REFLECTING ON THE USE OF PROJECT-BASED LEARNING FOR 21ST CENTURY COMPETENCIES IN AN IT EXTENDED PROGRAMME

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ABSTRACT – Employment in the information technology (IT) industry will most often result in project-based environments or project-based objectives. Preparing IT students for this industry is recommended through project-based learning (PBL). PBL has become increasingly popular over the past two decades for skills development in IT-related curriculum. The use of traditional pedagogies should be critically reviewed due to the noticeable skills gap in IT graduates' lack of 21st century competencies. This suggests that PBL should be implemented earlier in an IT degree. Literature reviews are offered on PBL and promoting reflective practice in PBL. A PBL strategy followed in an IT extended programme is presented. 30 student participants completed a reflective sheet towards the end of a module to provide insights on their 21st century competencies developed via PBL instruction. An interpretive approach is taken towards data analysis with the aim of understanding their experiences.

Keywords: Project-based learning, reflective practice, 21st century competencies, IT students, extended programme

INTRODUCTION

The goal of this paper is to highlight the value of implementing project-based learning (PBL) earlier in an information technology (IT) degree. PBL is a teaching and learning strategy where learners are exposed to real-world challenges, gaining a deeper understanding of the specific problem domain. The research questions for this study are *'how do we understand the value of a PBL strategy taken in an IT extended degree?'* and *'how do we improve the value of a PBL strategy in an IT extended degree?.'* It is important to note that *value* is used as a qualitative expression of suitability or appropriateness in this paper, and not as a value to be measured.

The central objective of implementing a PBL strategy for IT extended students is to improve their 21st century competencies. It is suggested that increased learning takes place for the student, as well as the facilitator, through methods of reflection.

The paper provides literature reviews on PBL, and reflective practice in context of PBL. The PBL strategy followed in an IT extended degree module is presented. An overview of the research methodology, data collection and analysis is provided. A discussion relating to the benefits of, and suggestions for, a PBL strategy for IT extended students leads into the conclusion and overview of future research.

THEORETICAL BACKGROUND

Project-based learning

Project-based learning and other pedagogical strategies that accentuate the development of skills needed at university and when entering the work-force are becoming increasingly popular (Huberman et al., 2014; Scardamalia, 2012). The theoretical groundwork for project-based learning was introduced by Dewey's philosophy on experiential learning and the 'project method' by Kilpatrick (Ravitch, 2000). The value of a PBL strategy lies in student-directed inquiry, with the aim of promoting deeper learning and supporting 21st century competencies. An overview of 21st century competencies are provided in Table 1 (Partnership for 21st Century Skills, 2019). The competencies are numbered for further use in the paper.

Table 1: Overview of 21st century competencies.

A: Learning and innovation skills		B: Information, media and technology skills		C: Life and career skills	
A1	Creativity and innovation	B1	Information literacy	C1	Flexibility and adaptability
A2	Critical thinking and problem solving	B2	Media literacy	C2	Initiative and self-direction
A3	Communication	B3	ICT literacy	C3	Social and cross-cultural skills
A4	Collaboration			C4	Productivity and accountability
				C5	Leadership and responsibility

With a PBL strategy, 21st century competencies are developed via student-directed inquiry instead of traditional teacher-directed approaches. Another reason PBL has been widely adopted at university level is due to poor perceived outcomes from secondary education (Duncan & Murnane, 2011). Project-based learning is seen as a strategy that can bridge these gaps by enhancing student motivation, and improving their theoretical and practical knowledge (Darling-Hammond et al., 2008; Thomas, 2000; Blumenfeld et al., 1991). Even though PBL is focused on student-centered learning, it can also be supported by facilitator-centered approaches such as lectures and demonstrations (Veletsianos et al., 2016).

Artefact development is often cited as a suitable assessment for a PBL activity (Krajcik & Shin, 2014; Grant & Branch, 2005). These artefacts are typically performance-based assessments and can be used to measure difficult criteria such as 21st century competencies (Pellegrino & Hilton, 2012). A concern experienced with using PBL activities, however, is that facilitators do not have the capacity or time to provide constructive feedback, or to assist students with engaging in self-reflection (Krajcik & Shin, 2014; Grant & Branch, 2005).

Promoting reflective practice in PBL

Cohen et al. (2013, p.14) emphasise the importance of embedding reflection to improve the long-term impact of strategies taken. They indicate that students should have an opportunity to think deeply about what they have learned, and that activities that promote reflection include journaling, class discussions and responding to structured questions. Nikolou-Walker and Garnett (2004, p.307) made use of reflective journaling where students continuously answered the question 'what did I learn?' throughout the course of an academic year. They also incorporated structured sections to encourage reflective and learning practice. Dunlap (2006, p.21) similarly suggests providing computer science students with prompts and structured questions to assist with focusing their responses in reflective journals. Even though reflective journaling has a long history as a learning strategy in the humanities, it has only been documented over the past two decades in computer-related fields (George, 2001). Supporting PBL with reflective practice approaches can address the concern experienced where facilitators feel that they do not have the capacity to engage students in self-reflection. Even though reviewing student reflections can be labour intensive, recent efforts have been made with automated detection of reflection for analysing reflective texts (Ullmann, 2017).

When reviewing and improving curriculum content and its successfully reached outcomes, student reflection is not the only perspective to take into consideration. It is crucial that facilitators engage in reflective practice when evaluating learning approaches that were effective and ineffective. Using a PBL approach requires critical reflection to ensure that a coherent strategy is implemented, and reflected on upon completion to improve future iterations of the module.

METHODOLOGY

Background of instructional design

A practical module is presented in the second year of a four year IT extended degree. The content of the module centers around design processes for IT artefact creation. The theoretical component includes topics of human-computer interaction (HCI), while the practical component allows for animated artefact creation in Scratch. The curriculum development plan is built on traditional assessment methods in the form of assignments and tests, and a written examination for summative assessment. This style of teaching and learning may be considered as outdated, based on the increasing concern that South African graduates struggle to find employment. Projects are central to the IT workplace, and training future graduates in a project environment is recommended. Project-based instruction is more established in exit-level modules but adopting project-based learning earlier in a degree should be considered.

The project-based learning strategy implemented during the course of this module is presented in the next section. Factors not changed for the module include the number of study hours allocated, the assigned contact sessions during the semester and the position of the module in the degree.

Project-based learning strategy

In an attempt to align module outcomes with industry expectations a decision was made to replace the written theoretical examination (summative assessment) with a project-based examination. This approach is overlooked in entry-level modules due to the manner in which Bloom's Taxonomy is integrated at each level in the university. Creation only takes place in the highest level of Bloom's Taxonomy, and is typically expected of exit-level students, but in an IT degree the creation of artefacts is already expected of first year students. Exposing an IT student to development and creation for the first time in his final year of study puts him at a disadvantage when entering the rapidly changing IT workforce.

For the summative assessment (examination *project*) of this module, students were required to create a serious game on a specific topic, along with supporting project. In order for this approach to be successful, a number of supporting formative assessments needed to be implemented. Table 2 provides a summary of all the activities that supported the project-based learning strategy, their context to the summative assessment and how they contribute toward 21st century competencies. The project is detailed in the next section.

Table 2: Overview of supporting activities in the PBL strategy.

Activities supporting the PBL strategy	Context of activity	21st century competency addressed by activity
Theory and practical lectures with related class exercises	Theory lectures pertaining to the components of HCI, interaction basics and design rules in preparation of elements to be considered in the project. Practical lectures pertaining to available gaming features in Scratch for possible inclusion in the projects.	A1, A2, B1, B2, B3, C1, C2, C4
Marshmallow Challenge (Wujec, 2010)	A Design Thinking (Brown, 2008:3) activity in preparation of Assignment 1. The aim of the activity is to encourage teams (4 members) to collaborate, think about design rules they have come across in the module, and to understand time constraints that are associated with development in the real world.	A1, A2, A3, A4, B1, C1, C2, C3, C4, C5
Assignment 1: Conceptual game design activity	A paper-based, group (4 members), class activity where teams draw a random movie theme from a hat. They need to complete a game design worksheet and indicate elements of a conceptual game based on the theme, such as the appearance of the avatar, game-play mode, the storyline, how resources are collected and used during the game, and which design rules should be considered. This	A1, A2, A3, A4, B1, C1, C2, C3, C4, C5

	assessment supports the examination project in that it encourages the students to reflect on the game components they should consider in the design of their artefact.	
Short workshop on professional writing and research skills	From previous research conducted, it was explained to the students that industry members feel that students struggle with professional writing and research skills, and that Assignment 2 would contribute toward improving these skills. A short workshop was presented to demonstrate features in Microsoft Word that they may not be familiar with e.g. using Styles, proper alignment and academic language. Additionally, a demonstration of research approaches on Google Scholar, and where to find the university's local repository was provided. Referencing was also reviewed.	B1, B2, B3
Assignment 2: Research project on HCI design principles	An individual digital research report to evaluate any existing website according to design principles from theory. This assessment supports the documentation component of the exam project in that students need to write professional project documentation in which they need to indicate HCI design principles used in their exam projects.	A1, A2, A3, B1, B2, B3, C1, C2, C4, C5

The project

One of the characteristics of PBL is that the scope of the project influences the motivation to complete the project (Helle et al., 2006). At entry-level, students cannot yet complete industry scope projects because they have not necessarily mastered the essential skills. In order to encourage the motivation of students to complete the project, they were asked to provide their preferred topics live in class using a Google Doc displayed on the overhead. The ideas were narrowed down to 7 themes. Students could vote via poll for the theme they preferred to have as scope for their exam project. The student-proposed-and-chosen theme for the 2018 exam was '*what happens after graduation*'.

The traditional written examination was replaced with a practical project. Students had to create a serious game on the topic 'what happens after graduation'. Students completed the project in teams of two members. Game requirements included a start-up screen with relevant options, 3 levels of increasingly difficult game play, and a credit scene. Rubric criteria additionally focused on the level of coding difficulty and structure, HCI principles applied in the design, suitability of sprites and backgrounds to the theme, error handling, and presentation skills.

Project documentation included a general explanation of their game idea, the logical game play, and scoring system. Students had to report on the design process followed for their game by using the Design Thinking process model. Rubric criteria also included evaluation on formatting, referencing and professional writing.

All 21st century competencies as mentioned in Table 1 were addressed through this method of project-based learning.

The following sections focus on the research approach taken by reflecting on the methodology and data analysis that informs the results of the study.

Research approach

An interpretive approach towards understanding the experiences and perceptions of IT extended students in context of the PBL strategy is taken. Orlikowski and Baroudi (1991) indicate that interpretive studies are preferred when a deeper understanding of data is required. Qualitative data gathering and analysis methods are used in context of interpretive research for increased understanding (Oates, 2006). Interpretive content analysis is used to prepare and process qualitative data for traceability (Zhang & Wildemuth, 2009). It is important to note that when using interpretive methods that the analysed data is not weighted. The purpose of interpretive data analysis is to ensure that all voices are heard through identified themes in the data.

RESULTS

Data collection

The research was conducted at a university in central South Africa as part of an entry-level module in an IT extended degree. The researcher only became aware of reflective journaling towards the conclusion of the module. The approach could not realistically be applied at this point as it would lack the reflective nature that is central to the process. As a pilot study to determine if value can be derived from this approach for future iterations, students were asked to complete a structured, reflective set of questions on a single A4 page after the completion of the module. The instructions comprised of taking a moment to reflect on the activities that had formed part of the module, structured questions to indicate preferred teaching- and learning methods, and self-reflections on the skills they thought they had improved on. The reflective sheets were readily available during the first examination opportunity for the module, and students were asked to provide their reflections voluntarily and anonymously. Out of 49 students that were enrolled for the module, 34 students returned their filled-in copies. After reviewing the feedback rate, 4 copies were removed as they stopped providing reflections after the second question/ lost interest in completing the sheet. The reflections provided on these 4 sheets were reviewed for value, and the decision to discard these responses were based on the fundamental principle of the hermeneutic circle (Klein & Myers, 1999). Quantitative and qualitative data were received due to the reflective nature of writing about personal experiences. A final set of 30 completed reflective writings were included for analysis.

Data analysis

Basic descriptive statistics were used to analyse quantitative data in the form of gender information, preferences between specific methods, and improvements in skill levels. Atlas.ti 8.4 was utilised as a scientific software tool for analysing qualitative data by identifying codes and groups. A directed approach to open coding was used to perform content analysis on the qualitative data that related to their personal experiences in context of 21st century competencies. The qualitative data analysis process followed in this paper to ensure traceability and rigour, with the aim of satisfying the fundamental principle of the hermeneutic circle, comprised of:

- A directed approach to coding focusing specifically on questions and answers that were related to 21st century competencies.
- Each individual question was coded based on the identified codes from the previous question. Each question made use of existing codes and produced additional codes.
- When the final question was coded, the process was restarted at the first question to check whether codes that had been produced in subsequent questions were not overlooked when the process was started.
- The codes for all questions were re-evaluated for coding consistency. Similar codes were merged, renamed, or deleted if redundant, which resulted in a final set of 26 unique code names across the qualitative data.

Data representation

The participant gender information indicated that 63.3% female students and 36.7% male students completed the reflective sheets. Racial information was not collected.

96.7% of students indicated that they enjoyed programming in Scratch for this module. In context of the PBL strategy taken, 63.3% indicated that the marshmallow challenge was valuable, 80% benefitted from the game concept creation assignment, and 83.3% found the workshop on professional writing useful.

Qualitative findings related to the theme of 21st century competencies were included for the purpose of this paper. Structured questions (4) relating to their experiences of the formative assessments, and suggestions for improvement were analysed. Figure 1 (depicted in the next

section) provides a summary of codes identified, as well as the number of times they occurred. It is important to note that the code was counted for every occurrence across all included questions. Some answers provided such as 'yes' or 'no' did not provide value to the qualitative analysis and was coded separately under a unique code *quantitative answer provides no insight (yes/no/etc.)*.

DISCUSSION OF RESULTS

As the reflective exercise produced largely qualitative data, the discussion on results is focused on the reflections, experiences and suggestions made by the student participants. Figure 1 also depicts the codes grouped according to 5 identified themes, namely 1.) 21st century competency/ skill needs further development (4 codes), 2.) Improved a 21st century competency/ skill (6 codes), 3.) Benefits of following a PBL strategy (5 codes), 4.) Suggestions for improving the PBL strategy (6 codes), and 5.) Not related to outcomes of PBL strategy (4 codes). 21st century competencies improved on during the PBL strategy included time management, team work, critical thinking, attention to detail, problem-solving, and professional writing. The two important themes to focus on in context of this paper are the benefits and suggestions in context of using a PBL strategy.

Name	Grounded	Groups
PBL strategy is challenging (negative view)~	2	
Problem-solving skill needs further development	3	[21st century competency/ skill needs further development]
Professional writing skill needs further development	1	[21st century competency/ skill needs further development]
Time management skills need further development	3	[21st century competency/ skill needs further development]
Resource management skills need further development	2	[21st century competency/ skill needs further development]
PBL strategy was enjoyed	18	[Benefits of following a PBL strategy]
PBL strategy informs future perspective of IT career	7	[Benefits of following a PBL strategy]
PBL strategy promotes a learning environment	5	[Benefits of following a PBL strategy]
PBL strategy is challeging (positive view)~	5	[Benefits of following a PBL strategy]
PBL strategy promotes self-awareness of skill levels	2	[Benefits of following a PBL strategy]
Improved time management skill	2	[Improved a 21st century competency/ skill]
Improved working in a team skill	3	[Improved a 21st century competency/ skill]
Improved problem-solving skill	7	[Improved a 21st century competency/ skill]
Improved critical thinking skill	4	[Improved a 21st century competency/ skill]
Improved attention to detail skill	2	[Improved a 21st century competency/ skill]
Improved professional writing skill	14	[Improved a 21st century competency/ skill]
Content with PBL strategy implemented	1	[Not related to outcomes of PBL strategy]
Absent for PBL activity	3	[Not related to outcomes of PBL strategy]
Lecturer: Personal praise	3	[Not related to outcomes of PBL strategy]
Quantitave answer provides no insight (yes/no/etc.)	10	[Not related to outcomes of PBL strategy]
Extended training on difficult concepts	1	[Suggestions for improving the PBL strategy]
Provide more homework and exercises	7	[Suggestions for improving the PBL strategy]
Provide more context-related examples	2	[Suggestions for improving the PBL strategy]
Add additional programming platforms for development	1	[Suggestions for improving the PBL strategy]
Provide additional training outside of class (student ass...	1	[Suggestions for improving the PBL strategy]
Keep PBL strategy up to date with current trends	2	[Suggestions for improving the PBL strategy]

Figure 1: Atlas.ti extract of all identified groups, codes and number of occurrences.

Benefits of following a PBL strategy in an IT extended programme can be summarised as:

- IT students generally enjoy the project-centered nature of a PBL approach. *"It was fun." (participant 3)*
- IT students feel that the activities that form part of a PBL strategy promotes an environment for learning. *"I learned to create ideas through animation or portray my idea." (participant 28)*
- IT students feel that a PBL strategy challenges them in a positive way. *"It is because programming in Scratch is interesting, challenging, and mind opening" (participant 18)*

- IT students become aware of their own skill levels through a PBL approach. *"It shows my way of thinking and how it can be improved." (participant 26)*
- IT students focus on their future IT careers when subjected to a PBL strategy. *"This will help me in the future." (participant 4)*

Student-suggested improvements for the implemented PBL strategy are summarised as:

- IT students want additional training on difficult concepts. *"Perhaps give the theory part a little bit more time and lecturing I found it hard to study because some topics were new." (participant 4)*
- IT students want more homework and exercises to better prepare them. *"Make the students do more assignments and challenge them more." (participant 21)*
- IT students want more context-related examples. *"More examples of different coding and methods." (participant 8)*
- IT students want to be trained in as many development platforms as possible. *"Combine scratch and another programme to allow students to get more knowledge." (participant 26)*
- IT students want additional support outside of the classroom. *"Try to have the SI [supplementary instructor] to assist students out of class." (participant 27)*
- IT students want to keep up with current trends. *"Put more time in doing external research." (participant 29)*

CONCLUSION AND FUTURE WORK

A PBL strategy was adopted in this module to improve the 21st century competencies of IT students in an extended degree. The aim of improving their 21st century competencies earlier in an IT degree is to prepare them for employment sooner. In this way, the gap between IT higher education and the IT industry can more easily be bridged.

The value of project-based learning as pedagogy for training IT students cannot be stressed enough. Even though PBL is most often used at exit-level, traditional teaching and learning methods at entry-level should also be reconsidered. This view is supported by the student participants who indicated that even though only 56.7% preferred a project-based examination to a written examination, 73.3% agreed that additional learning takes place through a project-based examination.

As part of the PBL strategy taken, a large number of the assessments were *class* activities and *class* assignments to promote increased facilitator support. A surprising finding however was that students still prefer to be overloaded with homework and specifically requested additional exercises for training (7 occurrences).

While an overall improvement in 21st century competencies of the IT extended students was clearly noticeable through the PBL strategy taken (32 occurrences total), further development of the approach needs to be refined. A strong focus of this paper is the reflection of the student as well as the facilitator. Through continuous reflection on the PBL strategy taken, it was noted that certain approaches can further be classified as guidelines for bridging the IT theory-practice gap. Some of these guidelines include:

Interventions for bridging the IT theory-practice gap should take place earlier in a degree to raise career awareness continuously. Interventions include adapting teaching and learning approaches to the context of the industry.

Project-based learning is a suitable instruction method for IT education at all levels but the scope of the project needs to be managed in the context/ level of the student. The motivation for entry-level students are different than that of exit-level students. Entry-level students are

motivated by project scopes that are relevant to their current environment, while exit-level students are motivated by project scopes that are similar to what they can expect in industry.

IT students should be encouraged to engage in reflective practice on a continuous basis to highlight aspects that they need further development on. Reflective practice can take place through methods such as journaling, reflective sheets, and autoethnography. Keeping a reflective account of the successes and struggles during the course of a module will promote self-directed learning as the student identifies competencies that he/she have mastered and need additional assistance with.

Additional workshops on improving 21st century competencies are beneficial. More often, educators focus only on the content of the module that they are teaching, and not on the different skills needed to support the content. For example, IT students rarely receive training on professional writing methods, as the courses are more focused on technical skills. It is however expected in industry that reports need to be written or project documentation need to be compiled. Providing a short workshop on research and professional writing may be beneficial for an IT student to complete their projects successfully, and will contribute to the quality of their assessments throughout their degree.

The research can further be extended by making use of reflective practice to review all data received via the reflective sheets for guideline building as suggested. Other available data not included in the body of knowledge for this paper comprises of self-reflections on skill levels, the created games and project documentation. The artefacts can be reviewed based on the perceptions students had of what happens after graduation when they created a theme and storyline for their games. Additional valuable data contained in the project documentation of each game is the manner in which students attempted to explain their game development in the context of the design thinking process. The data received from participants not included in this paper (as it was not directly related to 21st century competencies) could also be included for analysis to improve the future PBL strategy.

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