Project Leadership and Society 4 (2023) 100096

Contents lists available at ScienceDirect

Project Leadership and Society

journal homepage: www.sciencedirect.com/journal/project-leadership-and-society

Empirical Research Paper

Student experiences of project-based learning in agile project management education

Carl Marnewick

University of Johannesburg, Applied Information Systems, South Africa

ARTICLE INFO

Keywords:
Project-based learning
PBL
South Africa
Information systems
Agile
Scrum

ABSTRACT

Project-based learning (PBL) is applied in various disciplines across the world and its benefits are well known and researched. For the past two decades, undergraduate information systems students at South African universities have been required to develop an artefact as part of a module. This is in the form of a project. PBL was formally applied at a South African university to determine the benefits to the students as well as how to improve the module for future students. The results indicate that all 13 criteria of PBL were met and that the students benefitted from a formal approach. They acquired various skills due to PBL that can be directly applied to the workplace. The results also indicate that PBL and the iterative nature of agile as an approach to develop the artefact complement each other. Although PBL assisted the students in learning, the specific skill set required was not determined and measured. This will form part of future research.

1. Introduction

The success of an information technology (IT) project is measured at various levels (DeLone and McLean, 2003; Marnewick and Marnewick, 2022; Petter et al., 2008). Yet, the success rates of such projects are still a problem. Various studies, academic as well as industry, illustrate the low success rates of IT projects irrespective of whether a predictive approach (waterfall) or an iterative approach (agile) is used (Butler et al., 2019; Flyvbjerg and Gardner, 2023; Joseph et al., 2014; Khoza and Marnewick, 2020; The Standish Group, 2018). Various factors contribute to this phenomenon but a factor specific to this article is the education and training of project managers (Carvalho et al., 2015; Dikert et al., 2016).

In 2006, Cicmil et al. (2006) launched a study to determine the knowledge and skills required by project managers. They concluded that "*the learning, development and mastering of project management skills and competencies*" must go beyond the traditional prescribed mainstream literature. Using this as the foundation, Ojiako et al. (2011) argued new innovative ways of teaching are required in the design of the curriculum but also in the delivery and that students should master transferrable skills which can be applied in any situation across various domains and industries. They go further by stating that the pedagogy needs to be realigned to address this new delivery and design of the project management curriculum. Pedagogy per se is the foundation of education but has been defined, interpreted and used in many ways (Loughran, 2013). Furthermore, pedagogy creates the link between teaching and learning. Teaching is the delivery of information whereas learning is information gathering. Samuelowicz and Bain (2001) mentioned that teaching and learning are dependent on the '*teaching-centred and learning-centred orientations*' of the academic. This speaks directly to the teaching-centred orientation of South African academics involved in undergraduate project management training, especially when it comes to IT project management.

Any student enrolled for an undergraduate degree in computer science or information systems in South Africa is required to participate in a project during their final year of study. The outcomes of this project are generally captured in a specific module called *Information Systems Project* or *Information Systems Development Project*. This is typically a year-long project and spans the academic third year of the undergraduate student. These projects integrate the practical and theoretical knowledge gained throughout the course and, with the application of theoretical elements of project management, deliver a fully functional system. This has been done since the early 1980s when computer science and information systems courses were introduced into South African higher education institutions.

The intentions behind these projects are good, but it is not evident whether these projects are grounded on educational principles such as project-based learning (PBL) or whether the students are gaining any experience from it that they can take with them into the workplace. PBL extends problem-based learning through the addition of a product or artefact. The creation of a product involves authentic investigation,

E-mail address: cmarnewick@uj.ac.za.

https://doi.org/10.1016/j.plas.2023.100096
Received 24 March 2023; Received in revised form 16 August 2023; Accepted 23 August 2023
Available online 25 August 2023

collaboration with team members and the use of technology during the inquiry process (Barak and Dori, 2005). Current literature focuses on the use of PBL in science, technology, engineering and mathematics (STEM) modules, particularly on science and mathematics. There is considerable research focusing on problem-based learning in the information systems domain (Taipalus et al., 2018), but there is little evidence of how PBL is applied within an *information systems project* and whether the students benefit from such an approach. Most articles focus on software engineering as an aspect of information systems such as the article by (Alves et al., 2018). Adkins and Tu (2019) conducted a study in which they incorporated agile as an approach in an information systems capstone course. The students were at master's level and the instructor became the scrum master. Technical competencies were addressed in the research of (Espinoza-Robles et al., 2022), who found that there was a significant improvement. There is also limited evidence in project management journals on how to teach undergraduate students in the discipline of project management. This article attempts to fill this void by answering the following two research questions:

1. How can PBL be used to teach agile project management?
2. What are the learning experiences of students when PBL is used to teach agile project management?

An effort is made in this study to develop new knowledge and better understand students' experiences of PBL. PBL was applied in a third-year module whose outcome is an information systems artefact. A single case study was used to explore the phenomenon and involved 61 students' self-reflections. The results indicate that all 13 criteria of PBL were met and that the students benefitted from PBL. They acquired various skills through PBL that can be directly applied to the workplace. The results also indicate that PBL and the iterative nature of agile as an approach to develop the artefact complement each other. The results from this study contribute specifically to the current project management education body of knowledge and in general to the PBL body of knowledge. The specific focus on information systems as part of STEM provides new insight into the application of PBL. A second contribution is the use of agile as a project management approach to manage the project. The iterative nature of agile is well supported by the iterative nature of PBL.

The article follows a traditional flow with the next section focusing on the literature on PBL. This is followed by the research methodology section, explaining the case as well as the data gathering method. The data is then analysed based on underpinning theories and principles of PBL. The article concludes with a discussion of the applicability of PBL within the information systems domain.

2. Literature review

2.1. Project-based learning (PBL)

Various definitions of PBL exist but all have one thing in common: PBL needs to culminate in a product or artefact (Helle et al., 2006; Kokotsaki et al., 2016). This product distinguishes PBL from problem-based learning (Chen and Yang, 2019). The focus of problem-based learning is on engaging students in finding solutions to real-life situations. PBL extends problem-based learning through the addition of a product or artefact. The creation of a product involves authentic investigation, collaboration with team members and the use of technology during the inquiry process (Barak and Dori, 2005). Lehmann et al. (2008) are of the opinion that this creation of a real-life product is interesting to students and underpins authentic investigation.

The most distinctive feature of PBL, according to Helle et al. (2006), is problem orientation where the problem drives the various learning activities. This is supported by Lehmann et al. (2008) stating that a cognitive learning approach is followed during PBL where learning is organised around problems. The creation and acquisition of knowledge are done within a project environment (Scarbrough et al., 2004). The creation of a product within a project environment creates opportunities for reflection, students accept responsibility for their own decisions and multiple perspectives are incorporated during the learning experience (Ayas and Zeniuk, 2001).

PBL is based on constructivism (Lehmann et al., 2008; Tseng et al., 2013). As per Frank et al. (2003, p. 5), constructivism can be defined as "*a theory concerning learning and knowledge which suggests that the human being is an active learner who constructs his/her knowledge on experience and on his/her efforts to give meaning to that experience*". Knowledge is constructed through the connection of new concepts that are founded on prior theory (Asamoah and Oheneba-Sakyi, 2017). Wulf (2005) posits that students are the centre of the learning experience that takes place through exploration. Students create their own knowledge into which they incorporate their learning. By nature, constructivism is collaborative and students work together to discover knowledge (Tay et al., 2011) and is best suited for PBL (vanOostveen, Desjardins and Bullock, 2019). In the literature, three modes of constructivism are discussed, namely radical, contextual and social.

1. *Radical:* The focus is on the intrapersonal process of individual knowledge construction (Liu and Matthews, 2005). The argument is that knowledge is not directly transmittable from person to person, but it is individually and idiosyncratically constructed or discovered (Hardy, 1997; von Glasersfeld, 2001).
2. *Contextual:* As per Cobern (1993); (Cobern, 1994), the construction of new knowledge is based on existing structures founded by various theories. In other words, the construction of knowledge takes place in a specific context (Wulf, 2005).
3. *Social:* Vygotsky (1980) states that learning and the acquisition of knowledge are affected by other people and are mediated by community and culture. He explains that cognitive growth occurs first at social level, and then at individual level. Social constructivism examines the knowledge and understandings that are developed jointly by individuals (Amineh and Asl, 2015; Prawat, 1999).

This student-centredness of PBL is based on three constructivist principles as per Kokotsaki et al. (2016): (1) learning is context specific, (2) students are actively involved in the learning process (Lehmann et al., 2008) and (3) they share knowledge through social interactions (Beier et al., 2019).

Students master various competencies through a PBL approach. These competencies include problem-solving, contextual analysis, subject knowledge, technical skills, cross-disciplinary knowledge, knowledge management, collaboration, communication and project management and planning (Lehmann et al., 2008). These competencies are acquired and ingrained over an extended period as the project goes on for a considerable length of time (Helle et al., 2006).

Various benefits are associated with PBL education and teaching staff should ensure that they take note of these benefits and determine whether they are realised. According to Chen and Yang (2019), students experience increased academic achievement and are less likely to drop out of the course and institution. When PBL was applied to a mathematics course within a STEM environment, Han et al. (2015) found that low-performing groups of students improved at a higher rate than middle- and high-performing groups. The finding is that students exhibit differential achievement and growth within the same learning environment. Beier et al. (2019) are of the opinion that the biggest benefit is that students are exposed to real-life projects and that they gain experience without the risks associated with projects in a work environment. As a result, students obtain a realistic perspective of their prospective careers.

Through the review of the literature, the following criteria were identified for effective PBL. These criteria guide the lecturer in creating an effective PBL environment.

2.2. The South African context

Students enrolled for a bachelor's degree in computer science or information systems at South African higher education institutes are enrolled for a third-year module focusing on creating an artefact. This artefact is typically an IT system such as a patient booking system for a medical practitioner or a tutor system where tutors and students can link up with each other. This project typically relies on prior knowledge (radical constructivism) and students work in groups (social constructivism). This project is typically done over a one-year period. Table 2 sets out the purpose and learning outcomes of third-year information systems modules.

Table 1
Criteria for PBL (Ayas and Zeniuk, 2001; Barak and Dori, 2005; Beier et al., 2019; Chen and Yang, 2019; Kokotsaki et al., 2016; Scarbrough et al., 2004; Thomas, 2000).

Criterion	Description
Centrality	The project-based aspect is central to the curriculum. The projects are authentic in terms of the topics, the context in which the work gets done and the activities that students perform.
Driving problem	The focus of the projects is on problems that drive students to engage with the central concepts and principles of a discipline.
Constructive investigations	The central activities of the project must involve the construction of knowledge by students.
Autonomy	Projects are student-driven to some significant degree and establish a culture of student self-management. Students develop a sense of ownership and control over their learning.
Realism	Projects are realistic or authentic. Students are directed toward constructing their own understanding of the central principles of a discipline.
Sense of purpose	The project provides students with the opportunity to deliver on a project that has meaning. Learning is focused on the application of knowledge and not just the mere recital of theory.
Psychological safety	Students are performing PBL in a safe environment that is stripped from corporate pressure. When they do something wrong, there are no repercussions from a career perspective. The purpose is to learn from mistakes, which is part of the learning culture.
Communities of practice	Students are encouraged to work with others outside the classroom. High-quality groupwork ensures that students share equal levels of agency and participation.
Systemic and collective reflection	The emphasis of assessments is on reflection, self-evaluation and peer evaluation. Evidence of progress needs to be regularly monitored and recorded.
Practice-based nature of knowledge and learning, knowledge integration	Acquired knowledge is applied in a practical environment. This creates alternative insights that are not possible without practical integration of the knowledge. Students are mastering content as they are applying it.
Student support	Students need to be guided and supported. Emphasis should be on effective time management and student self-management, including making safe and productive use of technological resources.
Balancing didactic instruction with independent inquiry method	Students develop a certain level of knowledge and skills before being comfortably engaged in independent work.

Table 2
Learning outcomes of modules from South African universities.

University	Purpose and Outcomes
Uni_1	The purpose is to give students the opportunity to be part of a 'real-life' information systems development project. Students are expected to analyse, design, test and implement a business information system focused on essential business processes for a 'real-life' user, as part of a project team. It is important to note that pure CRUD and reporting (as found in a typical MIS) will not be sufficient – the system must include well-defined business processes.
Uni_2	The module aims to equip the student with crucial problem-solving skills using object-oriented software development techniques, and endeavours to improve technical document writing skills. This whole-year course is for students majoring in Information Systems to gain an understanding of the issues that influence ICT projects and to experience the development and implementation of such a project. This course combines the theoretical elements of project management with the practical implementation of these concepts through the completion of a systems development team project, integrating practical and theoretical elements obtained and developed during other undergraduate information systems courses. The theoretical parts of this course aim to make the project team experiences more true to life, aiding the development of a project practitioner. Students should be aware that successful project management consists of a sound plan (using project management tools and techniques) and strong people management to direct the plan through to the completion of the project's deliverables. The basis for this development process is an interactive optimised team environment of learning through experiences and reflection. The practical part of this course involves the application and implementation of these concepts following the full life cycle of a team-based IS project in a real-life setting.
Uni_3 (Case study)	The purpose of this module is to get students to integrate and use most of the tools they covered in the programme (BCom IS) to produce a complete software application that meets industry requirements. • Develop an integrated software project that must demonstrate all the skills required as a culmination of all the training during their qualification. • Present various deliverables during the different phases of the development of the project. • Produce relevant documentation according to acceptable standards.
Uni_4	The third-year systems development project runs through the entire third year and students work in development teams to produce a system. A waterfall approach is taken to the development as it is easier to manage and have them submit milestones along the way. The project is designed to give the students an opportunity to put into practice the full systems development life cycle that they learned in the second year. It is not a separate module and is integrated into other third-year modules. One of the important differences between these projects and those completed at some other universities is that all the teams develop a system based on the same problem outline.
Uni_5	This module is the capstone module to an undergraduate major in either Socio-Informatics or Information Systems Management. It brings together knowledge obtained across many of the other modules to form a complete end-to-end systems design and development process. In doing this, students are exposed to new techniques and/or programming languages and additional concepts not introduced in earlier courses. Students will spend most of their semester analysing a case study, which they will then use to design and build a complete and functional business information system.

2.3. Agile project management and scrum

IT projects are historically done using a predictive or waterfall approach, but due to the low success rates of IT projects using this approach, organisations have transitioned to an iterative or agile approach. The agile approach has been adopted by various international companies such as the ING group and Spotify. In South Africa, financial institutions (Standard Bank, Nedbank) and telecommunications companies (Vodacom) are adopting agile as the preferred approach to implement projects. Research also indicates that projects using an agile approach are more successful than those using a waterfall approach (Khoza and Marnewick, 2020; The Standish Group, 2018). Table 3 provides a comparison of the two approaches.

Most South African universities are still using a traditional waterfall approach to plan, implement and deliver the required IT system. In the case of Uni_3 (Refer to Table 2), an agile approach is used. The most used agile methodology is Scrum (Khoza and Marnewick, 2021; VersionOne Inc, 2020). This specific methodology is taught at Uni_3 instead of the formal waterfall approach during the second year. Students are then expected to apply the theoretical knowledge during the third-year project.

The Scrum methodology manages the delivery of an IT solution in sprints (Mahalakshmi & Sundararajan, 2013). The product backlog refers to the list of activities not yet executed within the project. A sprint is a specific development cycle that usually lasts two to four weeks. The Scrum team is allowed to add new activities to the product backlog that will be reviewed when a new sprint begins. Customers review implemented features at the end of each sprint. All the team members, including the customer, have the responsibility to assess the direction of the development process and adhere to changes as they might take place because they understand the final product better (Moe et al., 2010). Often customers will have a better realisation of what they want as the development process takes shape, features are implemented and there is a better understanding of the requirements. Scrum has its own defined roles, including product owner, team members and Scrum master, and each role has its own unique responsibilities (Mahalakshmi & Sundararajan, 2013).

Daily stand-up meetings are where the team members meet to evaluate the progress of the anticipated IT solution. This process encourages everyone to participate and to know what each member is doing to deliver the solution and therefore it increases the productivity of the team (Moe et al., 2010). The product backlog captures the list of tasks that need to be completed for the project. This list of activities in the sprint backlog is created by selecting activities from the top of the product backlog until adequate effort is settled for the upcoming sprint, bearing in mind the amount of work together with the performance of the team during previous sprints. The entire team must work together to accomplish the delivery of the final product and satisfy customer requirements. The product owner has a responsibility to clarify all requirements to the team, drive all releases and plan for sprints (Remta and Buchalcevova, 2021). The team will always report progress to the product owner, while the product owner assesses the direction of the development process, ensuring that it yields the benefits associated with the final product (Zwikael et al., 2019). The product owner can also propose changes in the implemented features.

Table 3
Difference between agile and waterfall approaches (Alshamrani and Bahattab, 2015; Ashmore et al., 2018; Ikonen and Abrahamsson, 2010; Kisielnicki and Misiak, 2017).

	Waterfall	Scrum
Approach	Freezes scope, estimates schedule	Freezes schedule, estimates scope
Customer involvement	At beginning and end	Frequent collaboration
Scope	Build everything in the specification documents	Build what customer really wants by priority
Design	Design all features upfront	Emergent design of few features per iteration
Development	Linear path across phases	Iterative incorporating learning
Delivery	Big bang at the end of the project	Frequent small increments
Testing	Separate phase after development	Continuous functional and unit testing inside iterations
Cost of change	High	Low
Requirements	Defined upfront and rigid	Allow changes as far as possible
Documentation	Upfront and exhaustive	Document only what is built and as needed
Team communication	At phase hand-offs	Continuous and cross-functional

3. Research methodology

A case study approach was used in this study. The rationale for this approach was to study the phenomenon in its natural context. In this instance the case itself was a third-year class enrolled for a bachelor's degree in information systems. An interpretative case study strategy was used, as the author was directly involved in the case study and provided an insider's perspective (Martinsuo and Huemann, 2021). The role of the researcher was to manage the learning process, provide feedback to the groups on a regular basis and engage with the mentors.

Students formed their own teams ranging between four and six members. In line with the Scrum methodology, each team had a product owner. The product owner was the person who wanted an IT solution to a specific business problem. The entire year was divided into sprints and at each sprint, the teams had to showcase what they had achieved and learned. There were ten sprints and a final assessment of the IT artefact. This final artefact was evaluated by four industry experts.

Each team was also allocated a mentor from industry. The role of the mentor was to assist the teams with general business acumen, the technicalities associated with agile and Scrum, as well as other technical problems. Feedback from the researcher was in terms of the deliverable for the specific sprint. Each sprint had specific deliverables that were evaluated by the researcher. These deliverables included a prioritised product backlog, a sprint backlog, a sprint burndown chart, a retrospective and the team's velocity, to name a few.

The case study met the criteria of PBL as stated by Helle et al. (2006): (i) it involved an IT solution to a business problem, (ii) the IT solution was highly dependent on the initiatives of the students, (iii) there was an end product, (iv) it was a lengthy project and (v) the researcher was involved only in an advisory role. Fig. 1 provides a graphical presentation of the academic process. The first two assignments (design thinking and product backlog) assisted the groups in understanding their product and planning the project over the academic year into ten sprints of two weeks each. The ten sprints followed a Scrum approach to incrementally develop the product. The product owner and mentor played a coaching role, and the lecturer assessed the outcomes of the sprint. At the end of the project, four industry experts assessed the entire year project focusing on (i) the students' knowledge and application of agile and (ii) the final artefact's functioning.

Some 63 students enrolled for this module and answered the following four questions at the end of the module in the form of a self-reflection journal:

1. Reflect on how your technical abilities and skills improved.
2. Reflect on your knowledge of agile and the application of agile.
3. Reflect on the overall application or artefact that your team developed.
4. Reflect on the social aspects of the project including the role of the mentor, the role of the product owner and the team's performance.

A self-reflection journal is a personal record of the student's learning experiences. These experiences include observations, team collaborations or engagement with literature and occur during the entire learning process. This is in line with the results of Guo et al. (2020) stating that self-reflection journals are one of five instruments used to measure and analyse PBL.

The purpose of the questions, which were open ended, was to determine the students' experiences. Inductive coding was used to prevent bias towards any preconceived ideas regarding PBL and the students' experience. This coding provided a richness that was not

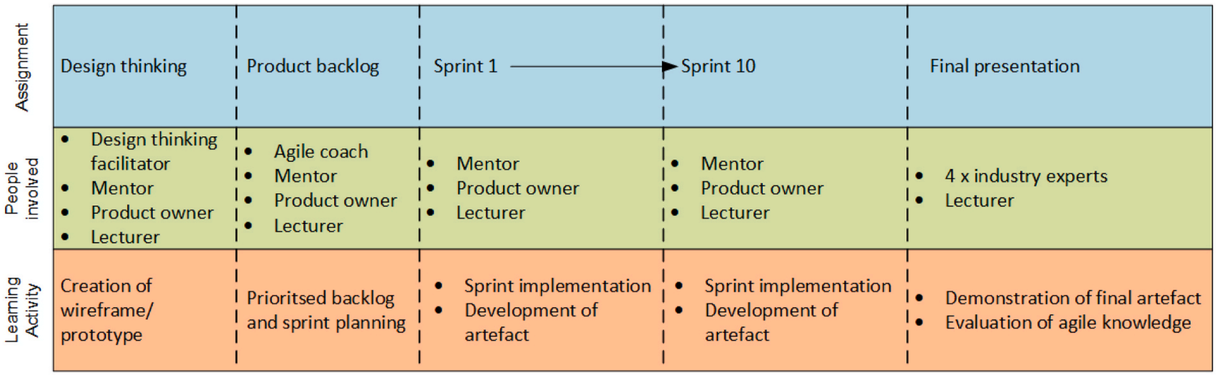

Fig. 1. Graphical presentation of the academic process.

possible through deductive coding. The following steps were taken to identify the codes and groups (Lewins and Silver, 2008; Von Seggern and Young, 2003):

1. Open coding was performed on each of the 63 student reflections. This step generated a large volume of codes which encapsulated the notion of "what is going on".
2. In the second step, axial coding was performed where all the codes generated were analysed. The codes were re-evaluated in terms of similarity and difference and consolidated where appropriate. This resulted in 75 unique identified codes and 603 associated quotations. This is on average eight quotations per code.
3. In the third step (selective coding), the 75 codes were revisited once more to identify themes and concepts. The four questions posed to the students informed the groupings of the codes into themes and concepts. Regarding skills and abilities, 15 unique skills were identified, two challenges (lack of leadership and technical skills) and one enabler (knowledge from previous academic years). The second question (agile knowledge and application of agile) resulted in 28 quotations and the artefact produced 29 quotations. The fourth question focused on the social aspects and two groupings were identified, i.e. the mentor and the product owner. The mentor group consisted of five codes (mentor, mentor availability, mentor coaching, mentor familiarity and mentor knowledge) and 159 corresponding quotations. The product owner grouping consisted of four codes (product owner, product owner availability, product owner communication and product owner involvement) and 92 corresponding quotations.

The next section presents the results of the thematic analysis.

4. Results

A total of 61 self-reflection journals were imported into Atlas.ti for analysis. Two students did not submit self-reflection journals. This section covers the results based on the four questions posed to the students. Certain themes emanated from the analysis and form part of the discussion. The first self-reflection component focused on technical abilities and skills improvement.

4.1. *Technical abilities and skills improvement*

The purpose of PBL is for students to gain new skills and knowledge through a practical application. Table 4 indicates the skills and knowledge that the students mastered throughout the year. These skills are mapped against the constructivism modes.

The acquired skills and knowledge address all three constructivism modes. What is not known is the extent to which these skills and knowledge address the constructivism modes and this will form part of future research. Although the students gained new skills and knowledge, various shortcomings were mentioned.

4.1.1. *Shortcomings*

The first shortcoming is a lack of programming skills. Although the students mastered new programming skills as per Table 4, they did not believe that the underlying programming modules prepared them for the project. "*In my opinion the information systems course does not equip a student with the appropriate programming skills required to dive into full application or website development*" [S21] and "*Prior to this project at the beginning of the year I only had a vague idea of coding without the practical aspect of how it could be applied in real life*" [S7]. Another shortcoming highlighted by S11 is leadership: "*I would have given the project leadership to another member as I do not have the skillset required to manage a team as effectively as I thought I did.*" Although new skills are acquired throughout the project, the project cannot be initiated and mastered without prior knowledge. The following quotes highlight how the students perceived their prior knowledge.

- "*These skills were not learnt throughout my university career for we did not receive the skills that we would need to achieve this project but rather having to self-learn*" [S17]
- "*Working on this project gave me escapade because it meant applying what I had learned from the previous years at the university*" [S26]
- "*Most of the data that was used in our web application was from the database. Fortunately, we had learned database in the previous year and continued with it this year so the only thing I needed to learn was how to integrate it with VB.Net*" [P37]
- "*Having learnt about agile from the previous year, I was to put the theory knowledge into practice*" [49]

4.2. *Knowledge and application of agile*

The purpose of this module is to produce a complete software application using the latest thinking, i.e. agile, to deliver the project. Throughout the year, the teams followed sprints to deliver the project. As discussed, the first artefact was the *product backlog*. "*We also, at this point, began to set and prioritize our backlog according to what [product owner] wants as opposed to what we thought he wanted*" [S1]. This was echoed by S13: "*The group first created a product backlog which allocated the items that required to develop the application along with their user stories and activities to be done.*"

Based on the *product backlog*, *sprints* had to be defined to assist with the planning and to deliver the project within the academic year.

- "*We began this journey with writing down the user stories for the system, then breaking it down into sprints which would permit us to develop up our project in steady phases*" [S10]

Table 4
Acquired skills and knowledge.

Skill	Verbatim Quotes	Constructivism Mode
Analytical/critical thinking	• "*The journey in this project improved my* ***analytical*** *skills, through my ability to do research and make analysis, forecasting the future of the project and solving problems as they arise*" [S6] • "*The design process and the problem solving was a great help to me as it improved my* ***critical thinking*** *skills*" [S8] • "*Development of the application put my* ***critical thinking*** *skills to the test as I was presented with various problems which seemed impossible at first but upon further research and learning these problems were overcome*" [S21]	• Radical • Contextual
Communication	• "*In the development of this application I improved my overall technical skills such as my coding skills and time management skills as well as* ***communication*** *skills and teamwork skill*" [S15] • "*Working with my mentor improved my* ***communication*** *skills, this provided me an opportunity to practice necessary skills, including empathy and active listening*" [S30]. • "*Another technical aspect that improved was the ability to interface operatively in both technical terms when* ***communicating*** *with the team and non-technical terms when* ***communicating*** *with the product owners and end users*" [S26]	• Social
Database	• "*The application required me to familiarise myself with firebase* ***database*** *to be able to create tables for saving the user's personal information and records for every task they performed*" [S12] • "*Skills on how to store, extract, manipulate and secure data were advanced during the project. I have learnt different methods on creating an efficiently run* ***database***" [S18] • "*Initially designing the* ***database*** *had been a challenge as we did not really know what goes into designing a database for an e-commerce site*" [S23]	• Radical • Contextual
Programming	• "*While doing the project; one of the many skills gained is being exposed to a new* ***programming*** *language*" [S28] • "*My IT* ***(programming)*** *skills have improved quite considerably since the beginning of this module. My perspective on programming has changed quite a bit since the start of this year, I have noticed that that I look at programming differently than I used to*" [S30] • "*I did a lot of self-learning throughout the year so that I can improve my* ***coding*** *skills and play my part in the group project*" [S49]	• Radical • Contextual
Problem-solving	• "*Also this project has challenged me into think outside the box and to try and find unconventional solutions to* ***solve problems***" [S5] • "*This year also helped me become more creative in my thinking and* ***problem solving*** *as most of the obstacles were faced with were going to be unsolved if we thought inside the box or of what is right*" [S16] • "*The skills of* ***problem – solving*** *is also something I have attained throughout the course of this project as we faced problems along the way*" [S24]	• Radical • Contextual • Social
Project management	• "*Being in a real-life project environment has enabled me to understand* ***project management*** *as a skill in a more meaningful way. Project management skills have enabled me to plan efficiently, critically analyse a problem, and to work within specific schedules*" [S2] • "***Project planning****, organizing, leading, and lastly controlling was very essential to make sure that all planned tasks are met in time and also to ensure that the project is a success*" [S6] • "*Furthermore, my IT* ***project management*** *skills significantly developed*" [S18]	• Radical • Contextual • Social
Teamwork	• "*In the development of this application I improved my overall technical skills such as my coding skills and time management skills as well as communication skills and* ***teamwork*** *skills*" [S15] • "*I learnt a lot from this module, not just how to use Agile methodologies but through it I have learnt time management skills, people skills and how to* ***work in a team***" [S28] • "*I enjoyed developing the application because it helped me to grow and showed me why* ***teamwork*** *is essential, and it showed me how certain people are*" [S50]	• Social
Technical	• "*My* ***technical*** *skills also improved in terms of learning more about security when we were improving the security of our system by using data encryption to secure the customers personal information*" [S9] • "*Working on this project greatly improved my* ***technical*** *skills and abilities by allowing me the opportunity to critically assess a situation and establish the relevant cause of action*" [S21] • "*My* ***technical*** *skills have improved greatly as I got to work with new technologies and various other collaboration tools*" [S48]	• Contextual
Time management	• "*Agile helped me and the group with* ***time management*** *as we had a productive feature to be present in a bi-weekly time period*" [S13] • "*In the development of this application I improved my overall technical skills such as my coding skills and* ***time management*** *skills as well as communication skills and teamwork skill*" [S15] • "*Being part of this amazing project with hard working individuals taught me a lot about* ***time management****, setting out goals and making sure within a set of time that goal is finished and met*" [S33]	• Radical • Contextual

- "*The one of the first advantages I've realised when using Agile project management is that when dividing the project tasks into sprints; it helped us better understand how much of work we needed to do to complete the project*" [S5]

An important aspect of Scrum is the *sprint retrospective*. The purpose of the retrospective is to review the sprint and find ways to improve the ways of working. "*We also had retrospective meetings where we identified what we liked, learned, lacked and the actions we too, from there on we would come up with ways to improve our performance for the next upcoming sprints*" [S26].

The analysis of the data concludes that the teams mastered agile thinking in general and the Scrum methodology in particular. All the teams managed to deliver a product that could be used by the product owner, which is the focus of the next self-reflection section.

4.3. Final application or artefact

The students did not reflect on the final application or artefact comprehensively. Only three students mentioned that the product owner was satisfied with the final product as reflected in the following quotations:

- "*looking at the final product, I think we did exceptionally well*" [S10].
- "*After the project was completed they were happy with the final product and believed it would help them a lot*" [S58].
- "*The coherence of the team is evident as the product owner was happy with the final product*" [S59].

4.4. Social aspects

The fourth self-reflection component focused on the social aspects of the mentor, the product owner and the team's performance.

4.4.1. Mentor

Zackariasson (2014) defines a mentor as a person that can show someone else the ropes and also instil know-how and self-confidence. An effective relationship should be established between the mentor and the mentee(s) as the mentor offers support from an objective perspective (Wilkes, 2006). In an educational environment, mentoring involves personal and intimate pastoral relations (Lindén et al., 2011). For the mentorship to be successful, the mentor should be engaging with the team on a regular basis. The feedback from the teams varied from being positive ("*He was really involved and gave us so much of his time in mentoring us and relaying what industry requires of a development team and the individual developer at many different points of a project*" [S1]) to extremely negative ("*although multiple efforts of the entire team to get in contact with her, she refused to attend any of our meetings so in our project we did not really have a role of a mentor*" [S48]).

The mentors were selected based on their agile knowledge and ability to impart their knowledge to the teams. The teams were appreciative of the mentors' knowledge and made use of this to enhance their own learning.

- "*With his vast knowledge of 'being agile' helped us customise our Trello board and laid the foundation and the structure for us to follow to be agile*" [S10]
- "*Our mentor made us see the importance of using the agile methodology, as he gave us tips which we would later put into practice in our sprints*" [S49]
- "*Through our sessions with our mentor we learned a lot. One of the things we learned was how to apply a RAG (Red Amber Green) status, which we did in our weekly meetings. It made it easier to assess our performance for a certain sprint*" [S53]

The teams that managed to create a rapport with their mentor clearly experienced the benefits associated with being mentored as per the following testimonies:

- "*He never solved our bugs for us but always gave us the resources needed to resolve the bugs*" [S4]
- "*Our mentor really made sure we work up to our full potential and she also made sure we clearly understood Agile*" [S22]
- "*Mr X helped us set realistic goals, monitored our progress, gave us guidance, constructive criticism, and support till the completion of our project*" [S26]

4.4.2. Product owner

The product owner has to maximise the value of the product developed by the team (Unger-Windeler et al., 2019). They are responsible for the elicitation and prioritisation of the requirements, and are solely responsible for managing the product backlog (Remta et al., 2020). For most of the teams, the role of the product owner was invaluable, with S21 stating that "*the product owner played a large role within the project and was really good to work with*". This was confirmed by S2's comment: "*the product owner has been an active member of the team from the early stages of the project*". As with the mentor, availability was crucial to the success of the projects. The consensus was that the product owners availed themselves to the teams and provided inputs on the final product. The reason for this involvement and availability could be that the product owners ultimately received a free and fully working product. Unlike some mentors who did not play their part, all the business owners were involved, albeit with some frustrations to the students. S7 made the following comment: "*It would be frustrating at times when the product owner would change his mind about some of the required features as agreed from the start, but it also made me appreciate agile more as work was done in smaller chunks instead of in big chunks*." This sentiment was also echoed by S15, stating that "*there were times where [X] continuously changed his mind as to what he wants in the project …*".

4.4.3. Team performance

For teams to perform, they need to go through the stages of forming, storming, norming, performing and adjourning (Dingsøyr and Lindsjørn, 2013; Pavez et al., 2022). The teams went through these stages, some teams quicker than others. "*Things slowly started working out as we got to know each other better established our roles towards tackling the project and our results would steadily increase accordingly*" [S3]. This sentiment was echoed by S4: "*We started of with communication problems because we were mostly all people that didn't work well in groups, and that reflected in our marks.*" S11 summarised the team's performance well: "*Over the weeks of working with them, we began to gel together and work more effectively as a team, and even developed friendships outside of the working environment.*" The students concurred that the reason why they could deliver a successful product was that they overcame their differences and collaborated.

Table 5 indicates how the modules map to the PBL criteria. It is evident that all criteria were met and that the students benefitted from this approach.

The word cloud in Fig. 2 summarises the students' experiences throughout the module. The key words that stand out are *project*, *us*, *team*, *product*, *group*, *skills*, *learning*, *experience* and *application*. These key words underline what PBL aims to achieve. The word cloud was generated using Atlas.ti and only words with a minimum count of 100 are included.

Leoni (2014) mentions that only a constructivist pedagogy like PBL can prepare students for a future where skills and competencies are continuously changing.

5. Discussion

This section focuses on three perspectives, i.e. PBL, project management education and explicit pedagogical implications. The first perspective is that of PBL.

The purpose of PBL is to create and acquire skills and knowledge within a safe project environment. The students acquired knowledge through the application of the theory in a real-life environment (refer to Table 4). The environment was safe and allowed them to make mistakes

Table 5
Mapping of module to PBL criteria.

Criterion	Evidence	Adherence
Centrality	The project-based aspect is central to the curriculum. The projects are authentic in terms of the topics, the context in which the work gets done and the activities that students perform.	✓
Driving problem	The focus of the projects is on problems that drive students to engage with the central concepts and principles of a discipline.	✓
Constructive investigations	The central activities of the project must involve the construction of knowledge by students.	✓
Autonomy	Projects are student-driven to some significant degree and establish a culture of student self-management. Students develop a sense of ownership and control over their learning.	✓
Realism	Projects are realistic or authentic. Students are directed toward constructing their own understanding of the central principles of a discipline.	✓
Sense of purpose	The project provides students with the opportunity to deliver on a project that has meaning. Learning is focused on the application of knowledge and not just the mere recital of theory.	✓
Psychological safety	Students are performing PBL in a safe environment that is stripped from corporate pressure. When they do something wrong, there are no repercussions from a career perspective. The purpose is to learn from mistakes, which is part of the learning culture.	✓
Communities of practice	Students are encouraged to work with others outside the classroom. High-quality groupwork ensures that students share equal levels of agency and participation.	✓
Systemic and collective reflection	The emphasis of assessments is on reflection, self-evaluation and peer evaluation. Evidence of progress needs to be regularly monitored and recorded.	✓
Practice-based nature of knowledge and learning, knowledge integration	Acquired knowledge is applied in a practical environment. This creates alternative insights that are not possible without practical integration of the knowledge. Students are mastering content as they are applying it.	✓
Student support	Students need to be guided and supported. Emphasis should be on effective time management and student self-management, including making safe and productive use of technological resources.	✓
Balancing didactic instruction with independent inquiry method	Students develop a certain level of knowledge and skills before being comfortably engaged in independent work.	✓

and learn from these mistakes. Throughout the entire project, the students were the masters of their own destiny. They made their own decisions on the programming languages, database and whether the final product should be a web application or a mobile application. This freedom of decision-making allowed them to understand the consequences of their choices and in some instances, teams got low marks if they did not meet the criteria for that specific assignment. Throughout the project, the three constructivist modes (Kokotsaki et al., 2016) were followed. Learning took place in a very specific context as described in the research methodology section. The students were actively involved in their own learning process. Some teams took longer to master some aspects, but at the end of the project, everyone had the same basic knowledge of agile and Scrum. The students also shared their knowledge and skills. In this instance, they experienced difficulties with social interactions due to the COVID-19 restrictions. As per Helle et al. (2006) and Lehmann et al. (2008), the students mastered various soft and technical skills. Mastering the soft skills would not have been possible in a non-PBL setting. The students might have mastered some of the technical skills, but they also mentioned that some of the technical skills were basic and did not prepare them for project work.

Fig. 2. Word cloud of students' experience.

One of the benefits associated with PBL is the low drop-out rate. Throughout the year, none of the students de-registered from the module and this is reflected in the 100% pass rate for the module with a final average mark of 72% across all the teams. The final marks varied between 62% and 82%.

The biggest benefit of the PBL approach for the students was the real-life project that they embarked on. They experienced the real trials and tribulations of a project but in a safe environment. They interacted with various stakeholders as well as the end-users and could see the product being used by real users in a real-life environment.

The second perspective is that of project management education in general. This article addresses the concern raised by Guo et al. (2020) that not enough research on PBL is conducted in higher education. The results can be assimilated with other research emphasising the benefits of PBL especially in a higher education context, but also an information systems project-specific context. As an answer to calls by Ojiako et al. (2011) as well as Cicmil et al. (2006), the introduction of PBL brings novelty into the teaching of IT project management at a higher education level. It also ensures that transferable skills are developed by the students that they can take with them into the workplace. As per Mnkandla and Marnewick (2011), students gained theoretical project management knowledge as they had to master theoretical concepts such as sprints, backlogs and team velocity. They also developed appropriate skills (Table 4) including technical and soft skills such as presentation skills. Lastly, they mastered tools and techniques. Tools include Trello (www.trello.com) to manage their backlog and Excel to communicate the various burndown charts. It is also important to note that teaching project management cannot be based only on standards and best practices. Pedagogy should also be considered and academics should become teaching-centred. Academics should ensure that the three constructivist principles of Kokotsaki et al. (2016) are addressed when they incorporate PBL into the project management curriculum.

The third perspective focuses on explicit pedagogical implications. When an academic is applying PBL to teach the principles of project management, several pedagogical implications need to be considered:

1. The lecturer guides and supports students throughout the project. Mastering theoretical content such as project management standards and frameworks is left to the student. The lecturer only provides the

necessary resources, clarifies concepts and offers feedback to the students.
2. The lecturer should design meaningful and challenging projects that align with the learning objectives of the module. More importantly, critical thinking and problem-solving skills should be at the core of the project design.
3. PBL relies on ongoing formative assessments to monitor the student's progress. There are no formal examinations or summative assessments. This implies the continuous involvement of the lecturer. Guidance and support are part of the formative assessment, ensuring that the students stay on track and make improvements.
4. Ongoing formative assessments require the lecturer to consider alternative forms of assessment, such as rubrics, peer evaluations, presentations and the valuation of the final project deliverable.
5. The lecturer plays a critical role in creating a positive and inclusive learning environment. Students are inspired to take ownership of their learning when curiosity is encouraged, their efforts are celebrated and a growth mindset is promoted.

Introducing PBL into the curriculum requires a different mindset from the lecturer and a commitment that goes beyond the norm of arriving at class and presenting a lecture driven by slides.

6. Conclusions

The advantages of PBL have been documented in various studies. The biggest advantage is the exposure of students to real-life projects and the experience that they gain. This article highlights the importance of PBL in providing authentic learning to students. Information systems students were exposed to PBL during their third-year project and the feedback was overwhelmingly positive. The students gained practical knowledge on how to manage a project using an agile approach and they gained skills that would not have been possible in a non-PBL environment. The research highlights the importance of PBL in information systems. The creation of an artefact cannot be done without the application of PBL. PBL can only be successful if the entire course is designed around the criteria as stipulated in Table 1. This implies that the lecturer or facilitator must design the course around the principles and criteria of PBL. An additional benefit that the research highlights is the symbiosis between agile and PBL. The iterative and continuous feedback that is part of agile is more conducive to PBL than the waterfall approach. The waterfall approach would not have met all the criteria of PBL. Various studies indicate the value of PBL, but none of these studies were done in a South African context. Although most of the studies were done in the STEM environment, this specific study was done within the information systems field. PBL is applicable to most courses, irrespective of the field or country. Students gain value from a course where the project is central to the course or curriculum. This is irrespective of whether a formal PBL approach is followed or not. Students will gain more knowledge and have a better experience if PBL is properly applied. This research focused on a specific cohort for a specific module. Future research will focus on three aspects. Firstly, the student perspective forms the core of this research. Therefore, the same research will be done each year. The feedback will be used to improve and enhance the module. Secondly, the students highlighted the skills that they mastered throughout the year. Future research will focus on their skills at the beginning of the academic year and these will be monitored and evaluated throughout the course of the module. This will be used to identify specific interventions either through formal training or as part of the PBL. Thirdly, feedback from the product owners and mentors will be obtained. The aim is to enhance their own experience but also to improve the module.

No study is without shortcomings. The first shortcoming is that there was no reflection on the actual artefact. Three students did reflect on the usage of the artefact, but no reflection was done to evaluate whether the artefact realised the intended benefits. Another shortcoming is that the students operated within their own information systems discipline without any engagement with other disciplines such as marketing and entrepreneurship. Marketing could have assisted the team in promoting their artefact and entrepreneurship might have sparked the idea of an own business.

Students enter the workplace well equipped as a direct consequence of PBL. The jury is still out on whether the success rates of future IT projects will improve because of this intervention.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

Adkins, J.K., Tu, C., 2019. Applying an agile approach in an information systems capstone course. Inf. Syst. Electron. J. 17 (3), 41–49.

Alshamrani, A., Bahattab, A., 2015. A comparison between three SDLC models Waterfall model, Spiral model, and Incremental/Iterative model. Int. J. Comput. Sci. Issues 12 (1), 106–111.

Alves, L.M., Ribeiro, P., Machado, R.J., 2018. Project-based learning: an environment to prepare IT students for an industry career. In: Computer Systems and Software Engineering: Concepts, Methodologies, Tools, and Applications. IGI Global, Hershey, PA, USA, pp. 1931–1951.

Amineh, R.J., Asl, H.D., 2015. Review of constructivism and social constructivism. J. Soc. Sci. Lit. Lang. 1 (1), 9–16.

Asamoah, M.K., Oheneba-Sakyi, Y., 2017. Constructivist tenets applied in ICT-mediated teaching and learning: higher education perspectives. Afr. Educ. Rev. 14 (3–4), 196–211. https://doi.org/10.1080/18146627.2017.1279956.

Ashmore, S., Townsend, A., DeMarie, S., Mennecke, B., 2018. An exploratory examination of modes of interaction and work in waterfall and agile teams. Int. J. Agile Syst. Manag. 11 (1), 67–102. https://doi.org/10.1504/IJASM.2018.091361.

Ayas, K., Zeniuk, N., 2001. Project-based learning: building communities of reflective practitioners. Manag. Learn. 32 (1), 61–76. https://doi.org/10.1177/1350507601321005.

Barak, M., Dori, Y.J., 2005. Enhancing undergraduate students' chemistry understanding through project-based learning in an IT environment. Sci. Educ. 89 (1), 117–139. https://doi.org/10.1002/sce.20027.

Beier, M.E., Kim, M.H., Saterbak, A., Leautaud, V., Bishnoi, S., Gilberto, J.M., 2019. The effect of authentic project-based learning on attitudes and career aspirations in STEM. J. Res. Sci. Teach. 56 (1), 3–23. https://doi.org/10.1002/tea.21465.

Butler, C.W., Vijayasarathy, L.R., Roberts, N., 2019. Managing software development projects for success: aligning plan- and agility-based approaches to project complexity and project dynamism. Proj. Manag. J. 51 (3), 262–277. https://doi.org/10.1177/8756972819848251.

Carvalho, M.M.d., Patah, L.A., de Souza Bido, D., 2015. Project management and its effects on project success: cross-country and cross-industry comparisons. Int. J. Proj. Manag. 33 (7), 1509–1522. https://doi.org/10.1016/j.ijproman.2015.04.004.

Chen, C.-H., Yang, Y.-C., 2019. Revisiting the effects of project-based learning on students' academic achievement: a meta-analysis investigating moderators. Educ. Res. Rev. 26, 71–81. https://doi.org/10.1016/j.edurev.2018.11.001.

Cicmil, S., Williams, T., Thomas, J., Hodgson, D., 2006. Rethinking project management: researching the actuality of projects. Int. J. Proj. Manag. 24 (8), 675–686. https://doi.org/10.1016/j.ijproman.2006.08.006.

Cobern, W.W., 1993. Constructivism. J. Educ. Psychol. Consult. 4 (1), 105–112. https://doi.org/10.1207/s1532768xjepc0401_8.

Cobern, W.W., 1994. Contextual constructivism: the impact of culture on the learning and teaching of science. In: Tobin, K.G. (Ed.), The Practice of Constructivism in Science Education. Routledge, New York, U.S.A.

DeLone, W.H., McLean, E.R., 2003. The DeLone and McLean model of information systems success: a ten-year update. J. Manag. Inf. Syst. 19 (4), 9–30. https://doi.org/10.1080/07421222.2003.11045748.

Dikert, K., Paasivaara, M., Lassenius, C., 2016. Challenges and success factors for large-scale agile transformations: a systematic literature review. J. Syst. Software 119, 87–108. https://doi.org/10.1016/j.jss.2016.06.013.

Dingsøyr, T., Lindsjørn, Y., 2013. Team Performance in Agile Development Teams: Findings from 18 Focus Groups, 2013//. Paper presented at the Agile Processes in Software Engineering and Extreme Programming, Berlin, Heidelberg.

Espinoza-Robles, A., Trujillo-Trejo, J., Fermín-Pérez, A., Chávez-Soto, J., Bustamante-Olivera, V., Muñoz-Casildo, N., 2022. Application of Project-Based Learning to Improve the Teaching and Learning Outcomes of a Course in Information System Design in a Computer Science Department, 13-16 March 2022. Paper presented at the 2022 IEEE World Engineering Education Conference (EDUNINE), Santos, Brazil.

Flyvbjerg, B., Gardner, D., 2023. How Big Things Get Done: the Surprising Factors that Determine the Fate of Every Project, from Home Renovations to Space Exploration and Everything in between. Pan Macmillan, London, United Kingdom.

Frank, M., Lavy, I., Elata, D., 2003. Implementing the project-based learning approach in an academic engineering course. Int. J. Technol. Des. Educ. 13 (3), 273–288. https://doi.org/10.1023/A:1026192113732.

Guo, P., Saab, N., Post, L.S., Admiraal, W., 2020. A review of project-based learning in higher education: student outcomes and measures. Int. J. Educ. Res. 102, 1–13. https://doi.org/10.1016/j.ijer.2020.101586.

Han, S., Capraro, R., Capraro, M.M., 2015. How science, technology, engineering, and mathematics (STEm) project-based learning (PBL) affects high, middle, and low achievers differently: the impact of student factors on achievement. Int. J. Sci. Math. Educ. 13 (5), 1089–1113. https://doi.org/10.1007/s10763-014-9526-0.

Hardy, M.D., 1997. Von Glaserfeld's radical constructivism: a critical review. Sci. Educ. 6 (1), 135–150. https://doi.org/10.1023/A:1008664626705.

Helle, L., Tynjälä, P., Olkinuora, E., 2006. Project-based learning in post-secondary education – theory, practice and rubber sling shots. High Educ. 51 (2), 287–314. https://doi.org/10.1007/s10734-004-6386-5.

Ikonen, M., Abrahamsson, P., 2010. Anticipating success of a business-critical software project: a comparative case study of waterfall and agile approaches. In: Tyrväinen, P., Jansen, S., Cusumano, M.A. (Eds.), Software Business: First International Conference, ICSOB 2010, Jyväskylä, Finland, June 21-23, 2010. Proceedings. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 187–192.

Joseph, N., Erasmus, W., Marnewick, C., 2014. The idle state of information and communication technology project management. J. Afr. Bus. 15 (3), 184–196. https://doi.org/10.1080/15228916.2014.956641.

Khoza, L., Marnewick, C., 2020. Waterfall and Agile information system project success rates – a South African perspective. S. Afr. Comput. J. 32 (1), 43–73. https://doi.org/10.18489/sacj.v32i1.683.

Khoza, L., Marnewick, C., 2021. Challenges and success factors of scaled agile adoption – a South African perspective. Afr. J. Inf. Syst. 13 (2), 164–185. Retrieved from. https://digitalcommons.kennesaw.edu/ajis/vol13/iss2/2.

Kisielnicki, J., Misiak, A.M., 2017. Effectiveness of agile compared to waterfall implementation methods in IT projects: analysis based on business intelligence projects. Found. Manag. 9 (1), 273. https://doi.org/10.1515/fman-2017-0021.

Kokotsaki, D., Menzies, V., Wiggins, A., 2016. Project-based learning: a review of the literature. Improv. Sch. 19 (3), 267–277. https://doi.org/10.1177/1365480216659733.

Lehmann, M., Christensen, P., Du, X., Thrane, M., 2008. Problem-oriented and project-based learning (POPBL) as an innovative learning strategy for sustainable development in engineering education. Eur. J. Eng. Educ. 33 (3), 283–295. https://doi.org/10.1080/03043790802088566.

Leoni, R., 2014. Graduate employability and the development of competencies. The incomplete reform of the "Bologna Process.". Int. J. Manpow. 35 (4), 448–469. https://doi.org/10.1108/IJM-05-2013-0097.

Lewins, A., Silver, C., 2008. Using Software in Qualitative Research. Sage Publications, London.

Lindén, J., Ohlin, M., Brodin, E.M., 2011. Mentorship, supervision and learning experience in PhD education. Stud. High Educ. 38 (5), 639–662. https://doi.org/10.1080/03075079.2011.596526.

Liu, C.H., Matthews, R., 2005. Vygotsky's philosophy: constructivism and its criticisms examined. Int. Educ. J. 6 (3), 386–399.

Loughran, J., 2013. Pedagogy: making sense of the complex relationship between teaching and learning. Curric. Inq. 43 (1), 118–141. https://doi.org/10.1111/curi.12003.

Mahalakshmi, M., Sundararajan, M., 2013. Traditional SDLC vs Scrum methodology – a comparative study. Int. J. Emerg. Technol. Adv. Eng. 3 (6), 192–196.

Marnewick, C., Marnewick, A.L., 2022. Benefits realisation in an agile environment. Int. J. Proj. Manag. 40 (4), 454–465. https://doi.org/10.1016/j.ijproman.2022.04.005.

Martinsuo, M., Huemann, M., 2021. Designing case study research. Int. J. Proj. Manag. 39 (5), 417–421. https://doi.org/10.1016/j.ijproman.2021.06.007.

Mnkandla, E., Marnewick, C., 2011. Project management training: the root cause of project failures? J. Contemp. Manag. 8, 76–94. https://hdl.handle.net/10520/EJC51118.

Moe, N.B., Dingsøyr, T., Dybå, T., 2010. A teamwork model for understanding an agile team: a case study of a Scrum project. Inf. Software Technol. 52 (5), 480–491. https://doi.org/10.1016/j.infsof.2009.11.004.

Ojiako, U., Ashleigh, M., Chipulu, M., Maguire, S., 2011a. Learning and teaching challenges in project management. Int. J. Proj. Manag. 29 (3), 268–278. https://doi.org/10.1016/j.ijproman.2010.03.008.

Ojiako, U., Ashleigh, M., Wang, J.-K., Chipulu, M., 2011b. The criticality of transferable skills development and virtual learning environments used in the teaching of project management. Proj. Manag. J. 42 (4), 76–86. https://doi.org/10.1002/pmj.20240.

Pavez, I., Gómez, H., Liu, C., González, V.A., 2022. Measuring project team performance: a review and conceptualization. Int. J. Proj. Manag. 40 (8), 951–971. https://doi.org/10.1016/j.ijproman.2022.11.001.

Petter, S., Delone, W., McLean, E., 2008. Measuring information systems success: models, dimensions, measures, and interrelationships. Eur. J. Inf. Syst. 17 (3), 236–263. https://doi.org/10.1057/ejis.2008.15.

Prawat, R.S., 1999. Social constructivism and the process-content distinction as viewed by Vygotsky and the pragmatists. Mind Cult. Activ. 6 (4), 255–273. https://doi.org/10.1080/10749039909524731.

Remta, D., Buchalcevova, A., 2021. Product owner's journey to SAFe—role changes in scaled agile framework. Information 12 (3), 1–18. https://doi.org/10.3390/info12030107.

Remta, D., Doležel, M., Buchalcevová, A., 2020. Exploring the Product Owner Role within SAFe Implementation in a Multinational Enterprise. Paper presented at the Agile Processes in Software Engineering and Extreme Programming – Workshops, Copenhagen, Denmark.

Samuelowicz, K., Bain, J.D., 2001. Revisiting academics' beliefs about teaching and learning. High Educ. 41 (3), 299–325. https://doi.org/10.1023/A:1004130031247.

Scarbrough, H., Swan, J., Laurent, S., Bresnen, M., Edelman, L., Newell, S., 2004. Project-based learning and the role of learning boundaries. Organ. Stud. 25 (9), 1579–1600. https://doi.org/10.1177/0170840604048001.

Taipalus, T., Seppänen, V., Pirhonen, M., 2018. Coping with uncertainty in an agile systems development course. J. Inf. Syst. Educ. 29 (2), 117–126. Retrieved from. http://jise.org/Volume29/n2/JISEv29n2p117.pdf.

Tay, L.Y., Lim, C.P., Lye, S.Y., Ng, K.J., Lim, S.K., 2011. Open-source learning management system and Web 2.0 online social software applications as learning platforms for an elementary school in Singapore. Learn. Media Technol. 36 (4), 349–365. https://doi.org/10.1080/17439884.2011.615322.

The Standish Group, 2018. The CHAOS report: decision latency theory. Retrieved from. https://www.standishgroup.com/store/services/10-chaos-report-decision-latency-theory-2018-package.html.

Thomas, J.W., 2000. A Review of Research on Project-Based Learning. Retrieved from San Rafael, California, U.S.A. https://tecfa.unige.ch/proj/eteach-net/Thomas_researchreview_PBL.pdf.

Tseng, K.-H., Chang, C.-C., Lou, S.-J., Chen, W.-P., 2013. Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. Int. J. Technol. Des. Educ. 23 (1), 87–102. https://doi.org/10.1007/s10798-011-9160-x.

Unger-Windeler, C., Klünder, J., Schneider, K., 2019. A Mapping Study on Product Owners in Industry: Identifying Future Research Directions. Paper Presented at the 2019 IEEE/ACM International Conference on Software and System Processes (ICSSP) (Montreal, Canada).

vanOostveen, R., Desjardins, F., Bullock, S., 2019. Professional development learning environments (PDLEs) embedded in a collaborative online learning environment (COLE): moving towards a new conception of online professional learning. Educ. Inf. Technol. 24 (2), 1863–1900. https://doi.org/10.1007/s10639-018-9686-6.

VersionOne Inc, 2020. The 14th annual state of agile report. Retrieved from. https://explore.digital.ai/state-of-agile/14th-annual-state-of-agile-report.

von Glasersfeld, E., 2001. Radical constructivism and teaching. Prospects 31 (2), 161–173. https://doi.org/10.1007/BF03220058.

Von Seggern, M., Young, N.J., 2003. The focus group method in libraries: issues relating to process and data analysis. Ref. Serv. Rev. 31 (3), 272–284. https://doi.org/10.1108/00907320310486872.

Vygotsky, L.S., 1980. Mind in Society: the Development of Higher Psychological Processes. Harvard University Press, Cambridge, Massachusetts, U.S.A.

Wilkes, Z., 2006. The student-mentor relationship: a review of the literature. Nurs. Stand. 20 (37), 42–47. Retrieved from. http://0-search.ebscohost.com.ujlink.uj.ac.za/login.aspx?direct=true&db=a9h&AN=21101669&site=ehost-live&scope=site.

Wulf, T., 2005. Constructivist approaches for teaching computer programming. Paper presented at the Proceedings of the 6th conference on Information technology education, Newark, NJ, USA. https://0-doi-org.ujlink.uj.ac.za/10.1145/1095714.1095771.

Zackariasson, P., 2014. Mentorship in academia. Int. J. Manag. Proj. Bus. 7 (4), 734–738. https://doi.org/10.1108/IJMPB-05-2014-0040.

Zwikael, O., Meredith, J.R., Smyrk, J., 2019. The responsibilities of the project owner in benefits realization. Int. J. Oper. Prod. Manag. 39 (4), 503–524. https://doi.org/10.1108/IJOPM-02-2018-0086.