Engaging with computer science when solving tangible problems

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ABSTRACT

This research investigates part of the challenge of widening participation and inclusion for teaching and learning about CS that the Institute of Coding plans to address. This research reports on working with a large number of schools, researchers and academics both formally and informally and across a wide age range and ability. The findings from a number of studies reflects important pedagogical theory, design and practice of teaching and learning about the computer science and engineering through tangible learning context. These findings and observations are examined in the light of these teaching and learning experiences and especially the observation of development of resilience in students learning and engagement in challenging areas of study.

KEYWORDS

Computer Science, Education, Pedagogy, Tangible Problem Solving, Learning about Internet of Things, Resilience

1 Introduction

The paper investigates students' engagement with learning about computer science (CS) within the multidisciplinary of tangible problem solving afforded through Internet of Things (IoT) experimental environments. An innovative approach was designed exposing students to the multidisciplinary potential of CS to move the focus away from 'coding' to creating solutions about problems that were of importance to the students. The approach was to understand the role of resilience when engaging in learning about technology, and computer science and determine if the relationship between resilience and critical thinking can be observed when solving tangible problems. This research reports on working with a number of schools, researchers and academics across a wide age range. The relationship between resilience of reintegration and interdisciplinary thinking are examined to contextualize the interdisciplinary learning and critical thinking about Tangible problem solving. These findings are used to set out a framework to explore the relationship between pedagogy, resilience and Tangible problem solving.

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2 Background to the study

2.1 Importance of Resilience

Resilience is often defined by three main elements: (a) The ability to cope with adversity; (b)The ability to bounce back after the problem is over and (c) A reduced vulnerability to problems and adversity. The resilience of an individual is linked to the development of self-efficacy beliefs through the understanding of causal relationships and practice self-observation or awareness [8]. The belief one can change and reach desired outcomes increases effort, persistence, and performance of tasks[8]. As desired outcomes become a reality through intentional action, self-efficacy is strengthened. In Reivich and Shatte [12] accurate thinking is a core competency of resilience indicating mental shortcuts allow simplification of information to assist efficient decision making, which may result in the erosion of resilience due to an increase of common patterns of inaccurate thoughts.

For this study, the focus is on Educational resilience [19]. In particular is the relationship between learning about CS through tangible problem solving and resilience that is identified by factors of optimistic outlook, self-efficacy and accurate thinking. To investigate this relationship the research draws on three processes identified by Rutter [14]: (a) building confidence and self-esteem (b) diminishing the impact of the risk factors and (c) to stop negativity cycles by fostering more favorable conditions for positive growth and change in the individual. As resilience is defined as a process that changes over time, Rutter suggests that the 'measurement' of resilience needs to be expressed in 'relative' terms.

Three resilience models often used when studying the impact of risk factors that may result in a negative outcome: compensatory, protective, and challenge [6]. In the learning experience we focus on the challenge model. In learning this means students exposed to moderate levels of risk may engage to complete the task. It is known in learning if a student is exposed to too low risk (no challenge has a tendency towards feeling bored) or too complex (feels impossible leads towards feeling overwhelmed) the student is unlikely to succeed. They both result in high likelihood of the student not engaging. However, a moderate learning risk means the student can see progress and feels the solution is reachable. In learning, similar to Rutter's 'measurement' of risk being variable and relative applies to learning - it is relative to the learner's knowledge and understanding.

There are three phases of resilience identified [13]. The first phase focused on the individual qualities that predicted social and personal success. The second and third phases are investigated as part of this study. Hence, the learning experience in the context of the "challenge model" of resilience, which provides "resilient reintegration"[13]. This second phase identified as resilient reintegration is considered successful when insight or growth is experienced due to the disruption. Resilient reintegration results in the identification or strengthening of resilient qualities. The third phase focuses on interdisciplinary exchange as a context to understand under what conditions we develop qualities of engagement and determination *"to grow through adversity."*(pg 113 [13]). These qualities of resilience identified relate to interdisciplinary learning and critical thinking that both require 'resilience through reintegration' of knowledge. The relationship between the pedagogical collaboration context and the process of resilience in third phase of '*interdisciplinary exchange*" is investigated through learning through tangible problem solving.

2.2 Critical thinking

Critical thinking cannot occur without creative thinking and vice versa according to Bailin and Segal [1]. The rational for this perspective is illustrated by the work of Chandrasekharan of building to discover [3]. The effective emergence of creativity was examined through a 'Tinker Media' process. The study provides an account of how the process of creating tangible artifacts is connected to the "imagination of movements" of the neurons to creating 'a space' for a new concept/idea to emerge [ibid]. A key observation by Sill [17] about engagement with critical thinking is its complexity and thus may be resisted by learners. However, when reexamining critical thinking through Chandrasekharan's 'Tinker Media' environments some of the barriers are alleviated. The environment reduces memory and cognitive overload. This is due to the "experiment" being available to be observed, stopped at any time etc. This process of 'simulation' in a 'tinker media' setting provided the conditions of experimentation and timely feedback – tangible problem solving. This study builds on the creativity dimensions provided in [9]. The study investigates the relationship between creativity and resilience and whether or not tangible context provides conditions to influence the development of resilience in learning.

3 Methodology

The affordances of learning about Tangible Problem Solving (see Table 1), in particular if evidence of learning experiences that supported "imagination of movements" and actual construction across both building processes and thinking processes were observable. The value of Educational resilience [19] in this narrow context of Internet of Thingswere examined, especially the impact of pedagogical designs by embedding explicit positive education context [16]. Certain pedagogical designs and approaches are similar to the case studies provided by [2] where they demonstrate the pedagogical implications and the context on delivering learning experiences. Similar to the comparative approach used in "Time for telling" [18]. These are the pedagogical ingredients of designs that exemplify conditions for interdisciplinary and active learning and collaboration that echoes with Dewey's purposeful learning [4].

TABLE I: The relationships between the general pedagogical context and the resilience indicators.

General Pedagogical context (creative dimensions)	Resilience indicators	Learning experience context
Interdisciplinary (Challenge)	A positive attitude to other disciplines Optimistic outlook	Provides an interdisciplinary context – diverse/multiple domains and multiple representations
Active learning & Engagement (Freedom, Idea time)	Self-efficacy Accurate thinking Patience Diligence	Authentic learning experiences and purposeful to the learner/physical & tangible connections/creativity
Collaboration (Trust, openness, playful/humour, risk taking, idea support & debate)	Self-image Risk factor reduction Open up new opportunities	Interdisciplinary context supports collaboration. No one person has the answer. It enables both teacher and student to move away from expectation of omnipotence.

Taking into account the creative dimensions [9] that are listed in table 1 in the context of the general pedagogical considerations and a 'Tinker Media' supporting imaginations of movement [3] approach the relationship with developing education resilience through learning about IoT are outlined. Authenticity of the learning experience enables active learning. This engagement develops important characteristics both for interdisciplinary thinking and resilience of self-efficacy, patience and a more accurate thinking (not taking shortcuts). Authentic conditions for creativity provides freedom to explore and time for ideas. Risk can be reduced in collaborative settings that are open and this helps in the development of a more positive self-image [16]. Hence, to reduce risk improving self-image by recognising that no one person can be expected to have all the knowledge, especially when the projects develop across domains. Learning through a 'tinker media' experience can support positive inclusion. Data analysed includes over 100 hours of recordings activities, workshops, mini-workshops and events. The data was analysed using an open coding method to develop an understanding of the relationship between the pedagogical context and the development of resilience through the affordances of Tangible problem solving. Due to space only the core findings of the results of large case study is provided: Hands-on learning through tangible problem solving.

4 Hands-on learning Through Tangible Problem Solving

This case study examines design and deliver a two-day Educational Hackevent in November 2012, bringing together 6 schools. The theme for the event was 're-designing Education by students'. The schools' culture and settings were all different. This case study reports on four of the schools working with over a 100 students over two months period to prepare for the hackevent.

TABLE 2: context for learning about Tangible problem solving

Learning experience	Mobile-based	Sensor-based	Notes
Interdisciplinary context	Introducing smart applications	Introduction embedded systems	Using everyday things
Student context & purpose setting	Students think about everyday things	Students think about everyday things	Understanding the context of the student – embedding authenticity
Authenticity: active learning & collaboration	Problems and solutions: Template designs	Hands-on experiments Arduino kits electronics and software	Students come up with there own projects (school)
Sharing solutions: Diversity	Presentation and balsamiq tool to share designs	Demos and presentation to class	What they had learned and what they wanted to work and do next.
Active learning & collaboration	Development of the prototype in MIT app inventor[1]	Extension projects and intro. to lilypads devices	Workshop 3 hour session at the lab

Most students were all new to computer science and in one school the students were studying their STEM certificate. The majority of the students were aged between 14 and 15. One class was in year 11 (aged between 16 and 17), and another was a CS club, which had a mix of ages ranging from 13 to 15. Resource packs were designed for teachers outlining the learning about Tangible problem solving in the education setting: Giving two options (a) designing solutions that work using mobile technologies e.g. mobile phone or (b) building sensor embedded systems (essentially Arduinos[2] and sensors). They had not studied or encountered the idea of CS & IoT before. This context of design came from an everyday experiential perspective need rather than technological driven. Three of the schools designed solutions using mobile IoT technology and one school worked with building sensor embedded systems. The pedagogical approach is described in Table 2. Interdisciplinary context of everyday education was used. Examples of student mobile-based applications focused on anti-bullying, homework and schedules and tracking applications for lost and found objects and events that could create social connections and support communities both in and out of the classroom. The students' sensor ideas were to help conserve energy in the school, queue sensors to know when to go to lunch, tracking sensors for traffic, some science experiments that included wearable tech to collect data about the environment and many more. The initial activities involved learning about the new tools. In the initial phase the mobile IoT designs were elaborate and demonstrated collaboration and exchange of ideas.

Interdisciplinary + Collaboration	*Articulations, observations and reactions from students*	*No.*
Mobile IoT design + building	Shared designs and ideas, some worried about other groups using their ideas. 'This is really interesting. I like being able to design with my friends. We have all worked on different parts' 'I never thought we would get it to work. But we all worked together. It was hard but now I know how it works'	28 out of 35 students who completed the survey expressed a positive experience
Sensor-based IoT design and building	Students from different groups helped each other. Students went from group to group to see what was happening. 'At first I wasn't interested at all. All the wires and stuff. But then I got to make my own music. I didn't know it could be fun' 'It was brilliant. We could make what we wanted and experiment together'	31 out of 36 students who completed the survey expressed a positive experience

TABLE 3 analysis of experiences.

Table 3 summarizes the initial engagement and collaboration experiences. The designs were student-led and open to include their ideas. This feature of 'freedom' to be creative and to bring own ideas was clearly valued by the students and the teachers. The opportunity to collaborate on their own challenges created a shift in thinking and engagement. Students valued their ideas being incorporated and including the ideas of others. The complexity of the problems to be solved meant collaboration was fostered. There are three observations that emerged (a) engagement with lilypads, (b) authentic learning and (b) complexity of mobile software environment. One noticeable engagement with one group changed when the lilypads were introduced. One group of girls had expressed their disinterest in the arduinos and the wires etc. The materials were not engaging but with lilypads this changed. The authentic connection with the artifact was key. Further observation on authenticity was a student with no interest in participating until the option to develop a music device emerged. According to his teacher he had until then shown no interest in the subject. However, designing and developing software for music changed that engagement and enabled fundamental aspect of resilience to emerge. A final observation was with the mobile applications. The main problem was the length of the programs the students needed to create to get the solution to work was very challenging. Two problems are examined here (a) MIT app inventor, at that time, while useful for

[1] http://appinventor.mit.edu/explore/
[2] https://www.arduino.cc

beginners to program did not scale easily to more complex problems and (b) the students' complex designs meant they were getting lost in the detail. The researcher should have realized this latter problem at the time. It required stripping back the design and helping the students to focus on one aspect of their design.

Dimension	***Description***	***No***
Imaginations of movement	Narrative Connecting hardware to software	55 students out 71 Understanding of the algorithm, variables through tactile explanation. Creative ideas emerged 'AHA'
Engagement /freedom	Creating own experiments	64 students out 71 developed their own ideas moving for beyond initial idea
Collaboration Idea support	Testing different approaches	62 students out of 71 Trying out colleague's suggestion
Risk taking Critical thinking	Breaking and fixing	54 students out of 71 taking the whole thing apart and trying a new approach
Trust	Helping/being helped	65 students out 71 Prepared to help and accept help (actively seek help)

TABLE 4 Summary of overall findings

Essentially, unlike the ardunio the polished finish to the mobile device hides the complexity that is important to reveal. This aptly expressed by Pallasmaa [11] that the computer, in this case the mobile device, puts distance between the maker and the object. The raw materials of the sensor kits put the designer in direct 'skin contact'. This relates in part to the 'imagination of movements' and the tinker media context. This connection is important otherwise as learners we lose context, especially when we are new to an experience. This means under such conditions the learner cannot benefit from the 'Tinker Media' reducing the memory and cognitive overload.

Table 4 provides a summary of findings. One clear aspect that emerged when viewing the activities was the students' connecting with through 'imaginations of movement' through the visual realization of their idea. The other factor was patience/diligence (accompanied by some frustrations) of breaking and fixing of their projects. The emergence of a tangible connection to their ideas generated a creative voice as a means to articulate with confidence beyond their projects about what else might be possible.

Conclusion

The inclusion of the students' context and motivations is critical [15]. Learners of all ages are more motivated when they can see the usefulness of what they are learning. The validation increases a sense of value and self-efficacy when this information has a positive impact on others in their community[19]. This tangible thinking through learning environment have potentially powerful implications. Not dissimilar to claims and hopes expressed by Papert[10] about creativity and learning that relates strongly to the investigation of the 'imagination of movement'[3]. When considering learning from this process of 'imagination of movement' that takes place when new concepts are emerging it provides a compelling link to the potential of learning through design and constructing. This is similar to the findings in the D&T study [7]. The account presented through resilience indicates the complexity of not just the subject matter but the disposition of the teachers and students. Hence, the bridging with students through the diverse context that tangible problem solving offers them supports more ways to connect with the learning. By considering resilience in education through a collaborative context enables risk reduction so potential for more engagement. The active learning meant not just the students' learning but also the teachers' resulting in forming knowledge construction together [15] and is similar to the findings in [4][5]. This formed the core design approach of the learning tangible problem solving in this study. The importance of this context cannot be emphasized enough.

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