A 21st Century Teaching and Learning Approach to Computer Science Education: Teacher Reactions

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Abstract. This paper describes a pilot study to evaluate its use for teacher Continuing Professional Development (CPD) in Computer Science (CS) using the Bridge21 model, a particular model of 21st century teaching and learning. A range of introductory Computer Science workshops are evaluated that include topics such as; Computational Thinking, Scratch, Raspberry Pi and Python. This paper includes a detailed look at the generalized activity model used in all Bridge21 activities. Combining the Kirkpatrick training evaluation theory with ethnographic methods the researchers analyzed qualitative and quantitative data gathered from 110 in-service teachers whom attended 9 CS CPD workshops. Using the Kirkpatrick framework as a taxonomy with which to code data relating to (a) teachers initial reactions towards the workshops and (b) intentions towards use of the Bridge21 model for supporting CS classroom delivery. Findings indicate that teachers' initial reactions towards the programme were positive and that teachers intend to use the model in their classroom.

Keywords: Teacher continuing professional development · Computer science · Evaluation · 21st century learning

1 Introduction

Current research highlights the need to understand what supports post-primary Computer Science teachers' need to deliver lessons which encourage their students become more active in their learning [9]. Computing lessons provide rich environments teachers can use to help their students develop content knowledge and skills applicable to real world contexts [16]. Problem based activities enable students to develop a deeper understanding of educational phenomena [33]. Developing problem solving skills is perceived as a core component of computer science education [11]. Incorporating problem solving activities into computing lessons [26] may in turn help teachers help their students learn computing and encourage them to become more active learners [13].

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1.1 Educational Context

This study is situated within the evolving context of 21st century education, in which teachers are increasingly adopting student-centred, technology mediated approaches to instruction [1]. Teacher adoption of these methods across second level education coincides with the emergence of the Computer Science (CS) curricula in a number of European countries including the United Kingdom [4] and the Republic of Ireland [22]. Teachers without formal qualifications in computing, perceive computing as a complex subject to teach and a difficult subject for students to learn [34]. Hence there is a need for innovative CS CPD programmes to empower teachers to meet the challenges they face in mastering CS content and developing appropriate strategies for transforming the teaching of CS in their schools [29].

Paper Structure. The remainder of this paper is structured as follows. The literature review sets up the argument supporting use of two research questions to explore the effectiveness of a social constructivist approach to Computer Science (CS) Continuing Professional Development. The proceeding methodology and data analysis sections, describe the evaluation framework and data processing procedures used to gather and analyse data according to the research questions. The findings and discussion section brings together results clustered into themes to explore the implications of using a social constructivist approach to CPD delivery for CS teachers. The concluding section summaries the findings and suggests areas for further research.

2 Literature

21st century learning is a pedagogical move from didactic, curricula centric, teacher-centred methods of delivery [6] towards facilitated, student-centred methods of instruction [24]. A 21st century approach to teaching involves the use of instructional techniques such as orchestration and facilitation to help the learner construct meaning and understanding by themselves [14]. Orchestration and facilitation methods incorporate the use of social learning protocols such as peer based learning, social interaction, and social discourse to help learners move towards greater learning autonomy [32]. An increase in learner autonomy may result in the gradual withdrawal of teacher-centred delivery methods [20]. Changing the instructional dynamics of the classroom to support 21st century teaching and learning is somewhat complex [27] and there are those who argue against the use of 21st century models [30].

2.1 Teaching Computer Science in the Republic of Ireland

As stated earlier a number of education systems are promoting the inclusion of CS at second level. In the Republic of Ireland, short courses in Digital Media [23] and Coding [22] are available for the first time in schools across the first three years or junior cycle levels (ages 12–15) of the curricula. These courses promote project work using a wide range of digital media including coding which aim to help learners develop expertise in the design, construction and implementation of computing generated artefacts.

The syllabi provided by the NCCA are exemplars and can be adapted by the teacher or used as a guide. However, despite the introduction of these new courses there is limited CPD available to teachers that targets the type of content as well as the 21st century approach to learning that is also promoted in these courses.

2.2 Bridge21 Pedagogy

Bridge21 is a pragmatic, pedagogical model of 21st century teaching and learning, elements of which include team-based, project orientated, technology-mediated activities [18]. The model is currently used by post-primary teachers across a number of schools, in subjects ranging from history [25] to mathematics [3]. The essential elements of the Bridge21 learning model are: (1) technology-mediated learning, (2) project based activities, (3) structured team-based pedagogy, (4) recognition of the social context of learning and (5) facilitation, guiding and mentoring, with teachers orchestrating these activities [8].

2.3 Bridge21 Activity Model

The Bridge21 Activity Model is partially inspired by ideas on Design Thinking [5] consists of several sequential steps which form the basis of each lesson.

The Prelude. The prelude is made up of a number of optional activities. Depending on the group dynamic (have they previous experience working together or in teams?) they may not be necessary. They are however recommended for groups new to teamwork and if the group is not familiar with each other.

Set-Up. The set-up activities are usually employed when the group is new to team work and does not know each other. It also provides an opportunity for team formation, a task that will be at the start of every Bridge21 activity.

Ice Breaker. Helps the members of the group to get to know each other and start intra-group communication. Ice-breaking activities often focus on sharing personal information such as names, hobbies, etc.

Team Selection/Formation. Learning models that seek to encourage high levels of student engagement and intrinsic motivation typically embrace collaboration and teamwork. The theories of Piaget and Vygotsky highlight the importance of the interaction between social, affective and cognitive states in a student's development and learning. Vygotsky's "more able other" identified the peer as a key figure in learning. With teamwork the pool of "more able others" includes all team members and in a project based approach different team members may be able to play that role at different stages in the process as peers learn from each other.

Warm-up and Divergent Thinking Activity. The general divergent thinking activity is used to warm up the teams and get them thinking creatively. If a group seems sluggish or unmotivated this can be a good activity to get them thinking and engaged with the activity.

Investigate. Depending how guided an activity teachers wish to make the activity, this is an opportunity for the teachers to provide the students with a primer in some domain knowledge, or get the teams to explore the domain knowledge as a research activity. Finally in this section the teams define the problem or context of their activity in preparation for the planning phase which follows. The planning phase gets the teams to plan how they are going to achieve what they have defined as their problem context. Here teams allocate roles, resources, tasks lists and schedule the activities involved. The following phases are used to investigate, ideate, research and define the problem context, which is defined by the teachers.

Problem Context/Brief. Here the teachers explains the problem context or the activity brief, outlining the activity. The topic should be focused enough that the teams are clear about what they are working on, but broad enough that they can take ownership and tackle the topic creatively.

Divergent Problem Thinking. Divergent thinking based on the problem context provides an opportunity for the teams and wider group to explore and think laterally about the problem. It is at this point that they get to think creatively about the problem context. It is important that this stage remains playful and gets the whole group "thinking outside the box". It is through this creative activity that the teams and individuals take ownership of problem.

Content Knowledge Development Exercise. This is an optional step that may not be applicable to all activities. If the group requires more content/domain knowledge or experience in skills needed during the main activity, exercises or mini-activities can be used to develop the necessary skills and/or knowledge. It can be combined with the research step which follows, where a priming activity is used to generate questions that may be answered through online research.

Research. This optional step can be used for the teams to gain more background information about the problem space. They can expand the ideas developed during the divergent problem thinking step or use those ideas as initial search queries to develop further ideas. This is a good opportunity to explain best practices in ICT information access (safely browsing the web, evaluating sources etc.)

Problem Refinement/Framing/Design. Here the teams are asked to focus and refine their problem context so as that the main activity has a well-defined problem scope. The teams should develop at least three potential directions (common design technique) at first and critically analyse them and pursue the one they consider the most interesting and plausible/practical considering the constraints (time and resources) course.

Planning. The planning stage is an opportunity for the teams to develop their plan of action. Here they develop a comprehensive task list and timeline or schedule for their proposed implementation. They then assign the tasks, roles and resources to individual team members (team members can share tasks and resources, but one team member should be encouraged to take responsibility for the task).

Develop Task List/Outline. A comprehensive task list should be developed based on the refined problem context that concluded the investigate phase. The teacher may provide a template that helps scaffold the activity and implementation (e.g. using a story boarding and crew roles templates for video production). The goal here is to get the teams taking responsibility of the activity and thinking practically about how they are going to achieve their goals.

Task, Role, Scheduling, Resource Assignment. Building on the task/overview developed in the previous step, further templates may be used by the teams to schedule tasks, and assign tasks, roles and resources to the various team members. Alternatively teams may be tasked with developing their own templates with teacher guidance. This step develops the student's sense of responsibility and appreciation of resources necessary to complete tasks.

Create. Now begins the main activity. The create phase is where the artefact and presentation is developed through an iterative/cyclical process of execute, test and reflect. Execution see them executing their plan that they developed in the previous step. Regularly (20–50 min, depending on activity duration) the team leader and/or teacher should have a brief review session with their team members as to how the plan is working out, and whether there needs to be corrective action taken. This should be followed by a quick individual reflective session focusing on personal perceptions of their process, progress and any learning opportunities and/or enlightenment. This cycle should be repeated until all allocated time has been utilised, later cycles may be used for improvement and refinement and further skill development.

Execute/Create. The execute/create step is where the teams task list/outline is put into action, there is opportunity to revise the plan in the steps that follow, should time allow for it.

Review/Evaluate/Test. This step provides the team with the opportunity to review how their actions are or are not meeting with their task list and schedule. It also provides an opportunity for the team to access their initial assumptions and revise where necessary.

Reflect. Reflect on their progress and process, particularly focusing on managing themselves, staying well, communicating, being creative, working with others and managing information and thinking.

The Finale. The finale is the culmination of the main activities work. Here the teams present their work to the teacher and whole group. Each member should contribute to the final presentation, but they may elect a member to handle the main presentation (does not necessarily have to be the team leader).

Evaluation and Feedback. This is an essential phase of the process, where the teams present their work and reflect on their learning throughout the entire activity.

Presentation. The central reason for the presentation is to develop both communication skills and confidence with public speaking. The teams should be encouraged to not only describe the output but to also comment on what role each team member played in the process and lessons learned during the activity.

Reflection. Here both teams and individuals reflect on their experiences using the provided templates. It provides an opportunity for the team members to reflect on how they worked together and what they personally learnt during the activity. Emphasis should be but on using the outputs from this step to improve future learning scenarios.

Whole Group Discussion. This is the final step. Here the whole group discusses what they learnt, found difficult, enjoyed or would recommend doing differently if the activity was to be repeated. Essentially it is a sharing of the lessons learned by all involved and provides an excellent opportunity for the teacher to get feedback from the students about how they found the activity.

2.4 Bridge21 CS CPD

In response to the twin challenges of empowering in-service teachers to up-skill in order to teach CS and the need to gain expertise in 21C teaching and learning strategies the authors' institution has launched a Post Graduate Certificate in 21st century Teaching and Learning. This certificate is in its first year of delivery with 113 teachers registered on the programme. Modules are delivered on campus during weekends and school holidays to offer maximum attendance. The programme consists of 12 modules, 4 of which are compulsory, with the remaining 8 as optional modules. 6 modules relate to computing and each is delivered using the Bridge21 learning and activity models [7].

The ***Digital Media Literacy*** module provides an introduction to the Bridge21 model, while also supporting the development of digital media editing skills and providing examples of how to use the Bridge21 model across a range of curriculum subjects. ***Problem Solving for the 21st century*** provides the teachers with a set of activities that are inspired by CS unplugged [2] in which algorithmic thinking is approached without the use of a computer. ***Introduction to Programming*** uses Scratch to introduce basic programming concepts through animation. ***Intermediate Programming*** through game design again utilizes Scratch to explore advanced concepts, such as events and concurrency. ***Exploring Computer Systems*** [7] uses the Raspberry Pi in conjunction with the Python programming language to introduce embedded systems and inputs and outputs. ***Advanced programming*** is introduced via the Python text-based programming language, which is used to solve a number of mathematical tasks.

3 Research Questions

Two exploratory questions underpin the research designed to explore teacher reactions. Question one explored the extent to which the Bridge21 model proved effective for the delivery of the CS CPD programme, while question two sought to explore the extent to which teachers intend to use the Bridge21 model in their classroom delivery. The next section details the methods and evaluation framework used to explore these questions.

4 Methodology

The evaluation framework used in this study was adapted from a training programme evaluation model used to explore corporate training programmes [15]. The researchers adapted this framework to measure educational outcomes or objectives relating to the provision of the Bridge21 CS CPD programme [12]. Learning objectives relate to the participants ability to understand and perform specific computer science tasks [21], and use elements of the Bridge21 model in the context of their classroom teaching. Each module exposes teachers to the Bridge21 learning and activity models and teachers are encouraged to use a similar approach in teaching CS.

4.1 Workshop Delivery

The following procedures were followed to address the research questions. The Bridge CS CPD programme comprised of 9 workshops delivered in Trinity College Dublin over the 2013/2014 academic year. Workshop delivery occurred on Saturdays and school holidays to facilitate maximum participant attendance. Workshops were free to attend and run on demand, resulting in some workshops delivered once, while others were delivered twice. A total of 9 workshops were delivered during the study period, generating a combined total of N = 110 attendances. Each workshop commenced at 10 am and concluded at 3.30 pm. Participants attended the workshops of their own accord, and thus samples where self-selecting. Participant profiling revealed that some participants identified as having prior CS delivery experience while others identified as being new to computing.

Participant Profiling Data. Participant profiling data was gathered as follows. Prior to attending the workshops, participants were invited to complete an on-line pre-questionnaire. The questionnaire asked participants to provide details relating to (1) prior computing expertise and details relating to (2) current computing delivery in schools. All pre-questionnaire questions were optional and a total of 51 responses from 110 participants generated a 46 % completion rate.

4.2 Kirkpatrick Adaptation

The Kirkpatrick framework operates over four levels. The first two levels refer to the training offering itself while the subsequent two levels focus on behavior and its impact. Level 1 gathers participant reactions to training and level 2 seeks evidence of learning through the assessment of skills, attitudes and content knowledge acquired in the context of the training environment. Level 3 seeks evidence of behavioral changes as a result of the training, and Level 4 seeks results based on evidence on the use of the training within the context of the workplace environment. All levels are sequential in so far that data obtained from one level, informs data collection in the next, maintaining a ‘chain of evidence’ across data sets. Table 1 describes each level and its purpose.

Table 1. Kirkpatrick model.

Level	Description	Purpose	Location
Level 1 – Reactions	Reactions to the training	Gather evidence relating to participant reactions to the training	Training environment
Level 2 – Learning	Learning by the participants	Evidence of learning through the assessment of skills, attitudes and content knowledge	
Level 3 – Behaviour	Behavioural changes	Evidence of changes as a result of the training	Workplace environment
Level 4 – Results	Evidence of workplace change	Results based on evidence of the use of the training in the workplace	

Level 1 – Reactions Evaluation. This paper analyses the results of data obtained from the distribution of a single page, hard copy Level 1 Reaction Instrument issued to individual participants at the end of each workshop. The reaction instrument contained a combination of 12 closed numeric questions and 4 open qualitative questions, each of which were adapted from an existing Kirkpatrick Level 1 Training Evaluation Form [17]. This instrument was adapted to gather participant reactions towards the workshop design, role of the facilitator, suitability of facilities and usefulness of the topics covered. Additional questions included an improvements indicator regarding more/less time spent on CS topics, participant reactions towards the use of the Bridge21 model for learning CS, perceived changes to practice as a result of the CS CPD intervention and perceived use of the model for CS delivery.

4.3 Data Gathering Procedures

Participants opted to attend workshops on their own accord, and thus were self-selecting. At the start of each workshop the research team briefed participants about the evaluation process and issued each participant with an ethics consent form and information sheet. Participants were then invited to counter sign copies to consent to the use of their data for research publication, or opt out and leave the forms blank. A total of N = 63 forms, from 110 attendances from 9 CS CPD workshop deliveries were received during October 2013 to May 2014. An average of 12 individuals attended each workshop, with some individuals attending one workshop, and others attending one or more workshops over the evaluation period. This paper includes responses from participants whom provided written consent to include their written accounts in published research.

5 Data Analysis

The researchers adopted an ethnographic approach to the reconstruction of research findings [10]. This approach views the transcription and reconstruction of text responses as a form of social discourse. A transcribed account is ‘limited insofar as it produces a partial perspective’ [28] of phenomena. This is because ‘the ethnographer interprets that which he or she observes’ [28]. In light of these limitations, we argue that such accounts, while subjective, yield rich and meaningful descriptions which are reconstructed from the observation of phenomena at a particular time and place [31]. This study brings together narrative segments from small samples so these accounts may be unsuitable for theoretical or statistical generalization.

5.1 Quantitative Coding

Numeric data from five Likert quantitative scales (arranged 1 *Strongly Agree,* to 7 *Strongly Disagree*) were processed using SPSS statistical processing software. SPSS calculated an average of means per scale then produced a total percentile score per scale.

5.2 Qualitative Coding

All qualitative written responses were manually and electronically transcribed, coded then stored in a searchable database. Three iterations of manual coding were performed against transcribed text responses. This process resulted in the production of 64 textual codes from a total number of 253 database records. Comparative coding was used to reduce the qualitative data set. Comparative coding or analytical induction seeks to extract dominant or contradictory themes from the process of data analysis [19]. This technique underpinned the generation of four themes from the coded data set. Table 2 illustrates the iterative cycles used to reduce the overall data set.

Table 2. Coding process.

Total data records	253
Inductive coding cycle 1	173
Deductive coding cycle 1	104
Deductive coding cycle 2	64
Themes	4

Themes. Four qualitative themes emerged from the comparative coding process. The themes of ‘*learner autonomy*’ and ‘*content knowledge’* relate to the research question one and the effective use of the Bridge21 model for the provision of CS CPD programme. While the themes of ‘*lesson planning*’ and ‘*orchestration and facilitation,*’ relate to research question two and explore ways in which participants intended to use the Bridge21 model in the context of their own CS delivery in schools.

6 Findings and Discussion

This section is organized as follows. Sections 6.1 and 6.2 start with some background profiling data on participants such as prior computing expertise and current delivery practices in schools. Section 6.3 discusses statistical analysis of participant reactions towards the workshop design, role of the facilitator, and suitability of facilities and usefulness of the topics covered. The next section (Sect. 6.4) discusses participants' reactions towards the effectiveness of the Bridge21 model for the delivery of the CS CPD programme. Finally, Sect. 6.3 discusses participant intentions towards using the Bridge21 model in their CS delivery.

6.1 Prior Computing Expertise

In summary, 65 % of participants whom completed the pre-questionnaire prior to attending the Bridge21 CS CPD programme identified as female (N = 33 responses), which the remaining 35 % identifying as male (N = 18 responses). Also, 23 % (N = 12 responses) of participants identified as having prior exposure to the Bridge21 models. In addition, 70 % (N = 39 responses) of the same participant sample also identified as not having a 3rd level qualification in computing. However, 54 % (N = 27 responses) of the sample identified as currently teaching computing in schools prior to attending the CS CPD programme. This initial profiling data captured a higher proportion of women attending the workshops and a low percentage of participants with prior expertise in using the Bridge21 model. The data reports a high percentage of participants teaching computing. This indicates drive and commitment by teachers towards making computing accessible to students via the delivery of extra curricula activities.

6.2 Current Computing Delivery in Schools

Analysis of the same sample population (N = 51 responses) yielded the following results in relation to current computing delivery. A total of 75 % (N = 38 responses) identified as running a computer programming club in their schools. The most common tools used with students included Scratch (+ combination of other tools such as Python, App Inventor, Raspberry Pi, Alice, Java Script) – with 94 % of participants using a combination of these with students both in computing classes, or in the context of the delivery of other subjects (N = 48 responses). One participant, who taught math, commented that that they liked to use '*tools like Geogebra online, Wikis online, MS Excel, MSOffice, MS Power Point, and much more. In ICT (Information Communication Technologies), I have used scratch.*' Another participant, whom taught History, commented that they liked to use '*Edmodo as a tool for more instantaneous feedback for students. I use Minecraft in History in order to create virtual worlds. I use Wikis for group projects/ collaboration.*' Participants also identified professional memberships and conferences run by organizations such as Computers in Education Society of Ireland (www.cesi.ie) - as important professional peer supports to assist with CS delivery.

6.3 Overall Reaction

This section explores participant reactions' towards the success of the workshops in terms of providing an overall satisfaction rating, a rating for the design of the workshops, a rating for the use of facilitation as a delivery method and a rating relating to the usefulness of workshop activities/content.

Workshop Satisfaction. Two thirds or 86.16 % response rate (from N = 63 individual participants) strongly agreed that they were satisfied with the Bridge21 CS CPD workshop experience and that the workshops were worth attending. Half of those participant responses (49 %) were awarded the strongest overall rating in terms of levels of satisfaction towards the programme (1 = Strongly Agree). In terms of expressing their satisfaction with the CS CPD training intervention, one participant commented that the workshop experience would '*help me integrate these topics across (the) curriculum that I teach'* while another participant stated that the workshop experience had given them a '*good understanding of how to apply computing to other subjects*'. Another participant highlighted the possibility of using elements of the Bridge21 model to introduce autonomous learning into the classroom '*I might be more inclined to let students problem solve on their own.*' These comments highlight intentions towards using the Bridge21 model to support CS delivery in the classroom.

Workshop Design. The majority of participants were satisfied with the design of the workshops (77.06 % response rate). One participant expressed that they intended to '*use the workshop model*' in on return to classroom teaching, while another participant stressed that they wanted to use elements of the workshops to '*bring in a structured course (computing) into teaching*'. Both these participants indicate incorporating elements of the Bridge21 model into their classroom delivery.

Facilitation Methods. Participants also reacted favourably to the use of facilitation as a method for delivering CS to professional in-service teachers (89.24 % response rate). One participant commented that the method of delivery used in the workshops (i.e. the use of mentoring and facilitation) had *'helped me to understand the basics (of computing) and focus on them for the benefit of my students.* This comment highlights an initial acceptance towards using facilitation and peer mentoring for exploring CS.

Workshop Activities and Content. Participants also registered a positive response rate (87.16 %) towards use of computing examples and practical activities used during the workshops. One participant liked the use of '*teamwork and collaboration'* for learning computing while another participant explained the Bridge21 model provided a '*good technique for team teaching.'* Another participant commented that workshop experience had enabled them to learned *'new IT skills'* but that they had also learned a *'new approach to (teaching) team activities'*. These comments highlight participant reactions towards using 21st century pedagogy for learning new methods and CS content.

6.4 Reactions Towards Bridge21 Model Effectiveness for CS CPD

This section explores participant reactions towards use of the Bridge21 model for CS CPD.

Content Knowledge. Again, participants reacted positively towards the use of the Bridge21 model for learning computer programming languages and as an aid to understanding how to apply computing concepts. One participant commented that they had obtained a '*better knowledge of scratch*' while another commented that they had learned '*a better understanding of python and similarities to scratch*'. In contrast, one participant commented that they would need *'more training in scratch, (as) I wouldn't be confident to deliver it in class yet.'* Two other participants shared this view. One participant stated that they would '*need more workshops*' to use Scratch in their classroom teaching, while a second participant agreed with this view and commented that they also did not yet '*feel confident enough to teach programming*'- indicating a need for more training in order to deliver Scratch programming.

Other participants registered an increased level in the confidence in teaching computer programming, as a result of the workshop experience. One participant commented that they felt they had obtained '*more confidence in (using) computers in classroom,*' while another participant stressed that they would be able to '*use scratch independently,*' as a result of attending a scratch workshop. Another participant commented that 'I *will be integrating scratch in my classroom,*' while another participant indicated that they '*would try to introduce this language (*Scratch) *to student's that are interested in coding.*' These examples highlight that some participants were satisfied with a single training intervention, while others required further workshops in the same topic areas.

Using the Bridge21 model for the delivery of CS CPD workshops also offered participants the opportunity to experience a '*different approach to teaching computers.*' This experience enabled participants to think about how '*to introduce teamwork in computer classes*'. Another participant stressed that the workshop experience had helped them *'to keep my teaching in scratch programming up to date and relevant to students I teach'*. Another participant expressed that the workshop experience had enabled them to '*extend (their) knowledge of raspberry pi technologies so that I may use it successfully in the classroom.*' One participant also concurred with this statement stressing that the workshop experience had '*introduced me to the possibility of using the raspberry pi.*' The Bridge21 workshop experience appeared to have helped participants engage with computing concepts and programming languages, helped participants identify and address potential knowledge gaps and helped participants explore how they might adopt a Bridge21 approach to teaching CS in their schools.

Learner Autonomy. The Bridge21 CS CPD workshop experience also provided participants with the opportunity to explore the experience of 'autonomous learning'. One participant commented that the workshop experience provided a supportive training environment which enabled them to '*approach group work in a different manner (mistakes are ok!).*' Another participant commented that the workshop experience had help them to '*be more open minded, (and) adaptable*' when learning new concepts, such as computer programming. Another participant stressed that the workshop experience had enabled them to *'feel more comfortable about working with scratch'* with a subsequent participant commenting that the experience enabled them to reach a level of expertise in which they felt '*able to pass on some knowledge of what rasp pi is about'* to their students, on return to the school classroom.

Another participant reflected on feeling empowered to '*promote self-directed learning'* with their students, while another participant felt equipped to begin '*exploring possibilities'* as to how they might delivery computing in the classroom using the Bridge21 model. One participant stressed that the workshop experience provided a platform through which to help their students engage with a variety of learning activities such as '*collaboration, the effect of group work, the diversity of ideas, and filtering*' – techniques aimed at helping learners explore and share their understanding of ideas.

However not all participants responded favourably to the experience of autonomous learning. One participant commented that delivering more open ended learning experiences required consideration of the '*importance of preparation materials'* while another expressed a need for more formal '*input on the tools'* used during computing and programming activities. Another participant stressed that professional development needs to '*give us the tech skills rather than just "do it" tasks'* highlighting unease at learning computing through peer supported, socially mediated group working.

6.5 Intended Use of the Bridge21 Models for Teaching CS

This section explores participant intentions towards the use of the Bridge21 model for supporting classroom delivery.

Lesson Planning. The majority of participants intended to use computing concepts taught in the workshop setting combined with elements of the Bridge21 model on return to classroom teaching. One participant intended to '*use python to consolidate maths problem solving*,' while another participant aimed to '*use the raspberry pi to teach python'*. Another participant commented that they had learned '*how to develop and define a working algorithm'* and intended to use elements of the Bridge21 model to help them teach *'Computational Thinking not just in IT as I had done previously'*. Another participant commented that they intended to use aspects of the Bridge21 model '*in classroom activities*,' but another participant stressed that they intended to use the model to help them *'use group work more carefully.*' Interesting, one participant commented that the workshop experience enabled them to '*create lesson plans and facilitate young people using scratch.'*

Exposure to the Bridge21 model had also helped participants to think about how they might adjust their delivery, to help their students engage with CS. One participant commented that the workshop experience had given them supports to think about creating 'a *module for TY (Transition Years)/1st Years' on programming.'* Another participant stated that the workshop experience had given them '*ideas on how to introduce programming to my students'*. One participant commented that the workshop experience had given them '*a better understanding of how I would utilise various resources in the classroom,'* for teaching computing. A number of participants also registered the intention to '*integrate scratch in some lessons,'* to develop '*short courses* *in IT and Transition Year IT programming'* with one participant indicating that they '*might talk to principle about adopting the model*' in the context of their classroom teaching. Another participant shared this view and indicated that they also planned to '*adopt the model in classroom as well.'*

In terms of using the Bridge21 model to support the delivery of CS, one participant stated that the workshop experience had equipped them sufficiently to '*introduce game design to my classes and develop a module on it,'* while another participant wanted to use elements of the models to '*let students work independently and figure out the coding problems,'* with a third indicating that they intended to use the models as a mechanism to help them '*introduce more project based group work*' into teaching.

Orchestration and Facilitation. Exposure to the Bridge21 learning model enabled participants to explore how they might adopt or use 21st century teaching methods in their classroom delivery, on return to the classroom. This exposure enabled participants to think about how to *'run group sessions differently.'* One participant reflected that learning how to orchestrate group work is a skill, as '*groups can be successful, but with careful make-up.'* Another participant commented that group working methods can assist in '*keep moving things along,'* while another participant had learned a technique to help them to *'ask more questions of class, (and) give less answers'* as a means of supporting students engage with learning materials. One further participant commented that this approach might create a learning environment for '*pupils in class to help each other.'* Another participant commented that the Bridge21 model provided a mechanism by which to control the *'pacing, input, leave students to it,'* with the aim of giving student learners, time, space and educational supports to explore phenomena.

The Bridge21 CS CPD workshop experience enabled participants to visualize how they might orchestrate learning experiences using the Bridge21 models. One participant commented that they '*could see clearly how it (the Bridge21 model) may be used in a classroom context*' while another participant commented that they might *'experiment with the methodology in class.'* These comments capture an openness to '*try new things with my class.'* The Bridge21 CS CPD workshop experience not only created opportunity for participants to *'try out more teamwork and self-directed teaching'* and '*promote self-directed learning,'* Bridge21 model exposure enabled participants to explore how they might organize learning activities to encourage student autonomy, and try them out before use in class.

In terms of teaching computing and programming, one participant commented that the Bridge21 CS CPD workshop experience had enabled them to reflect on the issue that '*programming is possible but it takes a lot of time.'* Two further participants echoed that when learning to program it is important *'not give up as easily,' or to 'never give up.'* Another participant shared this view and commented, the Bridge21 model may be perceived a way to help teachers *'talk less in class and get pupils to do more.'* This comment is situated in the context that 21st century pedagogical models emphasise that it is '*the process not the technology'* which helps the learner achieve their educational and learning goals.

Finally, one participant stressed that '*learning by doing works,'* hinting at the emergence of a sub theme relating to self-directed learning. This is encapsulated in the following participant comment – in which '*learning in order to achieve a specific task and figuring it out is more motivating that just learning because you have to.*' These comments illustrate ways in which the Bridge21 CS CPD workshop experience and use of the Bridge21 pedagogical models provided participants with an experience which enabled them to explore and learn computing concepts, but also with the opportunity to consider how and in what ways they might apply or adapt elements of those experiences in the context of their classroom teaching to help students learn CS.

7 Conclusions

This paper set out to explore the extent to which the Bridge21 model proved effective for the delivery of the CS CPD programme, and to understand the extent to which teachers intend to use the Bridge21 model in their classroom delivery. The Bridge21 model provided a context which enabled teachers to explore computer science from a number of perspectives, whether conceptually through the completion of project work, or practically through participation in hands on coding and programming.

While some participants liked this approach, and felt confident to use what they had learned in the CS CPD workshops in this classroom with their students, a number of teachers expressed the need for further workshops combined with additional training and supports to develop computing expertise, prior to demonstrating CS concepts in front of students. In terms of understanding how to apply CS concepts in the classroom – the Bridge21 models provided teachers with a sequence or structure through which they could explore and think about how to adapt elements of the process for integrating CS into their teaching. In some cases, the model enabled teachers to explore how they might change the social dynamics of the classroom, by implementing learning experiences where the answer to questions may not always be readability available or where the process is used to support learners find the solution to problems by themselves.

The Bridge21 model also provided teachers with the opportunity to not only explore the mechanics of an autonomous learning model, but also to explore how to facilitate the delivery of such a model through participation in group work and team based projects. While reactions were generally positive towards the use of the Bridge21 learning model for the provision of a CS CPD programme, there is still further work needed to look more closely at the way in which the model supports learners engage with CS concepts in the context of workshop delivery.

In terms of using the Bridge21 model to support CS classroom delivery, teachers expressed a range of views in terms of how they intended to use the model in the context of their classroom teaching. While some teachers intended to use elements of the Bridge21 activity sequence to help organise the delivery of CS classes across the curricula, other teachers expressed an interest in using CS concepts, and elements of the Bridge21 models to enhance the delivery of other subject areas. Also, while some teachers interested in teaching CS also aimed to adopt the Bridge21 models to enhance their CS delivery, other teachers looked to implement elements of the model, such as group work and team based activities as a means of helping their students engage more 'autonomously' with the curricula.

7.1 Further Research

This paper started with the suggestion that helping students become 'more active in their learning' lies at the heart of a 21st century approach to teaching and learning. However, teachers also need access to professional development programmes which enable them to upskill and develop techniques they can use with confidence in the context of helping their students take more empowered role in their learning. The Bridge21 CS CPD programme uses a social constructivist approach to CS delivery in an attempt to help teachers meet the demands of the 21st century classroom. The Bridge21 CS CPD programme also seeks to help teachers learn and develop expertise in CS, which may hopefully translate into the classroom in ways which make CS delivery interactive and engaging for both the teacher, and their students. It is with this aim, that further research is planned to explore use of the Bridge21 model as a mechanism for enhancing CS delivery. CS is and remains a difficult subject to teach and learn, and the authors hope that this paper sheds some light on these difficulties, but also successes inherent in using a social constructivist approach to learning CS, in ways compatible with the 21st century school classroom.

Next Steps. This Evaluation Paper Is the First in a Series, Which Seeks to Understand the extent to which social constructivist teaching and learning models enable teachers to empower their students to take a more active role in their learning. This paper explores the first level of the Kirkpatrick framework, in order to understand teacher reactions' towards the Bridge21 CS CPD programme. Level 2 analysis is underway to take a closer look at the impact of the CS CPD workshop experience in helping the same teachers learn computing concepts. The researchers have also initiated Level 3 analysis to determine the extent to which teachers have adapted workshop elements in their subject teaching. It is still too early to draw final conclusions on classroom impact based on the results.

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