PROJECT-BASED LEARNING IN HIGHER EDUCATION: EXPLORING PROGRAMMING STUDENTS’ DEVELOPMENT TOWARDS SELF-DIRECTEDNESS

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ABSTRACT

The purpose of the research reported in this article was to explore whether the application of project-based learning (PBL) in higher education could develop programming students’ self-directedness. This research was based on social constructivism and emphasised the construction of knowledge in which students were collaboratively involved. Both quantitative and qualitative methods were employed. The participants in the research were 89 second-year Bachelor of Science (BSc) students majoring in Computer Science/Information Technology. The students worked together in teams of two to develop a programming project. Data collection involved questionnaires, development of a project and a manual.
as well as various narrative reflections. The findings indicated that participants’ application of PBL may contribute to the development of their self-directedness.

**Keywords:** collaboration, higher education, innovation, programming, project-based learning, self-directedness

**INTRODUCTION**

The formal aims and purpose of higher education institutions (HEIs) are reflected in their mission statements, and include, among others, the following:

- to enable students ‘to develop, educate and empower through innovative and high quality teaching–learning, well-rounded graduates who are able to think laterally and critically in their service to the country and its people, the continents and the world’ (Mission element 2) (NWU 2013, 1);
- ‘to maintain student-centred and future-oriented learning and teaching that establish a passion for lifelong learning’ (SU 2013, 7); and
- ‘to offer a diverse range of quality educational opportunities that will make a critical and constructive contribution to regional, national and global sustainability’ (NMMU 2013, 1).

It is therefore indicated that innovative, sustainable high-quality teaching and learning are one of HEIs’ main priorities to enable students to think critically; solve real-life problems; and prepare themselves effectively for lifelong learning.

Project-based learning (PBL) is a strategy that enhances innovative and high-quality teaching and learning within a complex task-based environment by producing an artefact or end product (Grant 2011; Helle, Tynjälä and Olkinuora 2006). PBL skills involve students solving an open-ended problem or answering a driving question over a period of time (Helle et al. 2006). PBL also provides students with various opportunities to practice 21st-century skills as part of teamwork with regard to knowledge sharing, decision making, and critical thinking (Knowles 1975; Rotherham and Willingham 2010). Furthermore, PBL may enhance students’ self-directed learning (SDL) (Bagheri et al. 2013). According to Shin (2011), self-directedness does not focus solely on knowledge accumulation but it is rather developed as part of a process whereby students obtain real-life experiences in a specific domain. Students should therefore be actively involved in the learning process to develop these qualities during their studies at HEIs.

The reason for applying PBL in the current research was mainly to focus on pedagogical motives (Helle et al. 2006) in order to explore how the use of PBL can develop self-directedness in programming students.
THEORETICAL FRAMEWORK

The philosophical approach and theoretical overview are discussed in this section.

Philosophical point of departure

Constructivism is a theory that focuses on how people construct their own learning and understanding of the world through experiences and by interpretation of and reflection on those experiences (Cupchik 2001). Constructivism involves active and authentic learning that is student-directed and facilitated by the teacher or lecturer (Jiang 2013). Social constructivism extends constructivism, and refers to a sociological theory whereby groups construct knowledge collaboratively. More specifically, social constructivists attempt to understand social phenomena where reality is constructed by individuals who embrace various meanings depending on their experiences in a specific situation (Lodico, Spaulding and Voegtle 2010). The nature of social constructivism requires that teaching practices focus mainly on students’ facilitation and responsibility to construct the learning content. Social constructivism has been applied to a variety of teaching and learning approaches, such as SDL, PBL and reflective practice (Jiang 2013). Garrison and Akyol (2009) mention that there has been a shift in higher education to collaborative knowledge construction with the aim to enhance reflective, critical thinking and meaningful learning experiences.

Theoretical overview

The aim of higher education does not only include the teaching of knowledge but also how students learn specific content; apply various skills; and adapt to new challenges. After completing their studies, graduates are required to: apply their knowledge and skills in the workplace; adapt to a continuously changing world; and provide for future demands. As a result appropriate knowledge and skills must be taught more intentionally in higher education. Rotherham and Willingham (2010) emphasise that 21st-century skills favour student-centred methods, such as problem solving and PBL, which require interaction, collaboration and the solving of authentic problems.

Project-based learning

A project refers to the development of an artefact with a unique purpose that requires various planned activities, skills and resources (Schwalbe 2010). A project is ill-structured and involves uncertainty; it is sometimes difficult to develop; and it has a definite beginning and end (Hughes and Cotterell 2009; Schwalbe 2010).

PBL is a teaching–learning strategy that directs all the processes involved in developing a project or addressing a challenge. PBL is an innovative and instructional
approach in which students work collaboratively to solve a real-life problem or answer a driving question and provide an artefact (Bell 2010; Grant 2011; Helle et al. 2006). It is a time-consuming process that requires the lecturer’s facilitation, support and scaffolding (Helle et al. 2006). Nevertheless, the benefits of using PBL are an enhanced understanding of the topic; a high level of critical thinking; deeper learning; increased motivation; and development of independent responsible learners (students) (Bell 2010).

Larmer and Mergendoller (2010) identify eight essentials for PBL, namely: (a) significant content and concepts; (b) a need to know; (c) a driving question; (d) students’ insight and choice regarding a project topic within the driving question; (e) enhancing of 21st-century skills; (f) inquiry and innovation; (g) frequent feedback on students’ progress; and (h) presentation of the project. Krajcik, Czerniak and Berger (1999) mention the following four advantages of using PBL: (a) development of deep integrated learning; (b) collaborative problem solving; (c) responsibility for own learning; and (d) active involvement in the learning process.

When implementing PBL, the roles of the facilitator (lecturer) and student differ. The facilitator is usually responsible for the planning and implementation of PBL teaching activities, whereas the students participate in managing their own learning activities and developing a product (Andreasen and Nielsen 2013). The students are therefore not simply involved in solving a problem, they are also accountable for their learning activities and their collective contribution to the development of the project. With reference to their distinctive roles, 12 core PBL elements of students and facilitators are outlined. These elements are core constructs focusing on specific activities involved in PBL. Despite the fact that PBL is driven by a question of inquiry, all the mentioned elements are equally important in contributing to the development of PBL. The main focus of the research was on students’ application of PBL; however, the facilitator’s role was also included to outline his/her responsibilities in this instructional approach to give an overview of the implementation thereof in both teaching and learning.

The students’ 12 core PBL elements involve applying this instructional approach as well as designing and developing an artefact, and are briefly discussed below.

1. **Problem orientation and inquiry** is the driving force of PBL. Students are expected to address an ill-defined problem, complex question or challenge (Grant 2011; Larmer and Mergendoller 2010).

2. **Student centeredness** refers to students’ active involvement in the learning process to enhance independent learning (Helle et al. 2006; Pourshafie and Murray-Harvey 2013).

3. **Collaboration and communication** involves students applying team management and interpersonal skills, positive interdependence, collaborative reasoning and decision making (Johnson and Johnson 2013; Nussbaum 2012).
4. **Roles, responsibility and ownership** refers to students’ individual accountability, commitment, collective ownership and contract of agreement. Ideally, the PBL experience may elicit students’ intrinsic motivation (Bell 2010).

5. **Problem solving and critical thinking** involves students representing the problem, applying problem-solving skills, thinking critically, and making informed judgements (Helle et al. 2006; Markham 2012).

6. **Reflective thinking and metacognitive control** involves students managing their thinking processes (planning, monitoring, evaluation) and reflecting (self and group) on project design and development (Breed 2010; Grant 2011).

7. **Management of the learning environment** refers to students managing their own time, deadlines, risks, and resources (Markham 2012; Pourshafie and Murray-Harvey 2013).

8. The integration of various types of **technology and tools** is required to support PBL. Examples include tablets, cell phones, e-learning platforms such as Moodle, YouTube and MS Project 2010 (Markham 2012).

9. **Knowledge creation and integration** refers to the incorporation of new knowledge with previous knowledge and the synthesis of ideas (Helle et al. 2006).

10. **Creative and innovative construction** is expected in the development of an innovative artefact, end product or the application of creative and innovative thinking to address a challenge (Bell 2010; Grant 2011).

11. **Assessment integration** occurs where students apply self-assessment and group assessment of their own capabilities, accuracy and progress towards the goal (Helle et al. 2006).

12. **Performance, feedback and evaluation** is essential in the PBL process where students reflect on their performance and give constructive feedback to others in class (Ayas and Zeniuk 2001; Larmer and Mergendoller 2010).

The facilitator’s 12 core PBL elements involve planning, directing and teaching of PBL skills as well as facilitating students’ efforts to solve the problem. It is essential to the success of the PBL process that the facilitator is committed and that he/she assists the students to become actively involved in managing their own learning.

1. **Problem orientation and inquiry** is the driving force of PBL. The facilitator is required to select an appropriate ill-defined, open-ended problem, complex question or challenge and to formulate the learning aims and activities (Helle et al. 2006; Pourshafie and Murray-Harvey 2013).

2. **Facilitation and student centeredness** involves guiding students’ active involvement in the learning process and scaffolding learning rather than filling students with knowledge (Bell 2010; Pourshafie and Murray-Harvey 2013).
3. Promoting **collaboration and communication** by teaching team management principles and interpersonal skills; facilitating effective communication; and discussing why collaboration may lead to better outcomes (Markham 2012; Murray-Harvey, Pourshafie and Reyes 2013).

4. To promote **ownership**, the facilitator guides students in the assignment of **roles**; supports students to take **responsibility** for the project; and sets up a contract template. These actions are designed to elicit intrinsic motivation in the students (Bell 2010; Markham 2012).

5. To develop **problem solving and critical thinking skills**, the facilitator asks questions and discusses how to apply problem-solving skills and critical thinking to make informed judgements (Markham 2012).

6. To promote **reflective thinking and metacognitive control**, the facilitator provides authentic feedback and invites frequent reflection regarding students’ progress (Ayas and Zeniuk 2001; Gunter, Estes and Mintz 2010).

7. In **managing the teaching-learning environment**, the facilitator sets up requirements and deadlines to scaffold the students’ project development (Bell 2010).

8. The facilitator infuses the use of **technology and tools** to support project development (Markham 2012).

9. To promote **knowledge integration**, the facilitator asks questions; addresses knowledge gaps; and leads students to analyse and integrate new information with previous knowledge and synthesise ideas (Bell 2010; Markham 2012).

10. The facilitator **supports creative and innovative construction** by focusing on innovation and curiosity; discussing end products; providing scaffolding mechanisms; and facilitating incremental development of an artefact (Grant 2011; Markham 2012).

11. **Assessment integration** requires the facilitator to ensure that the objectives and assessments are aligned; that he/she develops or selects an appropriate assessment tool; prepares students for various types of assessments; and grades the projects (Gunter et al. 2010; Markham 2012).

12. The facilitator provides frequent **performance feedback and evaluation** on students’ PBL experiences and products as well as discussing learning gains and students’ performance (Gunter et al. 2010).

**Self-directed learning in higher education**

The application of PBL provides opportunities for students to guide, manage and monitor their learning activities through self-direction (Grant 2011). Bagheri et al. (2013) indicate that students who applied PBL performed significantly better in
terms of SDL skills than students only exposed to conventional teaching methods. SDL was initially defined by Knowles (1975, 18) as

a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes.

According to Fisher, King and Tague (2001), a student’s self-directedness can be defined in terms of the degree of responsibility and control he/she is willing to take, which largely depends on his/her attitude, abilities and personality.

Some characteristics of a highly self-directed learner include: showing initiative and persistence in learning; accepting responsibility for his/her own learning; self-discipline; a high degree of curiosity; a strong ability to learn independently; a love of learning; goal orientation; viewing problems as challenges; managing his/her time; and developing a plan for completing work (Guglielmino 1978). Additional characteristics are: applying appropriate learning strategies (Knowles 1975); working with or without the help of others (Knowles 1975); exploring a variety of learning resources (Knowles 1975); integrating self-reflection (Van Merriënboer and Sluijsmans 2009); being intrinsically motivated (Hsu and Shiue 2005); and assessing their own learning needs as well as a critical evaluation of their own SDL skills (Loyens, Magda and Rikers 2008).

The development of self-directed students should therefore be a strategic priority of HEIs to provide 21st-century skills, and high-quality teaching and learning. Such institutions should provide opportunities where students are required to manage their own learning processes and practise self-direction to enable them to learn real-life skills (Francom 2010). In addition, lecturers should equip students with a variety of skills to enable them to take responsibility and prioritise their own learning. Guglielmino et al. (2009) established a positive relationship between self-directed learning readiness (SDLRS) and performance. High performers had significantly higher SDLRS scores than other respondents where their jobs either involved a high degree of change or required high levels of creativity or problem solving.

The nature of programming

The aim of the programmer is to convert problems into solutions by using specific syntax and semantics as defined by a specific programming language (Sebesta 2013). The nature of programming requires checking errors, making corrections, testing and executing the program. Programming therefore requires precise planning of the solution and detailed coding of the program to solve the problem. Programming students require the ability to orchestrate high-level mental processes in a coherent way to direct their programming thoughts towards successful solution
of a programming problem (Havenga 2011). The use of PBL as a teaching–learning strategy may direct students in the complex task of developing a computer program.

To summarise this section, there is a gap between what students learn at universities and what they do in practice after graduation. Bagheri et al. (2013) mention that PBL can be used to bridge this gap between theory and practice and to provide opportunities to promote SDL. The main research question was: How can the use of PBL develop programming students’ self-directedness?

The empirical research explored the development of self-directedness in participants when applying PBL.

EMPIRICAL RESEARCH

The methodology and implementation of empirical research are discussed in this section.

Methodology

The research methodology focused on a quantitative study with an additional qualitative component to expand understanding of how students experienced PBL.

Research design

The research design involved a pre-test, an intervention and a post-test. Both the pre-test and post-test required the completion of questionnaires. During the intervention, students completed documents and developed a software project (see Table 1).

Table 1: The research design used in the study

<table>
<thead>
<tr>
<th>Pre-test (Individually completed)</th>
<th>Intervention (Team completion) 6 weeks</th>
<th>Post-test (Individually completed)</th>
</tr>
</thead>
</table>
| 1) Williamson’s questionnaire (Williamson 2007): Self-rating scale of self-directed learning  
2) Open questionnaire about  
a) various database questions and  
b) PBL questions | 1) Plan the project by including team completion of a detailed time schedule  
2) Submit weekly project sheets electronically to indicate progress of design and development  
3) Submit a software program and electronic manual as deliverables  
4) Submit narrative reflection on the project | 1) Williamson’s questionnaire (Williamson 2007): Self-rating scale of self-directed learning  
2) Open questionnaire about  
a) various database questions and  
b) PBL questions |
Participants
A population of 89 second-year BSc students with a major in Computer Science/Information Technology participated in the research. Students were requested to participate in a project in which two students had to work together in a team. The participants were required to plan, design and develop a programming project as part of the intervention. Although this project was part of the students’ summative assessment, they were not pressured to complete any questionnaires (see Table 1). The research was part of a larger SDL research project for which ethical approval was obtained.

Software project assignment
The purpose of the assignment was to give the students an opportunity (in addition to class time) to manage their own learning processes; to research additional information scientifically; and to develop a project using C# programming and MS Access databases based on a topic of their choice, for example, developing software for a DVD shop. The students were required to plan their project by: (1) completion of a detailed time schedule; (2) submission of weekly project sheets (Havenga and De Beer 2013) that outlined the detailed development and progress of their projects; (3) submission of project deliverables including a computer program and an electronic manual that explained the working of the program; and (4) submission of narratives to reflect on the project (see Table 1). The students were required to search, display and update information. The project, manual and related documents were assessed according to specific rubrics based on the initial project requirements. The assessment criteria used to judge the manual included: an introduction explaining the purpose of the program; a brief literature overview regarding databases; functionality of the program comprising snap shots of the software; technical information and resources used; as well as a summary and a complete list of references. The project was assessed using the following criteria: apply various menus and at least four forms to display the information; search and update of data; perform four different queries; and include message boxes for user-friendliness where applicable. In addition, the students obtained marks for their time schedules and weekly project sheets regarding the detailed activities described.

Data collection and analysis methods
Both quantitative and qualitative methods were used, including completion of Williamson’s (2007) questionnaire; some open-ended questions; as well as the submission of additional documents (see Table 1).
Quantitative methods and instruments

Williamson’s (2007) self-rating scale of self-directed learning (SRSSDL) in higher education was used where the participants were required to complete the questionnaire as a pre-test and post-test. The SRSSDL comprises 60 items categorised under five distinctive areas of SDL, namely: (1) Awareness; (2) Learning strategies; (3) Learning activities; (4) Evaluation; and (5) Interpersonal skills. The participants’ responses for each item were rated by using a five-point Likert-type scale. Statistical analysis included the use of both descriptive and inferential statistics. The SRSSDL was found to be a valid and reliable instrument (Cronbach’s alpha coefficient > 0.70 for each of the five broad areas).

Qualitative methods

Qualitative collection methods comprised the completion of: (1) a questionnaire regarding open-ended questions on databases and students’ individual experiences with PBL (see Table 1); (2) a time schedule, prior to starting the project; and (3) weekly project sheets regarding: (a) the team’s main aims and responsibilities for a specific week; (b) each individual’s responsibilities; (c) relevant information obtained; (d) problems or challenges experienced; (e) ways they solved the mentioned problems; (f) reflection on team members’ interaction and communication; and finally (g) a list of resources they had used. Although realistic allotments had been made to enable students to complete the weekly project sheets, they were required to submit these on time as electronic locks were set for each week. The students also submitted (4) written narratives regarding the project after they had completed their programming project. The qualitative data was analysed by manual coding of the students’ data involving the development of subcategories and themes. Concept-driven coding (Gibbs 2010) was mainly used where the thematic ideas came from the open questionnaire, time schedule, weekly project sheets and reflective narratives (see Table 1).

RESULTS

Both the quantitative and qualitative results are outlined in this section.

Quantitative results

Although 89 students enrolled for the Graphical User Programming module, only 45 students completed both Williamson’s pre-test and post-test. According to the students’ answers on the Likert-type scale of 1 to 5 for the 60 questions, they were divided into three distinctive groups regarding self-directedness, namely: Low (60–140), Moderate (141–220) and High (221–300). The focus of the research was on the
results obtained from the Moderate and High groups as there were no participants in the Low group.

Pre-test and post-test results
Although there were initially 20 participants in the Moderate group, seven moved to the High group after completing the post-test (see Table 2). This indicates that these students improved on their SDL skills after the intervention. Nine participants in the High group moved to the Moderate group after the post-test.

Table 2: Number of participants in a specific group after the post-test

<table>
<thead>
<tr>
<th></th>
<th>Post-test</th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Pre-test</td>
<td></td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td></td>
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<td>9</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22</td>
<td>23</td>
</tr>
</tbody>
</table>

Dependent t-tests and significance
The average and effect sizes of the Moderate and High groups are included in Table 3 and Table 4, respectively.

Table 3: Dependent t-tests and practical significance: Moderate group

<table>
<thead>
<tr>
<th>Williamson’s subcategory</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Significance</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean 1</td>
<td>SD 1</td>
<td>Mean 2</td>
<td>SD 2</td>
</tr>
<tr>
<td>Awareness</td>
<td>3.48</td>
<td>0.30</td>
<td>3.74</td>
<td>0.52</td>
</tr>
<tr>
<td>Learning strategies</td>
<td>3.21</td>
<td>0.36</td>
<td>3.45</td>
<td>0.54</td>
</tr>
<tr>
<td>Learning activities</td>
<td>3.30</td>
<td>0.37</td>
<td>3.48</td>
<td>0.52</td>
</tr>
<tr>
<td>Evaluation</td>
<td>3.21</td>
<td>0.45</td>
<td>3.53</td>
<td>0.54</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>3.37</td>
<td>0.35</td>
<td>3.69</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Practical significance: * Medium effect size; ** Large effect size

The Moderate group’s average increased in the post-test as a possible indication that students might have enhanced their self-directedness when developing the project (see Table 3). The effect sizes are practically significant, indicating medium and large-effect sizes (Ellis and Steyn 2003) (although the p-values are not relevant, they are reported for completeness).
Table 4: Dependent $t$-tests and practical significance: High group

<table>
<thead>
<tr>
<th>Williamson’s subcategory</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Significance</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean 1</td>
<td>SD 1</td>
<td>Mean 2</td>
<td>SD 2</td>
</tr>
<tr>
<td>Awareness</td>
<td>4.12</td>
<td>0.30</td>
<td>3.91</td>
<td>0.50</td>
</tr>
<tr>
<td>Learning strategies</td>
<td>3.85</td>
<td>0.30</td>
<td>3.74</td>
<td>0.41</td>
</tr>
<tr>
<td>Learning activities</td>
<td>3.89</td>
<td>0.32</td>
<td>3.77</td>
<td>0.49</td>
</tr>
<tr>
<td>Evaluation</td>
<td>3.94</td>
<td>0.36</td>
<td>3.76</td>
<td>0.64</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>4.02</td>
<td>0.30</td>
<td>3.72</td>
<td>0.48</td>
</tr>
</tbody>
</table>

Practical significance: * Medium effect size; ** Large effect size

As displayed in Table 4, the High group’s average decreased in the post-test (see detailed discussion below). The effect sizes have practical significance in the case of medium and large-effect sizes.

Final project marks obtained

The participating students obtained an average of 59 per cent for their projects. These marks were based on documents regarding the processes (time schedule, weekly project sheets), the computer project, and development of the manual. Some students did not complete all the weekly project sheets and/or their time schedules were incomplete. Participant 31 (P31) obtained the highest mark for the project (87%).

Qualitative results

Various themes emerged from the qualitative data gathered from the open questions on PBL, the time schedule, weekly project sheets and students’ reflections. The emerged themes were: (1) PBL experiences; (2) Problems and challenges; (3) Collaboration and communication; (4) Time management; (5) Construction and additional skills; and (6) Reflection on experiences.

Theme 1: PBL experiences

The results from the pre-test indicated that the programming students did not have knowledge regarding PBL. Some participants’ ideas were the following:
I understand it is learning while working on a project and know how to develop a project (P12).

You extend your knowledge outside the study outcomes (P14).

It [learning] is similar to self-study, however I think more effectively (P18).

Initially, the participants mentioned that PBL refers to ‘self-study’ where they should extend their knowledge. Most participants indicated that they did not have any experience regarding PBL. After completing the project, the students outlined their ideas on what PBL is as culminated from the post-test. Some examples were the following:

You are working in collaboration where each individual should complete a specific part of the project (P18).

It [the project] definitely helped me to understand the content and to learn for the test (P27).

Students learn to solve problems on their own when developing a project. I realised that I have learnt much more than planned in the module (P31).

Learners are required to take responsibility for their own learning and solve problems (P51).

When working on a project we are required to think ‘out of the box’ and thereby integrating knowledge to create something new (P51).

The students’ feedback from the post-test included various advantages of PBL, namely: working in collaboration; enhanced understanding of the content; gaining additional knowledge and skills; and taking responsibility for their own learning. Some challenges were also experienced as discussed in the themes that follow.

Theme 2: Problems and challenges

The students initially experienced some problems, namely: deciding on the topic of the project; comprehending which information was required; determining the project scope; and discussing their plans and each member’s responsibilities. Since these students did not have experience in PBL (Theme 1 – pre-test), they had difficulty in the initial planning of the project.

We decided on division of tasks, what should be done during the holiday and what should each [member] do (P7, P19).

We experienced problems to decide what project to do ... (P16, P45).

Additional problems were: to determine what precisely was expected from us ... determined the project scope, identified possible problems and assigned specific tasks to each member (P28, P48).
Theme 3: Collaboration and communication

Teamwork, collaboration and communication are important skills required when developing projects. Some students’ experiences were as follows:

There was no problem ... we supported each other to solve the problems (P10, P87).

We decided what each member should do to enable us to finish the tasks more quickly (P64, P96).

We communicated by listening to each view and then selected the best option (P16, P45).

Communication during holiday was difficult ... however we achieved all our aims. We used a telephone, email and WhatsApp (P28, P48).

We experienced problems to get together. We used DropBox to get the necessary information and resources to the other member (P14, P88).

We have different ideas and there is sometimes conflict as we do not see each other face-to-face all the time. But we pressed for the sake of the project and friendship (P23, P49).

We have solved the communication problem ... by having a group meeting and discussion. We have learnt to talk honestly and openly. Communication has improved after the group meeting and the tension in the group has decreased (P23, P49).

I cope however I should do more of the work as my team member does not work on the project (P37).

Some participants worked in collaboration, discussing their problems and dividing their responsibilities, whereas others experienced problems with getting together during the holiday and they were required to solve their communication problems by using, for example, email, WhatsApp and DropBox. Although some teams experienced conflict problems, they indicated the use of additional collaborative skills to solve their differences, such as holding additional group meetings. One participant designed the project on his own as his team member was not committed to working on the project.

Theme 4: Time management

The students experienced time management as difficult as they were required to work on their projects during a short break of two weeks.

We experienced problems to meet. The main issue was time (P41, P72).

Some additional reasons regarding problems with time management were:

We were busy with additional academic responsibilities (P2, P55).

... prioritising of project activities was not on the level where it should be (P62, P79).

We experienced problems with allocation of task responsibilities, [problems with] completion of group objectives and goals on time (P23, P49).

We realised that there was more work than we initially anticipated (P41, P72).
The students applied some of the following strategies to better manage their time.

- We decided to split the tasks (P64, P96).
- We tried to better manage our time and prioritise the work (P28, P48).
- We worked late evenings together (P41, P72).
- We first worked separately and thereafter together on the solutions of the problems (P51, P82).

The students experienced problems with time and the scope of the project. The work was more than they initially anticipated and they did not specify detailed responsibilities to members. However, some applied strategies to finish their projects on time as they worked late in the evenings and used their personal time.

**Theme 5: Construction and additional skills**

Since the students were required to solve a complex problem, some mentioned that they needed additional skills.

- We want to add additional things in our program and this requires more research (P9, P83).
- We need to use alternative methods (P10, P87).
- We need to develop a network sniffer. Problems we experienced were socket programming, capturing of packets, read the relevant data from the packets, IP header with all the attributes and network card discovery (P36, P40).

The students used various resources to support themselves. Two participants mentioned spending many hours on the Internet to develop a network sniffer. Others used alternative methods to obtain the required information.

**Theme 6: Reflection on experiences**

After completing the project, the students were required to reflect on their experiences. Examples of both positive and negative experiences were mentioned. The students’ positive experiences included:

- **Responsibility, knowledge and skills**
  - We learned to take responsibility for our own work and the teamwork (P64, P96).
  - If you did the project then you experienced the test as easy. We learned much about advanced programming (P5, P89).
  - I learned about programming through practical work and not just sitting listening to a lecturer (P26, P85).
We had an opportunity to select our own scope of what we want to achieve ... and how it can be implemented in real-life situations (P23, P49). It was easier to understand the work (P16, P45).

- **Collaborative skills**
  We did not only learn programming skills but also how to work in collaboration with others. It was a good experience (P9, P83).
  It was easier to solve a problem when working together in a team (P10, P87).
  We also identified good and bad characteristics of ourselves that we did not know we had (P51, P82).
  We enjoyed working in a pair ... and were motivated to work harder (P25, P56).
  We learned from each other and from our trial and errors. It helped us with problem solving (P68, P99).

- **Time management**
  Working on the project open time was nice ... work as hard as possible to achieve the goal (P26, P85).
  We learned how to plan our time and divided our tasks between ourselves (P59, P60).
  When doing self-study we learn more quickly, remember knowledge longer and learn new techniques (P62, P79).
  The project enhances our skills to work in a group as well as good time management (P71, P77).

The students’ negative experiences mainly focused on problems with communication, collaboration and time management.

- **Communication and collaboration**
  With group work there are always communication problems (P6, P42).
  I prefer to work individually (P23, P49).
  We differ regarding on how to program the solution (P28, P48).
  It was difficult to come together as a team and as a result we work individually on some tasks of the project (P64, P96).

- **Time management**
  We did not use our time correctly so there was a bit of rushing to complete the project but that was our fault (P1, P98).
  It was difficult to manage our time to come together (P5, P89).
  When doing a new project, we will start earlier and do more research (P24, P43).

A few students preferred to work on their own. Some reasons included communication and management problems in getting together. In addition, some students did not use their time effectively and had to rush to complete their projects. The participants
realised that they should have started earlier and that they should have done more detailed research. Nevertheless, many students experienced PBL as a positive learning experience as they obtained subject knowledge as well as collaborative skills, advanced problem solving, and creativity to design an innovative project.

**DISCUSSION**

The following research question is answered in this section: How can the use of PBL develop programming students’ self-directedness?

The results from both the quantitative and qualitative data are discussed. With reference to the SDL questionnaire (SRSSDL), seven participants moved from the Moderate to the High group after completing the post-test (see Table 2). In addition, the Moderate group’s average increased during the post-test (see Table 3). This indicates that these students’ SDL skills were enhanced after the intervention as they managed their own learning processes and activities during project development. However, nine participants, initially in the High group, moved to the Moderate group after the post-test (see Table 2). As displayed in Table 4, the High group’s average decreased in the post-test. Some reasons may include that the students realised that they were not as self-directed as initially thought, and students were busy with additional academic responsibilities and did not prioritise project activities.

Regarding the qualitative results, various themes were integrated to determine how the use of PBL could enhance self-directedness. Note that the SDL characteristics are referred to in square brackets, where applicable. Participant 31 claimed that he learned new ways how to solve problems, and P51 mentioned that, when students are working on a project, they learn on their own and are required to take responsibility for their own learning and solving problems (see Theme 1). According to participants P64 and P96, they learned to take responsibility for their own work and the teamwork (see Theme 6); [SDL skill: acceptance of responsibility for one’s own learning (Guglielmino 1978)]. Although initial planning was problematic (see Theme 2), the students developed skills to manage their thinking processes: ‘[we] determined what precisely was expected from us ... determined the project scope, identified possible problems and assigned specific tasks to each member’ (P28, P48); [SDL skills: goal orientation; viewing problems as challenges (Guglielmino 1978); diagnosing their learning needs (Knowles 1975)].

An integral part of PBL is teamwork. Since the students were not explicitly taught how to manage groups they initially experienced some problems. Nevertheless, this issue was solved in some teams: ‘We have solved the communication problem. Communication has improved after the group meeting and the tension in the group has decreased’ (P23, P49) (Theme 3); [SDL skill: work with or without the help of others (Knowles 1975); 21st-century skills as part of teamwork (Rotherham and Willingham 2010)].
Regarding time management (see Theme 4), the students were required to continue working on their projects during a short break of two weeks. This required them having to divide their tasks and take responsibility for specific sections or programming activities. Some of the skills the students used to address these problems were described as follows: ‘We tried to better manage our time and prioritise the work (P28, P48). We first worked separately and thereafter together on the solutions of the problems, (P51, P82) (see Theme 4); [SDL skills: effective time management (Jones et al. 2008); persistence in learning, developing a plan for completing work (Guglielmino 1978)].

Apart from time management, the students were required to apply additional skills as part of PBL (see Theme 5) when constructing their projects: ‘We want to add additional things in our program and this requires more research’ (P9, P83) (see Theme 5); [SDL skills: high degree of curiosity, independent learning (Guglielmino 1978) and intrinsic motivation (Hsu and Shiue 2005)]. PBL provided the participants with various opportunities: ‘We learned much about advanced programming (P5, P89); ... it was easier to understand the work’ (P16, P45) (see Theme 6); [SDL skills: obtaining real-life experiences in a specific domain (Shin 2011), self-reflection (Van Merriënboer and Sluijsmans 2009), and evaluating learning outcomes (Knowles 1975)].

To integrate the findings, Table 5 displays the qualitative results as exemplars of the students’ 12 core PBL elements, which are associated with some SDL characteristics.

<table>
<thead>
<tr>
<th>Students' core PBL element</th>
<th>Examples from qualitative data</th>
<th>Some SDL characteristics</th>
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</thead>
<tbody>
<tr>
<td>1. Problem orientation and inquiry</td>
<td>We are required to think ‘out of the box’ (P51). You extend your knowledge outside the study outcomes (P14) (Theme 1)</td>
<td>View problems as challenges, goal orientation (Guglielmino 1978)</td>
</tr>
<tr>
<td>2. Student centredness</td>
<td>I learn about programming through practical work and not just sitting listening to a lecturer (P26, P85) (Theme 6)</td>
<td>Demonstrate independent leaning (Guglielmino 1978)</td>
</tr>
<tr>
<td>3. Collaboration and communication</td>
<td>We learned from each other and from our trial and errors (P68, P99) (Theme 6). We have solved the communication problem ... by having a group meeting (P23, P49) (Theme 3)</td>
<td>Practice 21st-century skills as part of teamwork (Rotherham and Willingham 2010)</td>
</tr>
<tr>
<td>Students' core PBL element</td>
<td>Examples from qualitative data</td>
<td>Some SDL characteristics</td>
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<td>4. Roles, responsibility and ownership</td>
<td>We learned to take responsibility for our own work and the team work (P64, P96) (Theme 6)</td>
<td>Accept responsibility for one's own learning (Guglielmino 1978)</td>
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<tr>
<td>5. Problem solving and critical thinking</td>
<td>Students learn to solve problems on their own when developing a project. I have learnt much more than planned in the module (P31) (Theme 1)</td>
<td>View problems as challenges (Guglielmino 1978)</td>
</tr>
<tr>
<td>6. Reflective thinking and metacognitive control</td>
<td>We had an opportunity to select our own scope of what we want to achieve ... and how it can be implemented in real-life situations (P23, P49) (Theme 6)</td>
<td>Demonstrate self-reflection (Van Merriënboer and Sluijsmans 2009)</td>
</tr>
<tr>
<td>7. Management of the learning environment</td>
<td>We decided what each member should do to ... finish ... more quickly (P64, P96) (Theme 3). We worked late evenings (P41, P72) (Theme 4)</td>
<td>Apply effective time management (Jones et al. 2008), demonstrate persistence in learning (Guglielmino 1978)</td>
</tr>
<tr>
<td>8. Technology and tools</td>
<td>We used email and WhatsApp (P28, P48). We used DropBox ... (P14, P88) (Theme 3)</td>
<td>Identify human and material resources for learning (Knowles 1975)</td>
</tr>
<tr>
<td>9. Knowledge creation and integration</td>
<td>When working on a project we are required to think 'out of the box' and thereby integrating knowledge to create something new (P51) (Theme 1)</td>
<td>View problems as challenges (Guglielmino 1978)</td>
</tr>
<tr>
<td>10. Creative and innovative construction</td>
<td>We want to add additional things in our program (P9, P83) (Theme 5). We learned much about advanced programming (P5, P89) (Theme 6)</td>
<td>High degree of curiosity (Guglielmino 1978). Obtain real-life experiences in a specific domain (Shin 2011)</td>
</tr>
<tr>
<td>11. Assessment integration</td>
<td>We learned from our trial and errors (P68, P99) (Theme 6). I realised that I have learnt much more than planned (P31) (Theme 1)</td>
<td>Assess learning needs (Loyens, Magda and Rikers 2008)</td>
</tr>
</tbody>
</table>
### Students’ core PBL element

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<th>Examples from qualitative data</th>
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<tbody>
<tr>
<td>12. Performance, feedback and evaluation</td>
<td>We had an opportunity to select our own scope of what we want to achieve... and how it can be implemented in real-life situations (P23, P49). (Theme 6) (There was no time allocation for the 89 students to present their projects to peers)</td>
</tr>
</tbody>
</table>

Thus, the students applied a variety of skills, such as: independent and responsible learning; formulating their own learning goals; solving problems collaboratively; learning to plan and manage their time effectively; and applied monitoring and self-reflective skills. The results obtained are in line with previous research. Bagheri et al. (2013) claim that students who applied PBL performed significantly better in terms of self-directedness than students only exposed to conventional teaching methods. Furthermore, PBL provides opportunities for students to guide, manage and monitor their learning activities to promote SDL (Bagheri et al. 2013; Grant 2011).

### CONCLUSION

The article has reported on the application of PBL in higher education in order to develop programming students’ self-directedness. The findings indicate that PBL contributes to the development of a diverse range of skills, such as: solving complex problems; practising teamwork; constructing an innovative end product; and fostering self-directedness. The development of self-directedness encapsulated various distinctive attributes and qualities where students identified and managed their own learning needs and obtained real-life experiences. It should therefore be a strategic priority of HEIs to educate and empower students through innovative, sustainable high-quality teaching and learning to develop independent graduates who have a passion for lifelong learning.

### REFERENCES


NMMU see Nelson Mandela Metropolitan University.


NWU see North-West University.


SU see Stellenbosch University.
