

The influence of hybrid problem-based learning on Senior Phase preservice Technology teachers' self-directed learning abilities¹

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ABSTRACT

Hybrid problem-based learning (hPBL) may promote the ability of students to learn independently. This paper explores the impact of hPBL on preservice Technology teachers' self-directed learning (SDL) abilities. In this case study, a mixed-methods research design was used. The self-directed learning instrument (SDLI) developed by Cheng and colleagues was used to collect quantitative data. For the qualitative data observations, semi-structured individual interviews and self-reflective journals of preservice Technology teachers were used to give more meaning to the quantitative results. In this study, hPBL had positive influences on preservice Technology teachers' SDL abilities. Employing hPBL had a slightly positive impact on 'planning and implementation' as an SDL sub-domain. The preservice teachers' self-monitoring abilities increased statistically significantly. In addition, the hPBL intervention contributed to a slight improvement in the interpersonal communication abilities of these preservice Technology teachers. It is recommended that hPBL be implemented in larger classes in Technology Education, as well as in longitudinal studies to determine the long-term impact of hPBL on preservice teachers' SDL abilities.

Keywords: hybrid problem-based learning (hPBL), interpersonal communication, learning motivation, planning and implementing, self-directed learning abilities, self-monitoring, Senior Phase preservice Technology teachers

INTRODUCTION AND PROBLEM STATEMENT

The increase in information in the 21st century necessitates continuous self-initiated and self-directed learning (SDL) from everyone (Guglielmino, 2008; Loeng, 2020). In this regard, Van Zyl and Mentz (2019) state that university lecturers should develop preservice teachers' 21st

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century skills. Teachers fulfil an essential role in providing active learning environments to develop learners' self-directed skills (Golightly & Muniz, 2013). The literature reports that learner-centred teaching and learning approaches provide students with opportunities to enhance self-directed learning (SDL), critical thinking, problem-solving, communication and collaborative skills (Sebatana & Dudu, 2021). Importantly, lecturers offering teacher training should involve preservice teachers in active learning to enhance their SDL abilities and design learning spaces to develop these SDL abilities (Bosch et al., 2019).

A self-directed learner can identify and achieve learning goals through the effective implementation of learning strategies, monitor and reflect on their learning and search for appropriate resources (Francom, 2010). In the literature, PBL is highlighted as an active instructional strategy that fosters preservice teachers' SDL abilities (Golightly & Muniz, 2013; Sebatana & Dudu, 2021). The reason for this is that PBL conforms to the principles of SDL (Golightly, 2018; Havenga & Du Toit, 2022). In this regard, Du Toit (2020) and South Africa (2011) highlighted Technology education in a South African context, challenging teachers to use a problem-based approach. Technology education, in the current study, refers to teaching and learning of the South African school subject called 'Technology', which has a 'problem-based nature' (McCarthy-Kettledas et al., 2024: 211) and aims to develop learners' abilities to 'apply specific design skills to solve technological problems' (South Africa, 2011: 8).

Unfortunately, only a few studies focused on how PBL promotes preservice teachers' abilities to learn independently in a South African education context (Du Toit, 2015). No study focusing specifically on the preparation of preservice Technology teachers could be found. Against this background, this study investigates hPBL's influence on Senior Phase preservice Technology teachers' SDL abilities.

THEORETICAL AND CONCEPTUAL FRAMEWORK

Problem-based learning fits into a social constructivist view of learning (Hung et al., 2019), as the emphasis is on the construction of knowledge and an understanding in collaboration with others (Amineh & Asl, 2015; Chimwayange, 2024). This study uses social constructivism as a theoretical lens to promote learning by sharing knowledge among different players, namely facilitators and preservice teachers.

For meaningful learning in Technology education, the student should be actively involved in group work and be challenged to learn by solving real-world problems (Mello, 2016). The South African school curriculum for the subject Technology is embedded in 'active and critical learning' and focuses on planning real-life teaching-learning experiences for learners (South Africa, 2011). Training institutions need to expose preservice Technology teachers to social constructivist learning environments in their training (McCarthy-Kettledas et al. 2024). Karataş et al. (2021) also point out that social constructivist activities can enhance students' SDL abilities.

Self-directed learning abilities

Self-directed learning should be implemented at the school and university levels (Mahlaba, 2020). In SDL environments, it is expected that students have the ability to initiate learning, critically evaluate the learning resources they have selected (Loeng, 2020), deal meaningfully with learning activities and formulate learning objectives (Knowles, 1975). In this regard, SDL

abilities can be considered as students' abilities that assist them in engaging in SDL (Cheng et al. 2010). These authors developed four areas of their SDL instrument (SDLI), namely 'learning motivation, self-monitoring, planning and implementing, and interpersonal communication' (Cheng et al., 2010: 1156). It is no surprise that SDL environments can develop students' higher-order cognitive skills and increase their self-efficacy (Bhandari et al., 2020). In the following paragraphs, these four SDL ability domains are discussed in more detail.

'Learning motivation' is the 'inner drive of the students as well as external stimuli that drive the desire to learn and to take responsibility for one's learning' (Cheng et al., 2010: 1155). The literature rates intrinsic motivation high in the promotion and development of students' SDL capabilities (Altinpulluk et al., 2023). The intrinsic motivation of students can be increased through PBL as an active instructional strategy (Aldayel et al., 2019; Chimwayange, 2024), encouraging them to learn more independently (Baresh et al., 2019). Students with intrinsic motivation are eager to learn and take pride in their learning achievements (Chin et al., 2014). It is essential to note that extrinsic motivation for SDL refers to external rewards that encourage students to participate in SDL activities (Wang et al., 2020). Du Toit-Brits and Van Zyl (2017) concur with these authors, stating that extrinsic motivation can play an important role in motivating students to take ownership of their learning.

'Self-monitoring' is a student's ability to monitor the progress toward learning goals regularly and is crucial to the development of SDL (Cheng et al., 2010). Students should assess their learning progress and outcomes regularly. According to Bunt (2023), self-monitoring refers to the ability of students to assess gaps in their knowledge and learning progress. Students with high SDL abilities can integrate new knowledge gained through collaborative learning into their personal experiences and contribute to the assessment of their progress in learning (Al-Drees et al., 2015; Aldayel et al., 2019). Furthermore, Guo (2022) points out that self-monitoring is linked to self-control, self-evaluation and self-reflection, which can improve students' academic performance.

'Planning and implementing' as an SDL ability domain refers to 'students' ability to determine learning needs, express the learning issues concisely, and identify necessary resources, as well as to select and implement useful learning strategies that will support SDL' (Cheng et al., 2010: 1155). Van Rensburg and Botma (2015) point out that students who are proactive in identifying their learning needs, setting learning objectives and controlling the process of learning based on their learning needs show SDL skills. The effective integration of SDL has been demonstrated when learners can plan and implement various learning strategies (Shen et al., 2014).

'Interpersonal communication' refers to a student's ability to interact with other students (Cheng et al., 2010) or communicate effectively at an interpersonal level (Yoel et al., 2023). Through communication, students share information and learning experiences, verbally and non-verbally, to enhance their learning (Shen et al., 2014). Effective communication among student groups is important to help achieve meaningful learning (Adedokun et al., 2017). Dede (2010) also stated that effective communicators collaborate well with fellow students and have strong interpersonal skills. Therefore, students should construct knowledge and clarify their understanding through negotiation, defend their viewpoints and opinions and

search for information sources (Malan & Ndlovu, 2014). Baresh et al. (2019) argue that group discussions help students develop skills such as asking for clarification, making arguments and explaining their opinions. Group discussions and interaction between students develop students' communication, collaboration and presentation skills (Aldayel et al., 2019). Communication is viewed as a key 21st century skill required in Technology education (McCarthy-Kettledas et al., 2024).

The literature review points out that active teaching and learning strategies, including PBL, can promote students' SDL abilities when compared to direct instructional strategies (Bailey, 2016; Dongani, 2023; Van Rensburg & Botma, 2015).

Problem-based learning and hybrid problem-based learning

There are many definitions of PBL in the literature, but Barrows's (1986) definition is the most widely accepted. Barrows (1986) defines PBL as an active teaching-learning strategy that uses a real-world ill-structured problem for acquiring and integrating new knowledge. Shinde and Inamdar (2013) define PBL as learner-centred collaborative learning that is centred on complex real-world problems with multiple solutions.

Problem-based learning is reported to develop students' SDL skills and bridge the gap between theory and practice (Du Toit & Petersen, 2023; Golightly, 2018). Similarly, Williams and Ringbauer (2014) state that PBL can help students prepare for future professional careers by involving them in problem-solving and developing their data collection, collaboration in groups and decision-making skills, as well as enhancing several 21st century skills (Chimwayange, 2024).

Problem-based learning process

In the literature, various PBL processes are documented. In this study, the seven-step PBL approach developed by Moust et al. (2001) was employed to facilitate learning. First, the students were presented with a real-world problem (Havenga & Du Toit, 2022). In the different PBL groups and with the facilitator's assistance, they discussed the problem and clarified important concepts in step 1 (see Schmidt et al., 2019). In step 2, the groups defined and demarcated the real-world problem. Step 3 was the problem analysis, while in step 4, the group members discussed the problem. These discussions enabled the group members to identify what they did not know about the problem, after which they formulated learning objectives as step 5. These learning objectives acted as pointers for self-directed research in step 6 (see Malan & Ndlovu, 2014; Schmidt et al., 2019). During the PBL tutorial sessions, group members searched for information to achieve the set learning objectives and shared their findings with other group members during the next tutorial session (see Al-Drees et al., 2015). The members and the facilitator discussed the new information they had acquired through self-directed research (see Havenga & Du Toit, 2022). In step 7, group members reflected on their information about the stated learning objectives and generated ideas (Schmidt et al., 2019). In some instances, it is expected of group members to conduct further research on some of the stated learning objectives (Mansor et al., 2015), whereafter the group members formulated various solutions to the real-world ill-structured problem (Al-Drees et al., 2015).

In the present study, an hPBL format was implemented as most of the South African preservice teachers had never encountered PBL before. Hybrid PBL differs from pure PBL in that the facilitator integrates direct teaching methods, such as lectures and explanations by the facilitator, during the seven-step PBL process to support and assist students (Carrió et al., 2016)

(Hybrid) problem-based learning and SDL

As an instructional strategy, PBL, including hPBL, can positively influence the development of students' SDL skills and abilities. PBL has been implemented in various other disciplines, such as in Nursing Education (Ali & El Sebai, 2010), Consumer Studies (Du Toit, 2015) and Life Sciences (De Villiers et al., 2016), to develop students' SDL skills and abilities. Hybrid PBL has been successfully implemented to develop SDL abilities and skills in other disciplines, such as English (Baresh et al., 2019), Life Sciences (Greyling, 2020) and Optics and Photonics (Tan & Shen, 2019). Chaiyasit et al. (2023) also reported that hPBL positively influenced undergraduate students' SDL abilities at some Thailand universities.

Senior Phase Technology Education in South Africa

It is important for Technology teacher educators to involve Technology preservice teachers in active teaching and learning strategies that would empower them to make appropriate teaching and learning choices when teaching Technology in schools (McCarthy-Kettledas et al., 2024; Mtshali, 2020). Technological and scientific investigations are related to problem-solving (Kibirige et al., 2021). Technology teacher educators should involve preservice technology teachers in PBL environments to demonstrate how PBL can be implemented as well as promote their SDL skills. It is necessary to point out that the South African context has not been studied concerning the implementation of innovative teaching strategies such as PBL for preservice Technology teachers.

RESEARCH METHODS

In this case study, data collection was conducted using a multi-phase mixed-methods research design. The qualitative findings supported and provided more in-depth meaning to the quantitative results. The researchers explored the influence of hPBL on the SDL abilities of preservice Technology teachers in a Technology module in the BEd programme of a South African university. The case study was bound by time and activity, and detailed information was gathered through various data collection methods over five weeks. The study was conducted using a pragmatic theoretical perspective (Creswell & Plano Clark, 2018). In this study, the population entailed all the preservice Technology teachers registered for the module FETE 121 (n=29) at this specific university. For the semi-structured interviews, a sample of eight participants (n=8) was selected from the population.

Quantitative and qualitative data collection and analysis

In this study, a mixed-method research design, using quantitative and qualitative data collection and analysis, was chosen. The quantitative data originated from a standardised 'self-directed learning instrument' (SDLI) completed by preservice teachers at the beginning and end of the hPBL intervention (five weeks). The SDLI (Cheng et al., 2010) was used to measure preservice teachers' SDL abilities. The SDLI consisted of 20 items, grouped into four domains, namely learning motivation, planning and implementing, self-monitoring and

interpersonal communication. A five-point Likert-type scale was used to rate each item, with 5 = strongly agree and 1 = strongly disagree. A maximum score of 100 and a minimum score of 20 can be obtained (Cheng et al., 2010, p. 1152). Higher SDL scores indicate a higher level in that domain, and lower scores indicate a lower level in that domain of SDL abilities. The scores per domain for the preservice Technology teachers were calculated after the SDLI pre- and post-tests of the hPBL intervention.

The Cronbach alpha coefficients for the four SDLI domains for the 20 items of this study were calculated and are as follows: learning motivation, $\alpha=.909$; planning and implementing, $\alpha=.822$; self-monitoring, $\alpha=.796$; and interpersonal communication, $\alpha=.699$. The overall SDL ability was $\alpha=.807$, which is a good reliability measurement.

In this study, the researchers analysed the quantitative data collected by the SDLI using descriptive and inferential statistics. The dependent *t*-test was used to compare the SDLI pre- and post-test mean scores. *P* values and effect sizes were calculated to determine the statistical and practical significance of the SDLI pre- and post-tests after the implementation of hPBL to enhance the preservice Technology teachers' SDL abilities.

Qualitative data collection and analysis

The following qualitative data collection techniques were employed to contribute rich, deep data and enable triangulation of the results and findings:

- The researchers and the research assistant conducted classroom observations and made field notes during the interviews, focusing on the four SDL domains, namely learning motivation, planning and implementing, self-monitoring and interpersonal communications.
- Semi-structured open-ended individual interviews were conducted with eight participants ($n=8$) to collect qualitative data from volunteering FETE 121 preservice Technology teachers about the influence of hPBL on their abilities to learn independently.
- The preservice Technology teachers ($n=29$) completed reflective journals to indicate their experiences of how hPBL influenced their SDL abilities.

Qualitative data analysis was conducted using concept-driven data analysis, focusing on preservice teachers' perceptions of the influence of hPBL on their SDL abilities. To ensure data trustworthiness, transcribed copies of the interviews were sent to the preservice teachers for participant verification (see Miles et al., 2014), and a research assistant was involved in the independent reading and coding of the qualitative data. The classroom observation of the researcher and student assistant researcher, and preservice Technology teachers' narratives are included in the subsequent sections to provide deeper meaning and to support the quantitative results and are referenced as follows: CO1 and CO2 represent qualitative findings about classroom observers 1 and 2, respectively. The pseudonyms FP1 to FP4 refer to the qualitative interview data obtained from the four female participants, while MP1 to MP4 represent the data gained from the four male participants. SJ1 to SJ29 are used when references are made to the 29 self-reflective journals received from the participants.

To ensure data trustworthiness, the researchers provided a detailed step-by-step explanation of the research process undertaken, to enable future researchers to follow a similar research framework. Before presenting the final findings, the researchers checked the information with participants to ensure the information reported was correct. To further ensure the trustworthiness of the findings in this study, examples of raw data representing quotes from participants were provided.

This research was approved by the university's ethics committee and met all prescribed ethical regulations. Preservice teachers were asked to give written consent for the use of their information. The researchers also assured the participants that their identities and responses would be kept confidential throughout the study.

RESULTS AND FINDINGS

The results and findings of the impact of the hPBL intervention on the SDL abilities of the participating preservice Technology teachers are presented below.

The hPBL intervention's influence on the preservice teachers' learning motivation

From Table 1, the implementation of hPBL in the Technology module had a statistically significant increase (P -value = .03) and a medium, practically significant increase (d -value = 0.48) in preservice teachers' learning motivation.

Table 1:

The hPBL intervention's influence on the preservice Technology teachers' learning motivation domain

Learning motivation domain items		N	Mean	Standard deviation (SD)	P value	d value
'Regardless of the results or effectiveness of my learning, I still like learning.'	Pre	29	3.17	1.10	.01	0.69
	Post		3.93	0.79		
'My successes and failures inspire me to continue learning.'	Pre		3.52	1.43	.05	0.46
	Post		4.17	0.93		
'I will not give up learning because I face some difficulties.'	Pre		3.52	1.21	.09	0.43
	Post		4.03	0.82		
'I strongly hope to improve constantly and excel in my learning.'	Pre		3.83	1.47	.12	0.40
	Post		4.41	1.12		
'I enjoy finding answers to questions.'	Pre		3.45	1.40	.16	0.34
	Post		3.93	0.88		
Total	Pre		3.46	1.08	.03	0.48
	Post		4.07	0.71		

In this domain, it is evident that the item 'Regardless of the results or effectiveness of my learning, I still enjoy learning' showed the highest increase in mean scores from the pre-test (\bar{x} =3.17) to the post-test (\bar{x} =3.93) with the implementation of hPBL, indicating a moderately significant increase (d -value = 0.69). Preservice Technology teachers' interviews and self-reflective journals have shown that the preservice teachers believe that the hPBL intervention offers opportunities for learning despite the challenges. The following quotations from the preservice Technology teachers highlighted this matter:

The support I received from fellow students and the facilitator helped me to like learning regardless of the results of my learning. (SJ15)

When I do not understand the electrical concepts or procedure to carry out the experiment, I can freely consult my fellow students and the facilitator for help, which motivates me to learn. (FP1)

The observers also highlighted that when the preservice teachers did not understand electrical concepts or procedures, they demanded assistance from the facilitator and group members.

In this study, preservice Technology teachers believed that hPBL experiences challenged them to identify what they needed to learn to solve the given technological problems. The item “I know what I need to learn” increased in mean scores from 3.28 to 3.93 after the hPBL intervention, with a medium practical significant increase (d -value = 0.58). The following quotations from the interviews with and self-reflective journals of the preservice teachers summarise this matter:

During hPBL tutorial sessions we were provided with the opportunity to set our learning issues which helped us to know what to learn during self-study to solve technology problems. (MP1)

The learning issues that we developed during the hPBL activities helped us to know what to learn to solve problems. (SJ15)

Both observers reported on the preservice Technology teachers’ engagement in formulating learning objectives that they used to guide them during their self-directed search for information. Observer CO1 noted that the preservice Technology teachers were challenged (solving real-world ill-structured technology problems) to learn on their own, and as a result, they were motivated to learn. Thus, from the results and findings of this domain, the implementation of hPBL activities positively influenced the preservice teachers’ learning motivation.

The hPBL intervention’s influence on the preservice teachers’ planning and implementation

There was no statistically significant difference (P -value = .19) in the influence of hPBL on the preservice Technology teachers’ ‘planning and implementing’ domain scores. However, there was a small practically significant increase (d -value = 0.27) after the hPBL intervention.

Table 2:

The hPBL intervention’s influence on the preservice Technology teachers’ planning and implementing domain

Planning and implementing domain items		N	Mean (\bar{x})	SD	P value	d value
'I know how to find resources for my learning.'	Pre	29	3.07	0.96	.10	0.47
	Post		3.52	0.99		
'I know which learning strategies are appropriate for me in reaching my learning goals.'	Pre	29	3.38	1.32	.14	0.42
	Post		3.93	0.96		
'I set the priorities for my learning.'	Pre	29	3.45	0.95	.16	0.36

	Post		3.79	0.98		
'I can proactively establish my learning goals.'	Pre		3.24	0.83	.45	0.21
	Post		3.41	0.87		
'Whether in the practicum, classroom or on my own, I am able to follow my own plan of learning.'	Pre		3.55	1.06	.69	0.10
	Post		3.66	0.86		
'I am good at arranging and controlling my learning time.'	Pre		3.03	1.05	.81	0.07
	Post		3.10	0.82		
Total	Pre		3.29	0.76	.19	0.27
	Post		3.57	0.61		

All the items for the 'planning and implementing' domain in Table 2, have slightly higher post-test mean scores when compared to the pre-test items. The item "I know how to find resources for my learning" had a medium practically significant increase (d-value= 0.47). Most of the preservice Technology teachers stated that the hPBL activities involved them in searching for learning material that would assist in formulating solutions to the stated problems. Most of the preservice Technology teachers interviewed stated that their involvement in the hPBL activities had helped them learn how to conduct self-directed research to find useful learning resources. One of the participants during the interview summarised it as follows:

[The] hPBL activities provided us with the opportunity to find and use different resources to solve the problems. I can consult different resources such as Electrical books and the internet to solve problems depending on the nature of our learning needs. (MP2)

The two observers highlighted that the preservice Technology teachers searched for resources on the internet using their mobile phones to find information about the learning objectives.

Regarding the item 'I know what learning strategies are appropriate for me in reaching my learning goals', a medium practically significant increase in the mean scores occurred (d-value = 0.42). Most preservice Technology teachers had a feeling of knowing and applying appropriate learning strategies to achieve the stated learning goals. Most of the interviewed preservice Technology teachers concurred with the above-mentioned perceptions, as reflected below:

[The] hPBL activities provided us with the opportunity to figure out and apply different learning strategies to achieve our goals and that encouraged me to work hard. (MP2)

I critically question and analyse the given electrical concepts that I find in Electrical textbooks, and I also question my understanding of the electrical concepts I am studying. (FP1)

The hPBL intervention's influence on the preservice teachers' self-monitoring

In the 'self-monitoring' domain, the pre-test ($\bar{x}=3.34$) and post-test ($\bar{x}=3.84$) scores of the preservice Technology teachers indicate a statistically significant difference (P-value = .01) and a medium practically significant increase (d-value = 0.54) after the hPBL intervention (see Table 3).

Table 3:

The hPBL intervention's influence on the preservice Technology teachers' self-monitoring domain

Self-monitoring domain items		N	Mean (x̄)	SD	P value	d value
'I can monitor my learning progress.'	Pre	29	3.21	0.77	.01	0.67
	Post		3.72	0.75		
'I can evaluate my learning outcomes on my own.'	Pre	29	3.00	0.78	.06	0.57
	Post		3.55	0.96		
'I can connect new knowledge with my personal experiences.'	Pre	29	3.45	1.02	.06	0.54
	Post		4.00	0.93		
'I understand the strengths and weaknesses of my learning.'	Pre	29	3.69	1.07	.09	0.39
	Post		4.10	0.72		
Total	Pre	29	3.34	0.76	.01	0.54
	Post		3.84	0.52		

In the domain of self-monitoring, the statement 'I am able to track my progress in learning' showed the most significant practical increase after the implementation of the hPBL activities (d-value = 0.67). This view was confirmed during the interviews with the preservice Technology teachers and in their self-reflective journals when the following were noted:

During my self-study, I used the provided assessment rubric to monitor my learning. I also have the checklist drawn which helped me to see if I am making progress or not. (FP4)

Hybrid PBL provided me with the opportunity to share what I have found during the self-study and through discussion with other students, I had the opportunity to monitor my progress. (SJ7)

The preservice Technology teachers highlighted that their involvement in hPBL activities assisted them in assessing and monitoring their learning outcomes. The item 'I can evaluate my learning outcomes on my own' showed a medium practically significant increase (d-value = 0.57) after the hPBL intervention (see Table 3). Most of the preservice Technology teachers concurred with this view, as highlighted by the following quotation:

[The] hPBL activities provided us with the opportunity to monitor our own progress and evaluate the learning outcomes and this helped us to take control over our thinking and learning process and equipped us with learning how to learn. (FP1)

In addition to assessing their learning outcomes, the preservice Technology teachers were able to link new knowledge with their personal learning experiences. The item 'I can connect new knowledge with my own personal experiences' showed a medium practically significant

increase (d-value = 0.54) after the hPBL intervention. This matter was confirmed as follows by a Technology student teacher in her interview:

I was amazed by the functioning of a fridge light, which I questioned myself about without getting an answer for quite a long time. After our research about different switches to use for the brake system of our trailer, my fridge light problem was solved. Brake systems – like fridges – use a normally open switch. (FP1)

The results indicate that the preservice Technology teachers could recognise the importance of connecting their knowledge about electrical concepts to their personal experiences. These preservice teachers were also able to relate that knowledge to their strengths and weaknesses, which helped them assess their learning outcomes. As a result, the hPBL activities encouraged the preservice Technology teachers to monitor their learning objectives effectively.

The hPBL intervention's influence on the preservice teachers' interpersonal communication

After the implementation of the hPBL activities in the Technology curriculum, there was a slight increase in the total scores from the pre-test to the post-test of the preservice teachers' interpersonal communication (P-value = .10; d-value = 0.31).

Table 4:

The hPBL intervention's influence on the preservice Technology teachers' interpersonal communication domain

Interpersonal communication domain items		N	Mean (\bar{x})	SD	P value	d value
'My interaction with others helps me plan for further learning.'	Pre	29	3.28	1.09	.09	0.44
	Post		3.76	1.02		
'I am able to communicate messages effectively in writing.'	Pre		3.34	1.20	.16	0.32
	Post		3.72	0.96		
'I would like to learn the language and culture of those with whom I frequently interact.'	Pre		3.52	1.18	.32	0.29
	Post		3.86	1.03		
'I am able to express messages effectively in oral presentations.'	Pre		3.28	0.96	.53	0.18
	Post		3.45	0.94		
Total	Pre		3.36	1.02	.10	0.31
	Post		3.70	0.64		

In Table 4, the statement 'My interaction with others helps me plan for further learning' showed no statistically significant difference (P-value = .09) but had a moderately practically significant increase (d-value = 0.44) after the hPBL intervention. In the preservice teachers' semi-structured individual interviews and self-reflective journals, they emphasised that their collaboration with group members during the hPBL activities supported them in planning for further studies. The following quotations summarise this aspect:

We worked well together in identifying learning issues that helped me to plan for further learning. (MP2)

[The] interactive discussions we had enabled me to plan for further studies on the discussed electrical concepts. (FP1)

Engaging actively in discussion[s] with fellow students [have] broadened my electrical knowledge and I was highly motivated to do more research about electrical concepts involved in solving Technology problems so that I can effectively contribute during discussions. (SJ23)

Both the observers also reported that the preservice Technology teachers discussed the formulation of the learning objectives and the self-directed search for information among themselves during the hPBL activities.

The item 'I am able to communicate messages effectively in writing' showed a small practically significant increase (d-value = 0.32) after the hPBL intervention. The preservice Technology teachers highlighted that being involved in the hPBL activities had improved their communication skills with fellow group members through written communication in an SDL context. The preservice Technology teachers' interviews and journal entries affirm this aspect:

In hPBL we had to provide a summary of the self-studied information. That contributed to my improved writing skills as the hPBL compiler effectively compiled our documents for submission without difficulties. (MP2)

Before [the] hPBL activities I struggled to write down a meaningful sentence. Through continuous practice during self-study, I can now effectively communicate in writing in such a way that the reader can clearly understand the message I am conveying. (SJ4)

From the abovementioned results and findings, it can be concluded that hPBL is an effective teaching and learning strategy to enhance and improve preservice Technology teachers' SDL abilities.

DISCUSSION

This study's findings report that the hPBL intervention positively impacted preservice Technology teachers' SDL abilities. These results and findings concur with the results of other studies from other disciplines, such as Nursing Education (Ali & El Sebai, 2010), teacher training (Golightly, 2018), undergraduate students (Chaiyasit et al., 2023) and secondary education (Venter, 2018) where hPBL positively impacted students' and learners' SDL abilities and skills (Golightly, 2018). However, the results and findings of this study are contrary to those of Walker and Lofton (2003), which found that the implementation of hPBL activities resulted in a decrease in students' abilities. In Greyling's (2020) study, an hPBL intervention with Grade 10 Life Sciences learners had no real influence on the learners' SDL abilities.

The increase in the preservice Technology teachers' SDL abilities in the current study may be ascribed to the solving of real-world technology problems, collaboration and communication among group members, conducting self-directed searches for information and the use of assessment rubrics as a scaffold during the hPBL tutorial sessions, echoing findings by Petersen et al. (2023). The same authors also confirmed that students were encouraged to learn using ill-structured problems, while they were supported and guided by the facilitator and fellow group members. Furthermore, Van Deur and Murray-Harvey (2005) emphasise that

interaction with fellow group members and the facilitator can positively influence a student's motivation to learn. In another study, Schulze and Van Heerden (2015) point out that Science teachers are essential in motivating learners about the active learning environments they create. This concurs with the view of Sweller et al. (2024) that teacher-centred instructional strategies, such as mini-lectures, explanations and demonstrations, in learner-centred instructional strategies, such as hPBL, are important to guide and facilitate students' learning during the learning process.

In this study, the hPBL intervention in Technology education positively impacted preservice Technology teachers' learning motivation. It concurs with Venter's (2018) results and findings, reporting an increase in Life Sciences learners' learning motivation with the use of problem-based case studies. In this regard, Du Toit (2015) similarly reported an increase in preservice Consumer Studies teachers' learning motivation when solving real-world problems. A possible reason for the increase in preservice Technology teachers' learning motivation scores after the implementation of hPBL, is that they reported that solving real-world ill-structured technology problems in a collaborative learning environment motivated them to learn. Similar results were reported by Chimwayange (2024).

In the current study, the use of hPBL activities had a slight positive impact on the preservice Technology teachers' planning and implementation as an SDL ability domain. These results and findings concur with those of Venter (2018), who found that the planning and implementation of Life Sciences learners increased after the use of problem-based case studies. Ali and El Sebai (2010) reported an increase in Nursing Education students' planning and implementation after a PBL intervention. However, these results differ from those of Greyling's (2020) study, which found no changes in learners' planning and implementation after the implementation of hPBL activities.

The increase in the preservice Technology teachers' planning and implementation domain mean scores after the implementation of hPBL activities in this study can be ascribed to the fact that the preservice teachers had to self-search for and apply various resources to solve the stated real-world problems (see Bailey, 2016; Dolmans et al., 2016) and assess the appropriateness of these resources for solving the problem (see Tjakradidjaja et al., 2016). Another possible reason for the increase in students' planning and implementation abilities could be the preservice teachers' involvement in formulating learning issues to solve the stated problem and then searching for the necessary information (see Schunk, 2012). Furthermore, the student teachers worked together and learnt from fellow group members to formulate solutions for the problems presented in the case studies (see Akili, 2014; Chimwayange, 2024).

The implementation of hPBL activities in the training of preservice Technology teachers showed a statistically significant increase and a medium, practically significant increase in their ability to self-monitor their learning. This result correlates positively with the results of Ali and El Sebia (2010) in Nursing Education and Venter (2018) in Life Science Education. A possible reason for this could be that the preservice Technology teachers had to monitor their learning progress and assess their learning objectives. This opportunity enhanced their self-regulated learning and critical thinking skills. In the preservice Technology teachers' interviews and self-reflective journals, most of them highlighted the importance of the assessment rubric in guiding them

through the PBL process and in formulating solutions to ill-structured problems. They also stated that the assessment rubric provided by the facilitator was influential in guiding them in identifying knowledge gaps and conducting self-directed research to achieve the stated learning objectives. This study's results and findings are similar to those of other studies on hPBL or PBL, which report the enhancement of students' monitoring of their learning (Bailey, 2016; Golightly & Muniz, 2013; Tan & Shen, 2019). Chaiyasit et al. (2023) highlighted that students' involvement in hPBL activities promotes their self-monitoring skills, as they are actively involved in planning and assessing their learning progress, seeking support from the facilitator or fellow group members, searching for educational resources and assessing their learning outcomes.

From the above-mentioned information, the use of hPBL activities in the preservice Technology teachers' education caused a slight increase in their interpersonal communication skills (see Table 4). These results are consistent with Venter's (2018) results which reported an improvement in the Life Sciences learners' interpersonal communication skills after the implementation of a problem-based case study. Ali and El Sebai (2010) and Chaiyasit et al. (2023) also found an increase in students' interpersonal communication after their involvement in PBL experiences.

The preservice teachers in the current study highlighted that social interaction and discussion with the facilitator and group members during the hPBL tutorial sessions encouraged them to discuss and debate issues to solve the problem. The preservice Technology teachers pointed out the caring and committed relationships they developed with fellow group members. Chaiyasit et al. (2023) highlight that the collaborative nature of hPBL engages students in discussions with group members to provide solutions to real-world ill-structured problems. Similarly, Skinner et al. (2016) mention that people with good interpersonal communication skills are sensitive to cultural differences, have more empathy and listen more attentively. It is, therefore, important that, during their training, South African school teachers develop the necessary interpersonal communication skills to deal with diverse learning situations and learners with different languages and cultures in their classrooms.

LIMITATIONS OF THE STUDY

This study had potential limitations in that the preservice Technology teachers completed a self-reported SDL instrument to measure their SDL abilities. It is possible that they did not respond truthfully to the SDLI items. The small sample size may also be a limitation, as it could influence the statistical and practical significance of the effect of hPBL on preservice Technology teachers' SDL abilities. However, qualitative data were used to overcome this limitation. Therefore, caution is advised with generalising the findings.

CONCLUSION AND RECOMMENDATIONS

The incorporation of hPBL activities in the Technology module had a positive impact on the perceptions of these preservice teachers regarding their SDL abilities. In the four domains of SDL, the hPBL intervention resulted in a medium to small, practically significant increase in the SDL abilities of the preservice Technology teachers. The main reasons, as highlighted and reported by the preservice Technology teachers, include the use of real-world technology problems, working in collaborative learning environments, communication among the group

members, self-searching for learning resources, the essential role of the facilitator and group members, as well as the use of assessment rubrics in assessing their learning progress.

Important recommendations include the integration of hPBL activities in other Technology teacher education modules to support the development of preservice Technology teachers' SDL abilities. It is essential that the necessary training of preservice Technology teachers take place as part of the implementation of hPBL in the early stages to develop their SDL abilities. It is recommended that hPBL be implemented in larger class sizes in Technology education at other South African tertiary institutions and schools. To explore the long-term influences of hPBL interventions, researchers need to conduct longitudinal studies. It is also necessary to do experimental studies with a control group, to better understand the actual changes in pre- and post-test SDL abilities better. The results of this hPBL study need to be confirmed through replication using larger sample sizes to explore how preservice Technology teachers' abilities to learn and continue to learn on their own in practice can be improved.

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