Perceptions of using the Raspberry Pi to learn computer architecture

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Abstract

The Raspberry Pi is a credit-card sized, low-cost computer designed for educational use. While initially developed to teach computer programming concepts, the device is increasingly being used in more advanced hardware projects in secondary and post-secondary educational settings. This paper reports on perceptions of an introductory course in an undergraduate Information and Communications Technology programme that was redesigned to utilise the Raspberry Pi in a Problem Based Learning context, with dual aims of developing 21st century skills while achieving the course learning outcomes. Data was gathered using two surveys, one institutional and one custom, in addition to two focus groups. Key themes emerging include student perceptions of understanding the tasks assigned to them, the value students placed on these activities and the enjoyment of using the Raspberry Pi device to achieve the learning outcomes. While the device was a cornerstone of the learning within the course, limitations emerged as to its suitability to teaching some core concepts.

Keywords

technology in education, Raspberry Pi, Problem Based Learning, 21st Century Skills

Introduction

The Raspberry Pi is a low-cost computer, approximately the size of a pack of cards and is typically used in secondary education (Raspberry Pi Foundation, 2015). With the shifting of focus in schools from teaching applications to teaching computer science skills such as programming, the Raspberry Pi provides a low-cost, expandable platform for educators to create activities and projects that develop the so-called 21st century skills (Voogt, Erstad, Dede & Mishra, 2013). Despite having relatively limited capabilities, it is ideally suited to small projects with a wide range of add-on components readily available (Raspberry Pi Foundation, 2015). While the device is typically associated with primary and secondary schools, it is increasingly being used at third level as a core computing device in advanced projects (Cox, et al., 2014) and to challenge first year undergraduates (University of York, UK, 2014). This paper reports on an effort to redesign an introductory first-year computer systems course at a Middle Eastern Higher Education Institution (HEI). The intention was to integrate the PBL methodology to facilitate knowledge of computer architecture and foment the acquisition of the 21st century skills through the use of the Raspberry Pi.

Literature Review

That technology is important in today's society is without doubt. Ever-increasing demands are being made of educators to incorporate technology into pedagogical practices to ensure the workers of the future are equipped with the requisite 21st century skills (Soulé & Warrick, 2015). Problem solving, critical thinking, teamwork and creativity are some of these skills demanded by employers, yet these types of skills have been in demand since the industrial revolution (Voogt, Erstad, Dede, & Mishra, 2013). What makes the 21st century skills unique is the requirement for a new form of digital literacy and creativity demanded by jobs that may not yet exist. While some consensus on the definition of 21st century skills has been reached, what is not yet clear is the definition of the role of these skills and their placement within the curriculum (Voogt & Pareja Roblin, 2012). This new digital literacy, rather than replacing traditional literacies such as reading and mathematics, instead overlays on top of them developing more abstract skills such as creativity, problem solving and critical thinking (Higgins, 2014). The challenge for educators is how to develop these

skills and provide authentic 21st century learning opportunities (Soulé & Warrick, 2015).

Problem Based Learning (PBL) is one of a number of inquiry based learning strategies that centres around a discovery-orientated, constructivist approach to learning which incorporates significant scaffolding and reflection on the learning process (Hmelo-Silver, 2004). Learners are provided with a loosely-defined problem that is reasonably authentic and are tasked with solving this problem while working collaboratively. One of the key characteristics of such a learning philosophy is that in addition to scaffolding, the teacher in her role as a facilitator delivers just-in-time teaching of critical material as learners discover what they know, and just as importantly, what they do not know. While PBL has been criticized for the propensity of learners to engage in little more than surface-level learning, such concerns can be addressed with additional scaffolding, teaching and resourcing (Hmelo-Silver, Duncan, & Chinn, 2007).

Methodology

As the course has no prerequisites, no prior knowledge in the discipline of computers is assumed and therefore the course was also available as an elective to students whose primary programme of registration was other than ICT. A total of 38 students enrolled in the course, split over two classes of 18 and 19. The cohort of two classes consisted of 79% ICT students, 5% Business and 16% Engineering. All students ranged in age from 18 to 21 and all were second language speakers of English (ESL). A total of 32 students completed the course. The lead researcher taught one of the classes, the secondary researcher worked in the Teaching and Learning Unit of the institute and outside of this study, and had no connection with the course or the students.

In keeping with the PBL philosophy, students were presented with a loosely-defined problem on the first day of the course. This problem was framed as the need of a person to store and manage her media collection (for example, music, videos, films, photos, etc.) on a device that connects to a standard domestic television. An additional requirement was that the device may be controlled remotely with a touchscreen device such as a phone or tablet. The presentation of the problem also included a working

demonstration of one proposed solution, using the Kodi media center software (Openelec, 2015). The problem was assessed as a group project, with an individual component and was worth a total of 40% of the students' final mark. As part of the project, students had to deliver the working media center on a memory card, a report document and a video to be played on the media center on a topic of their chosing. The remaining 60% of the marks were split between an exam (45%) and a set of weekly reflections (15%).

Three sources of data informed the study in the effort to gather student perceptions – institutional surveys, a custom survey tailored to the study, and two focus groups, one from each class. In conducting the research, we sought to investigate the perceptions of students relating to the course structure and content, and more specifically understand how the cohort in question perceived the changes to teaching in the context of a higher education setting. Northcote (2009) presents the idea of examining the connection between the practice of teaching and perceptions of it (from a student and teacher's perspective) - the so-called *belief-practice* connect, in an institutional context. Drawing on Northcote's (2009) thematic analysis of students perceptions, we categorised the data, firstly in broader themes, and latterly in the four areas of perception identified in her study: content, teachers and learners (people), process and purpose.

As part of the quality control process within the institute, student surveys are administered twice per academic year, once in each semester. For each course a student takes she is requested to fill in two surveys one about the course and one about the teacher. Each survey consists of 13 multi-choice questions using a four point Likert scale, delivered over the internet and completed via a web browser. Respondents also have the option to add free text at the end of the survey to comment on specific matters they deem of importance.

To obtain specific information on student perceptions of the course, a custom survey was also developed by the researchers to ascertain student prior knowledge on the topic, student perceptions on the course and some general background data. Of the 32 students who completed the course, 26 completed the survey giving a response rate of

81.25%. The survey was administered in the final week of the semester using a Google Docs form and completed online using classroom desktop computers via a web browser. Participants were made aware that answering the survey was voluntary.
Two focus groups, each comprising of five students from each of the two classes were randomly selected by a researcher unconnected with the course. The researcher was presented with two lists of student identification numbers and randomly picked out five from each. Two focus groups were held, each lasting approximately 40 minutes. Participants were made aware that participation was voluntary and were asked to sign a consent form. The focus group was conducted with permission from, and under the guidelines of, the institute's ethics committee.

Findings

The institutional surveys are carried out by the Quality Unit of the institute during weeks 6 to 8 of the semester. As no students had withdrawn from the course at this stage, the average of 30 respondents represents a response rate of approximately 79%.
The responses to the survey suggest students are generally happy with the course, however given the generic nature of the survey, only limited data can be elicited. One noteworthy finding relates to student responses regarding completion requirements and assessments. In line with the PBL philosophy, the need to present learners with the loosely defined problem to stimulate learning contrasts with the need to clearly state completion requirements. Results from the survey suggest this balance was achieved as two questions ("I know what I need to do to pass this course") and assessments ("Assessments are related to what is studied in this course") were two responses that had the highest rate of agreement. The initial survey responses suggest that the students display some level of engagement with the course, enjoy and value the collaborative nature of the teaching and learning focus, and are able to discern the reasons for the formative activities within the module of study.

The custom survey was divided into two sections – general background information on the students' prior knowledge of computing and student perceptions of the course. The answers were ranked on a Likert scale of 1 to 5, where 1 represented no familiarity with the topic of the question, and 5 representing strong familiarity with

the topic of the question. As expected, a substantial portion (77%) of the students had little or no knowledge of the Raspberry Pi, with two students reporting that they were very familiar with it. Other questions on the survey confirmed what was expected – participants who were enrolled in the ICT programme had a higher level of background technical knowledge in topics such as networking and operating systems, whereas students who were taking the course as an elective displayed relatively little background technical knowledge in these areas.

Perceptions

Students were also asked about the extent to which they felt they had achieved the learning outcomes of the course. The responses indicate that students feel they have achieved the learning outcomes of the course to a great extent. When asked specifically about the contribution of the Raspberry Pi to the learning, results were more neutral than anticipated – as course designers, we hoped that the introduction of a novel device to support learning would garner more decisively positive feedback from the respondents. Upon reflection, it is important to note the use of the Raspberry Pi was limited to one aspect of the course, which included less experiential and more abstract content. As we did not ask specifically about these component aspects of the course, we can assume that the responses given may refer to the course as a whole, rather than particular components of the course.

One of the key deliverables for students was the production of a research document investigating the nature of media centers and how they are constructed. Responses to the question about the research document suggest students saw the value of it, although perceived it to be quite specific to the main project, rather than relevant to the overall goal of meeting the course learning outcomes. When asked about the video component of the project, the results are more neutral. While students did not necessarily dislike this aspect of the coursework, it is apparent that it was not as popular as the other components of the project. The final question on the survey about the overall perception of the course and its use of the Raspberry Pi suggests that students enjoy using the device and that perhaps the course designers could add in a number of extra activities or assessments using the device.

The focus groups, each of five students and one researcher, were held in the same week as the custom survey was administered. Due to time constraints a detailed analysis of either of the survey results was not possible prior to the holding of the focus groups. The focus groups yielded a variety of responses which mapped very clearly to Northcote's categorization of thematic indicators of student perceptions of learning and teaching: people, process, content and purpose (Northcote, 2009). Broadly speaking, there are three emerging themes from the data generated. Firstly, the respondents demonstrated understanding, both of the purpose of the project and the decision to divide the project into two components. Secondly, the participants spoke of the value of the course, and how it had benefitted them; they identified a clear link between theory and practice. The majority of the respondents (in both groups) indicated that the course had positive experiential value, and while challenging at specific points during the life-cycle of the project, they understood the purpose and intrinsic value of the task ("I think, like in the future, when I look back, I see all the benefits of it."). A third emerging theme is that of enjoyment - the focus group responses suggested an elevated level of personal satisfaction. A summary of these themes and the mapping to Northcote's sub-themes are presented in Table 1.

The overall theme to emerge from both focus groups was that students enjoyed the use of the Raspberry Pi device, appreciated the novelty factor of the project and generally found the course interesting. In terms of ranking of perception (Northcote, 2009), student feedback prioritized process and purpose over people and content, indicating an alignment with the intention of the institutional drive to emphasise the construction of knowledge through the PBL process.

Theme	**Northcote's Sub-theme**	**Sample comment**
Understanding	Purpose	It's about all about connecting theory...
		It's learning by doing.
		Like everything you do, you should face problems in order to learn from that problem.

	Process	Well, the project is about…..we have a raspberry pi hardware device and,….we are asked to implement a media center on it, and er, there are some specific tasks and features that we should implement….
Value	People	It relates to everything he [the teacher] taught us…
		Also, you know how much you have to give, because you know that the person you are working with is ready to give as much as you, so you are ready to give your best.
	Process	We can learn how to be adaptable, like…we should adapt to different (sic); because if you don't adapt easily you will not adapt to all the work.
	Purpose	Overall, the project was good, you know. A good experience.
	Content	Knowing that wow, I actually learned something was, it was really good. To learn something on your own and you don't have anyone teaching you.
		Usually, you just learn the theory and write it up. You never learn this much. You enjoy more this work, you know what is going on. You can be creative as well about how you operate it.
Enjoyment	Content	I really enjoyed every minute doing this project, 'cos I had to learn all about it alone, I had to implement it alone.
		(I enjoyed) everything!
	Process	It was fun!
		It's a new experience. It's great. It's awesome! I never thought I could make something like this. It's amazing!

Table 1 - Focus Group Findings

Discussion

The Raspberry Pi, now in its third iteration, is still relatively new to the market and much of the software and tools available for the device are still somewhat

underdeveloped; this can also be seen as positive for the learning experience. In order to conduct the prescribed tasks in the student brief, participants had to engage in a wide range of cognitive and experiential tasks, draw on prior knowledge, identify gaps in knowledge and resolve those gaps. The risk of using an underdeveloped artefact provided the students with an opportunity for reflection and interaction, which we believe enhanced learning. Our findings suggest that the effort to transform the course from a dry, heavily didactic, low-technology course to a more engaging, student and task-centred offering with a significant experiential learning component, was successful. The research findings suggest that the embedded changes have been effective in supporting the learning outcomes of the course; equally, this work gives a good starting-point for further action research across the School for programmes which have effected substantive revisions, particularly when considering the context of a whole-institution drive to embed a student-centered PBL approach to teaching and learning across the curriculum.

The findings suggest that students did not enjoy the theoretical nature of the content; moreover, there were a number of comments which suggested that the students thought the materials were not up to standard. This is surprising considering the course was redesigned and material was significantly updated and redeveloped by the teaching team. We also speculate that the contrast between theory and the experiential nature of the portfolio of in-class activities may be a factor.

While it is noted that respondents did not generally express negative views towards the Raspberry Pi device, we were surprised to find a lower rate in general of positive qualitative feedback. We speculate that this may be attributed to the variety and number of activities the students undertook that were conceptually more abstract that did not involve use of the device, particularly towards the end of the course.
Students expressed a positive sentiment towards the group component of the final project, specifically the application of the learning throughout the semester to the design and construction of the media center. This further reinforces our conviction that the novelty factor of the device itself, and the relative lack of familiarity of the students with a media center contributed greatly to the overall perception. It is interesting to note that this component was completed on an individual basis, so we

question whether this is related to the social-constructivist view of learning as a group activity or Prensky's (2001) concept of Digital Natives where students are simply more comfortable working in groups.

We note that the emerging theme of enjoyment, corroborated by the survey findings, appears to be related to the novelty factor of the device and the experiential nature of the tasks undertaken during the course. Such tasks, we would assume, facilitated engagement with 21st century skills as students worked on a multi-faceted, unfamiliar problem. The importance of scaffolding cannot be over-emphasised. In this study, we found students were unsure of how to proceed, requiring the occasional prompt from the instructor. In observing students there were occasions where we felt the problem was perhaps too loosely defined and while we expected students to request information on particular technical aspects, they appeared to be struck with a sense of not knowing what they did not know. Accordingly, they did not always identify what they should be asking for (in line with PBL philosophy) and therefore teaching staff had to prompt students more than expected. We believe that some more workshops on the PBL methodology would have been beneficial for the students to broaden their understanding of the expectations placed upon them as learners.

There were a number of topics within the course that the Raspberry Pi was unsuitable for such as digital logic and assembly language. For the former, we decided to revert back to software used in a previous delivery of the course and associated material. The latter, assembly language programming, provided a particularly unique challenge. While it is possible to undertake these activities on the device, we felt that the editor tools and the environment available on the device were extremely rudimentary and could conceivably be detrimental to the learning process. Again, we reverted back to tools used in a previous incarnation of the course. These experiences raise the question whether the course redesign should have been more comprehensive, ensuring that the Raspberry Pi device could have been used in every activity, or whether the phased approach we used, reverting back to older, proven methods for learning when the technology did not fit was the correct approach. We note the latter approach worked in this context. Overall, we feel the changes to the course were successful and well received by students, which is congruent with the findings of our research. The

data indicates that the Raspberry Pi appears to engage learners and the activities built around these devices reinforce the learning outcomes and develop the 21st century skills.

However, as expected, there are a number of areas that we feel could be improved for future iterations of the course. The first is the scaffolding provided to students. In addition to the Raspberry Pi itself, the concept of the media center was quite new to the majority of students. We also believe that more background tutorials on technical topics were warranted, as predicated by the PBL advocates, who note that a key feature of ensuring success is the provision of extensive and appropriate materials and lectures to support learning.

The second is the 21st century skills. Developing student activities and project work proved relatively straightforward, however the assessing of these skills was surprisingly problematic. A consistent theme in the literature discussing 21st century skills is the need to redevelop not only the curriculum, but also the assessments (Voogt & Pareja Roblin, 2012). We feel that as academics with a computer science background, developing marking rubrics for subjective and creative activities required a lot more effort than we envisaged. While the moderation process within the programme confirmed that the assessments delivered in the course were fair and valid, we believe this is one area where the effort required to accurately assess such student work should not be underestimated.

Conclusion and further research

Our study reports on student perceptions of using the Raspberry Pi in a first year, first semester course as part of a four-year undergraduate programme. The course was redesigned premising the PBL philosophy and incorporated the use of the Raspberry Pi, while the learning outcomes were left unchanged.

The findings of this action research project support, in the main, the embedded changes and give a good basis for further research. In terms of further study, we propose that in order to fully interrogate the beliefs of both students and teachers, it would be useful to conduct a follow-up study, including within the sample set of

respondents students and teachers, as in the present study the focus was primarily on students enrolled on the course. In this way, we hope that we may begin to test Northcote's hypothesis of similarity of belief between students and teachers, and in turn identify additional implications for course review and refinement.

It is clear from the literature that technology, when used in a careful, planned manner, can make a significant positive impact on learning (Tamim, Bernard, Borokhvoski, Abrami & Schmid, 2011). However, issues such as professional development for educators, technology cost, pedagogical practice and technical support are barriers to incorporating technology which require a concerted effort from all stakeholders to ensure success (Pittman & Gaines, 2015; Phillip & Garcia, 2015). The desire to enhance learning with technology at a course level should be tempered with clear goals, aims, resources and training.

In a time of every-increasing instrumentalist drives to embed technology in learning, our experience demonstrates that with a clear focus on information sharing, experiential learning and strong scaffolding, the use of technology as an artefact to promote development is clearly evident. In this way we can attest that if we wish to produce a generation of independent thinkers, with the requisite 21st century skills it is incumbent upon us as educators to ensure that we avoid simply resorting to the gadget-educator archetype through the constructive alignment of experience, learning and assessment. That technology is important to both learners and educators is not in question. The question is how this technology can be used effectively to develop students into lifelong learners, with the skills and knowledge demanded by society not only today, but also in the future.

References

Cox, S. J., Cox, J. T., Boardman, R. P., Johnston, S. J., Scott, M., & O'Brien, N. S. (2014). Iridis-pi: a low-cost, compact demonstration cluster. *Cluster Computing*, 17(2), 349-358.

Higgins, S. (2014). Critical thinking for 21st-century education: A cyber-tooth curriculum? *Prospects, 44*, 559-574.

Hmelo-Silver, C. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3) 235-266.

Hmelo-Silver, C., Duncan, R., & Chinn, C. (2007). Scaffolding and Achievement in Problem-Based and Inquiry Learning. *Educational Psychologist, 44*(2), 99-107.

Northcote, M. (2009). Educational Beliefs of Higher Education Teachers and Students: Implications for Teacher Education. *Australian Journal of Teacher Education, 34*(3), 69-81.

Openelec. (2015). Retrieved March 1, 2015, from OpenELEC: http://openelec.tv/

Phillip, T., & Garcia, A. (2015). Schooling Mobile Phones: Assumptions about proximal benefits, the challenges of shifting meanings and the politics of teaching. *Educational Policy, 29*(4), 676-707.

Pittman, T., & Gaines, T. (2015). Technology integration in third, fourth and fifth grade classrooms in a Florida school district. *Educational Technology Research and Development*, 539-554.

Prensky, M. (2001). Digital Natives, Digital Immigrants. *On the horizon, 9*(5).

Raspberry Pi Foundation. (2015). *Raspberry Pi Projects*. Retrieved June 4th, 2015, from Raspberry Pi Foundation: https://www.raspberrypi.org/forums/viewforum.php?f=15

Soulé, H., & Warrick, T. (2015). Defining 21st Century Readiness for All Students: What We Know and how to get there. *Psychology of Aesthetics, Creativity, and the Arts, 9*(2), 178-186.

Tamim, R. M., Bernard, R. M., Borokhvoski, E., Abrami, P. C., & Schmid, R. F. (2011). What forty years of research says about the impact of technology on Learning: A Second-order Meta-Analysis and Validation Study. *Review of educational research, 81*(1), 4-28.

University of York, UK. (2014). *Raspberry Pi Challenge*. Retrieved January 23rd, 2015, from University of York, Computer Science department: https://www.cs.york.ac.uk/undergraduate/challenge/

Voogt, J., & Pareja Roblin, N. (2012). A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of Curriculum Studies, 44*(3), 299-321.

Voogt, J., Erstad, O., Dede, C., & Mishra, P. (2013). Challenges to learning and schooling in the digital networked world of the 21st century. *Journal of computer assisted learning*, 403-413.