nice bridging approach to highlighting similarities between scratch and python; I gained more confidence with the syntax'*. Using Scratch as an entry point to the Python programming environment helped one participant '*engage with the software (and helped me) learn to navigate the options …much is hidden. More examples of good programming please… 'Discovery' takes time – 1 day not enough'!*

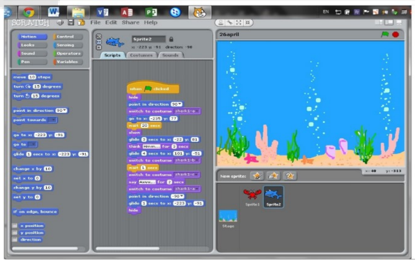

Figure 2: Basic Scratch Animation.

5.1.6 Hardware

The workshops also exposed participants to hardware. This experience helped one participant '*learn about the Raspberry Pi set up and Makey-Makeys. We successfully set up Raspberry Pi and used Scratch on it. The circuitry breadboard piece* *was challenging'*. The experience of configuring hardware helped another participant *'learn about the Raspberry Pi. (I) got to use. I got to play with Makey-Makey (which I had only heard about before). I also watched as breadboard was wired'*. Providing participants with the opportunity to unbox computing hardware, install devices and install software linked to controllers, allowed participants to *'explore the potential of computing hardware through group work, successfully install the raspberry pi, and explore python'*.

5.2 Attitudes towards Computing

Having examined participant perception of learning, computing knowledge and skills, the following section explores participant attitudes.

5.2.1 Attitudes and Intentions

Participants shared the following views of the workshop experience. One participant liked a project orientated approach to learning where *'problems arise during the workshop (and through) discussion; - trial and error the team overcame those problems'*. Another participant liked *'having the opportunity to create new content that isn't directly related to my job as a teacher / writer. I've learned that I am overly analytical and tend to complicate topics. I've learned that I am in a good place in terms of my content knowledge and IT Skills'*. However one participant disliked the lack of direct instruction or teaching which was perceived as necessary for encouraging peer collaborating within teams; '*I disliked how little guidance / explanation was given on the actual details. I know that is partly because as a teacher I'm used to pushing through the syllabus with very little time for self-learning or practicing! I expect "teacher" to give out the formulas / examples'!*

5.2.2 Replicating Coding Activities

Participants reported confidence in believing that they could replicate workshop activities in their own teaching. One participant intended using workshops activities to increase student engagement on return to the classroom *'I will research potential lessons that would translate well into the classroom environment and engage children further. I will try to source additional courses that will build on what I've learned. I can give examples of the potential of the raspberry pi in the classroom'*. Another participant intended using the learning model to deliver scratch programming to their students: '*I will try to integrate Scratch into my daily teaching through project work for my more visual learners. I will share Scratches cross-curricula usefulness with my colleagues'*. Another participant intended using workshop ideas in the context of delivering history lessons: *'I will use the ideas generated in our presentation in my classroom and apply them across the history curriculum. I will further delve into the materials provided for my own development. I will share my work with my colleagues'*.

5.2.3 Social Constructivist Learning

Participants also expressed a range of views in relation to using the Bridge21 model for teaching computing. One participant stated that they would like to use the model to *'to introduce hardware aspects and perhaps try to build some of the hardware (e.g. the controls) as part of a science /engineering project'* while another participant would use the model '*to help in my approach to problem solving in my present role. It's also given me new methods of working with teams and groups'*. However for some, further preparation was required to bring 21st century teaching and learning into the classroom '*I won't be applying anything yet as I am not familiar enough with scratch – a lot more time and engagement is needed for use with the programme before I will be doing it with my students. I would not be confident in sharing any info with colleagues apart from telling them that scratch is an animation program'*. For one participant, the workshop experience had introduced them to '*new peers. Learn new concepts to introduce into practice. Formed friendships and support mechanisms and felt challenged at time. Overall enjoyed the workshop and how it created a safe learning environment'*. The workshop experience had helped participants explore computing ideas for teaching delivered in a safe learning environment.

6 CONCLUSIONS

This paper set out to examine two research questions. In relation to research question 1, team work enabled teachers to discuss ideas, ask questions and draw from the expertise of the group to solve problems and work through issues, independent of the facilitator. Team working also created a safe learning environment where teachers with varying technical expertise could work together and produce a technical product. Learning activities played a key role in helping teachers apply computing skills, where they could work at their own level, however facilitation was sometimes needed to guide teams through unfamiliar problems.

In terms of research question 2, teacher attitudes towards the use of the Bridge21 model for teaching computing were reported as largely positive. Teachers enjoyed the relaxed atmosphere, and the opportunity to explore concepts at their own pace. Furthermore, the workshop experience exposed teachers to open questioning, where facilitators would guide problem-solving without necessarily providing answers. This in turn, encouraged teams to converge to work together through problems in order to seek out and then report back answers. Certainly, some participants expected a more teacher-centred approach to teaching and this in turn influenced the reporting of some negative comments. Overall, teachers reacted warmly to the Bridge21 approach and reported time and time again the importance of team work in supporting discovery oriented learning

6.1 Next Steps

This evaluation paper is the second in series, which seeks to explore the influence of social constructivist learning models on teaching Computer Science. This paper explores the second level of the Kirkpatrick framework to understand teacher perceptions of their learning and attitudes to using a social constructivist approach to teaching computing. The authors are in the process of analysing Level 3 data to explore implementation in the classroom, with follow up interviews planned (Level 4).

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