Chapter 10
Robotics Simulations: Developing Essential Student Teachers' Skills for the Digital Age

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Abstract Technology and digitalization are ubiquitous in the Fourth Industrial Revolution. An important aspect is the emergence of robotics, especially within multimodal learning contexts. In this regard, this research drew on the scholarship of robotics in terms of multimodality and online learning. This chapter focuses on practices and reflections of student teachers studying a Postgraduate Certificate in Education through a distance mode. The aim of this chapter is to report on students' active involvement in online robotics simulations, as part of a module on Information Technology, with the aim of developing essential skills for the digital age. Such skills include problem-solving, creative and critical thinking, and innovation, among others. The researchers in the current study employed a general qualitative methodology which involved document analysis of student assignments, student-generated multimodal artefacts as well as reflections. In total, 11 students participated in this research. The findings show that students had some challenges working online and they experienced a steep learning curve, as they had not been introduced to robotics prior to the research. However, participants developed particular skills that are valuable for the digital age, and this was also evidenced through the multimodal artefacts. Finally, recommendations are made for skills development and practices of robotics simulations in a multimodal context.

Keywords Digital age · Essential skills · Robotics simulations · Student teachers

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10.1 Introduction

Teacher education and the wider education sector have been impacted by the needs and affordances of the digital age, and within the context of the Fourth Industrial Revolution (4IR), more changes are envisaged. According to Klaus Schwab (2015), this revolution will change the way we work and even relate to each other. In a review of research on robotics in South Africa, the relation of research with the 4IR was evident (Boje et al. 2019). Furthermore, in the South African Department of Basic Education's Annual Report 2018/2019, the implementation of the 4IR in schools was proposed (DoBE 2019). However, there are still some criticisms about whether South Africa, as a country, is ready for the needs of the 4IR (Sutherland 2020). These aspects have also had an impact on teacher education in the digital age.

Within this wider context, there has been a drive from the South African government to promote coding and robotics at the school level as part of an effort to support the learning of science, technology, engineering and mathematics (STEM) (Mondada et al. 2016). These efforts are part of a trend in education where, according to Seemiller and Grace (2018), "coding is the new cursive, and that teaching kids to code may be far more useful than spending time teaching obsolete cursive writing" (p. 191). In the South African context, there have already been attempts to promote robotics in schools to also support learning abstract concepts (Govender 2021; Mondada et al. 2016). Furthermore, universities have supported schools in creating cost-effective open-source robotics platforms (Ettershank et al. 2017) such as Open Robotics, Sparki, and Turtlebot. The draft Coding and Robotics National Curriculum and Assessment Policy Statements (CAPS) for Grade R–3, 4–6 and 7–9 was made available to the South African public for feedback. This document indicates that this topic/subject will be prominent in schools in the future, and therefore prospective Information Technology teachers should be introduced to and be prepared to teach this subject.

This chapter deals with practices and reflections of student teachers studying a Postgraduate Certificate in Education (PGCE) by means of a distance mode at a selected South African university. The aim of this chapter is to probe students' active involvement in online robotics simulations, as part of a module on Information Technology, with the aim of developing essential skills for the digital age. To this end, this qualitative study not only involved student perceptions but also related to the nature of skills such as problem-solving, creative and critical thinking, innovation and technical abilities in this context.

10.2 Literature Review

This section outlines relevant theoretical concepts pertaining to essential skills for the digital age, the digital context of teacher practice as well as robotics and multimodality.

10.2.1 Essential Skills for the Digital Age

Being digitally positioned prompts the need for certain skills within an interconnected world. Regarding the interconnected world of the 4IR, Schwab (2016) considers people's digital presence to be crucial in the near future. Online personal profiles and virtual social presences are expected to be pivotal for interaction and collaboration, building relationships, seeking relevant information and discussing work-related issues (Schwab 2016). The 4IR also demands that people are continuously skilled to be relevant in a dynamic world of work, be able to adapt to changes and develop the ability to be productive in a digitized society (Chakravarti 2020).

Sousa and Wilks (2018) highlight the following valued skills for career requirements and the work environment in the digital age: problem-solving ability; critical and creative thinking; people skills, such as emotional intelligence; adaptability; decision-making and judgmental thinking; argumentation; and negotiation skills. Regarding the relevant technological capabilities, they refer, among others, to artificial intelligence, robotics skills and digitalization. Desired skills for a demanding future also include intellectual abilities; cognitive and creative skills; technical competencies; practical dexterity and hand-eye coordination; social and interpersonal skills; perseverance; as well as the demonstration of specialized, integrated knowledge and applied learning (UNESCO 2018, p. 5, 7).

Fleaca and Stanciu (2019) examined digital requirements with the aim of enhancing teaching and learning in the fields of manufacturing education and business engineering education. They focused on learning needs in the digital era and mentioned specific dimensions and related features, namely: information and data processing (browsing, critical evaluation and data management in the digital context as supported by digital technologies); digital communication (management, collaboration and information sharing using digital technologies); digital content creation (development and integration of digital content, application of copyright principles/rules/licenses); and digital problem-solving (exploration of digital technologies to solve problems, and creative and interactive implementation of such technologies in the learning context) (Fleaca and Stanciu 2019). Chakravarti (2020) highlights learning as a "lifelong endeavor" (p. 1716) that is relevant for the digitized challenges of the future. Importantly, teaching practice will increasingly take place in a digital context.

10.2.2 The Digital Context of Teacher Practice

Digital technologies have impacted all aspects of life, and their role in education and teacher training is inevitable (Borba et al. 2018; Howard et al. 2021). Although digital technologies have been used for some time, the COVID-19 pandemic accelerated the transformation to online learning across the globe as an essential modality of delivery when face-to-face learning was not allowed because of lockdowns (Mhlanga and

Moloi 2020). This also prompted the need for additional teacher literacies (Sánchez-Cruzado et al. 2021). In this context, students are expected to work on their own and use appropriate technologies for learning. With this expanded scope of learning, it is essential to explore the digital context of teachers' practice in challenging times.

In the digital age, learning is characterized by the enrolment for online courses, use of online educational platforms, electronic textbooks and open educational resources (OER), Internet access, and the use of resources such as YouTube, wikis and Google Docs (Makarova and Makarova 2018; Olivier 2020a). Moreover, digital technologies in education provide opportunities for "equitable access" for those who aim to obtain relevant knowledge and skills and develop essential competencies for the future (Makarova and Makarova 2018, p. 57).

Already in 2010, Starkey discussed digital skills that are crucial for novice teachers in such contexts. She emphasized pedagogical reasoning and action, based on Shulman's model (Shulman 1986), as essential for the digital age and compiled the "Digital Age Learning Matrix" which was implemented with teachers in their first year of teaching. The digital skills include accessing information, presenting and processing information, gaming and the use of interactive programmes, and communication. These technologies were aligned on a matrix according to learning features such as doing, thinking about connections (comparing and sharing), thinking about concepts and "big ideas", critiquing and evaluating (limitations and potential), creating "new reality", and sharing knowledge (sharing new knowledge by means of authentic settings) (Starkey 2011, p. 22). Furthermore, she emphasized the importance of teachers to be knowledgeable about a digital society, which is part of this wider context, and that they should be able to apply digital skills in praxis based on their theoretical views regarding active learning in the digital age. Howard et al. (2021) have recently highlighted the specific digital competencies needed for student teachers. According to them, these require an integrated and iterative approach to developing competencies.

Future teachers need to develop knowledge and competences for a digital learning environment. Demeshkant (2020) refers to the interplay of pedagogical, technological and professional competences for professional practice. She argues that the ubiquity of digital artefacts/devices requires that teachers not only develop digital skills but also integrate digital technologies into the classroom for creative and innovative teaching and learning experiences.

In the teaching profession, teachers require a compendium of skills to be digitally competent (Artacho et al. 2021). These authors refer to digital teaching competence as the ability to activate specific skills to search and select relevant resources, employ ICTs to integrate new knowledge and the ability to communicate the acquired knowledge by using various digital media. Scholars emphasize the importance of adopting digital teaching-learning practices to engage students in a digital world (Fleaca and Stanciu 2019). Finally, in this chapter, the concept of multimodality is also highly relevant.

10.2.3 Robotics and Multimodality

In the context of this chapter, robotics—which also implies that this research links up with the extensive literature related to robotics as a means to learn programming (cf. Boje et al. 2019; Dolenc et al. 2014; Govender 2021; Hudson et al. 2020; Kucuk and Sisman 2018; Lück and Lareau 2016; Yilmaz Ince and Koc 2021)—is viewed from a perspective of self-directed multimodal learning. This involves both multimodality and multimodal learning, as "multimodality refers to the dynamic application of different modes, while multimodal learning refers to individual modal preferences, communicating through different modes, learning and teaching by means of different modes, and education taking place through different modes of delivery" (Olivier 2020b, p. 119). In addition, the need for self-directedness is evident, as students need to be able to take charge of their own learning and be able to manage their goals, resources and self-evaluation in an interdependent manner. To this end, the theoretical background of self-directed learning (SDL) (cf. Garrison 1997; Guglielmino and Guglielmino 2001; Knowles 1975) is also highly relevant to this chapter.

In this chapter, multimodal learning draws on the theoretical framework of multimodality (Bezemer and Kress 2016; Kress 2010) where learning is approached in terms of the meaning-making processes. Consequently, the semiotics and sign-making process of both programming and praxis of robotics are relevant. For Kress (2010), semiotics is relevant in any theory of learning, and this "sign-making is meaning-making and learning is the result of these processes" (p. 178).

Consequently, the creation and programming processes for robotics are considered as sign-making processes in themselves. Furthermore, in this chapter, both instructional multimodality and interactional multimodality (Olivier 2020b) are relevant. In terms of instructional multimodality, the learning itself happens through a distance education mode, whereas in terms of interactional multimodality, different modes of communication are employed in the process of setting up and handling the environment and programming itself.

In the next section, the empirical research conducted—to determine how student teachers can develop essential skills for the digital age through robotics simulations—is unpacked.

10.3 Empirical Research

10.3.1 Research Methodology and Paradigm

A generic qualitative approach was adopted for this research, conducted within an interpretivist paradigm (Bakkabulindi 2015; Tracy 2020). Such a generic qualitative inquiry investigates rich sources of data such as individuals' views, beliefs, reflections and experiences regarding a particular aspect by using an interpretive lens, for example.

10.3.2 Study Context, Participants and Activities

The distance mode of delivery involves that students who do not attend class and/or practical sessions could undertake their courses remotely. A prerequisite for enrolment in the PCGE programme with Information Technology as a major subject is that students have at least a qualification in Computer Science (as part of a Bachelor of Science or Bachelor of Commerce degree, for example) with a background in computer programming up to second-year level.

Although a total of 21 students enrolled for the PCGE in 2020 and completed all class activities, only 11 students provided informed consent, thus indicating that their data could be used for research purposes. The cohort comprised of a diverse group of students in terms of gender, mother tongue and age. The research project was approved by the relevant ethics committee and the University Research Data Gatekeeper Committee. Furthermore, this research adhered to institutional and national standards of research ethics in terms of independent recruitment, voluntary participation, confidentiality, privacy and safe data management.

Within the distance mode of delivery, interaction with lecturers took place using eFundi, a Sakai-based Learning Management System (LMS). The LMS was used to communicate, act as an e-guide to direct learning activities and for the submission of assignments, among others. Lecturers used a specific electronic marking tool to perform assessments and provide feedback to support students' learning experiences. As part of the course activities, PGCE students worked individually and had to submit four assignments to the LMS before the deadline. Note that only the last assignment focused on coding and robotics, where students worked with Lego Digital Designer (LDD) to build the virtual robot. LDD is free, like computer-aided design programs, and enables individuals to build a variety of models using virtual bricks. Although LDD is no longer supported by LEGO, it is still available for download and is deemed a valuable resource that can be utilized to introduce students to robotics through an online modality.

The assignment—relevant to this research—comprised both theoretical and practical aspects such as the following:

- discussion and motivation of appropriate teaching-learning strategies for active learning;
- design of a maker space learning environment for the school (e.g., drawings of floor diagrams; selection of appropriate furniture and types of devices to be used in class, e.g., robots/drones/eye tracking);
- designing and building one's own robot using simulation software (LDD). It was expected of students to copy five images in succession to indicate how they built the robot using various components. Upon completion, students were requested to write a two-page narrative reflection on their experiences and challenges regarding the building of the robot. Figure 10.1 shows an example of a partially built design.

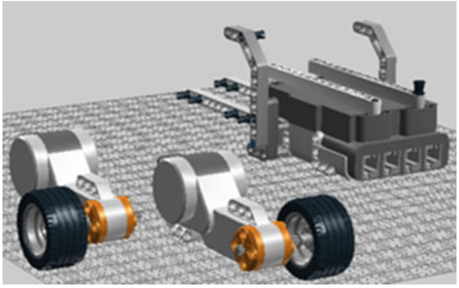

Fig. 10.1 An example of a partially built robot design

Fig. 10.2 Examples of student-generated multimodal artefacts

10.3.3 Data Collection

Data collection involved collecting students' robotics assignments, student-generated multimodal artefacts as well as their narrative reflections. Some examples of students' multimodal artefacts are shown in Fig. 10.2.

10.3.4 Data Analysis

Data were manually coded and analyzed qualitatively. This also included document analysis of students' data. In the current study, an open-coding approach was followed, codes were organized into categories, and main themes were identified after an inductive analysis of the data (Saldaña 2011).

10.3.5 Trustworthiness

Trustworthiness, or the rigor of a study, indicates whether the qualitative research findings are credible (accuracy and truth of the findings), transferable (applicable to other research contexts), confirmable (based on participants' feedback and responses) and dependable (findings are consistent and can be replicated) (Lincoln and Guba 1985). Credibility was assured by applying investigator triangulation (where more than one researcher analyzes the data independently) (Korstjens and Moser 2018). In this study, both researchers analyzed the data.

10.4 Research Findings

The following research question is addressed in this section: How can student teachers develop essential skills for the digital age through robotics simulations?

Table 10.1 summarizes some codes that emerged from the data. This is followed by a short discussion of the main themes, with some selected quotations that illustrate the views of the participants. Note that quotations are verbatim and were not language-edited.

It is essential that student teachers themselves develop cognitive and self-directed learning skills to assist learners in the future. Table 10.1 shows some responses where participants took responsibility for addressing an unfamiliar problem.

Reflective thinking is a valued skill, especially when making corrections and solving unknown problems. Table 10.2 demonstrates examples of reflection and control of one's thinking as indicated in some student responses.

Digital skills are crucial for the future and student teachers need to be knowledgeable about working in unknown and online environments to develop higher-order thinking abilities. Table 10.3 shows active involvement and some challenges that students experienced in building the digital robot artefact.

From the student responses, there was clear evidence of the importance of cognitive and SDL skills. There also seemed to be an awareness of their thinking processes and hints of metacognitive awareness; however, these were not specifically probed.

Table 10.1 Theme: cognitive and self-directed learning skills

Asking essential questions: where to start, what should I do? What? How? (P2)
What finally helped: think out of the box (P7)
Took a break: really think of a way that I can solve this issue: correct parts (P4)
Practice: familiarize myself with components (P2)
Learn: creative thinkers, learn problem-solving techniques (P1)
Understand computerization better: an effective way to learn (P3)
Improve critical thinking (P3)
Apply research skills to acquire more knowledge regarding the software (P9)
Triggered my critical thinking and problem-solving skills (P9)
I do not have the knowledge & skills to build the robot: enrol in a short course (P8)

Table 10.2 Theme: reflective skills

Wrong components: had to go back, change model (P1)
Deleted first attempt: started using the 'track' wheels (P6)
Won't be able to meet up with deadline: using backup plans: very demanding (P8)
After building for two hours: more familiar with controls and functions: became easier: enjoyed it (P6)
Finally managed, get components: build structure (P7)
Start all over again: building design was not coming right (P8)
Learned: putting knowledge & skill into designing of robots (P8)
Brick library difficult: had to study it to become familiar with every function (P9)
Reflect: very interesting: see my thought process, the progress of the robot to the final product (P6)

Furthermore, as is clear from the quotation below, students felt the need to take charge of their own learning.

> More practice is what I should do so that I can familiarize myself with other components. (P2).

This quotation emphasizes the importance of SDL as well as the student's engagement with the multimodal environment. The concept of SDL relates specifically to a dynamic process where students take responsibility for their own learning on their own or with the aid of others; by determining their own set goals and by identifying, and selecting resources that can be either material or relevant to others; then selecting and applying relevant learning strategies, and evaluating goals set by themselves (Knowles 1975). Furthermore, the responses also emphasize the importance of critical thinking (Garrison 1997; Gibbons 2002) and problem-solving (Guglielmino and Guglielmino 2001; Havenga 2016) in this context, and literature has shown that

Table 10.3 Theme: Active involvement in online robot simulations

Go cautiously: find parts I had to assemble with each other (P4)
Alignment on building mode: affect how components should be placed (P10)
Place components, change their direction, left, right, upward, downwards (P10)
Turned robot around: zoomed in and out: could see better (P6)
Look for correct parts: wheel with correct rim (P6)
Build truck robot: lift light and middle weight objects (P7)
Build robot: track a single source of light (P9)
Rotate components: fit together (P1)
Robot needs to sit on a base: connecting blocks in a particular way (P10)
Get some height: make arms for the robot (P6)
Fix problems, set the structure I wanted (P7)
Use different logs to build war robot (P8)
Put blocks using specific angle: have to redo as the angle was not correct, blocks were not aligned (P10)
Robot designed: change directions (left, right, forward, backward): using light sensor (P9)
Robot: two motors connected to rim, tyres: 3rd wheel balance, prevent from tilting backwards (P9)

these two elements can contribute towards fostering SDL. The following quotations are relevant in this regard:

> …when learners are taught robotics they will become creative thinkers and they will learn problem-solving techniques. (P1).

> I also enjoyed how it triggered my critical thinking. I also enjoyed how it triggered my problem-solving skills. (P9).

The data also showed the prominence of reflective practices for the students within this context. The importance of reflectivity in terms of SDL is also evident from the literature (Abdolhosseinzadeh Amini and Kruger 2022; Lee and Mori 2021). From the data, it was clear that the students had to constantly reflect and sometimes change their approaches to successfully solve problems they encountered. The following quotation is an example of how the students approached the process.

> I just took a break to really think of a way that I can solve this issue of not finding the correct parts. (P4).

Only through this reflective process could students identify problems and plan their further actions in the process of working within the different parts of the multi-modal environment. Clearly, reflective skills are essential for learning about robotics, especially within this mode of delivery. Moreover, Straková and Cimermanová (2018) note the affordances of reflective skills for student teachers specifically in virtual learning environments and how these can be actively developed.

One of the students also noted how after struggling to start, they considered their immediate context:

> What finally helped me to think out of the box was then to think about my own school (school around my community), thinking about what the school is lacking, or things that can be done to get certain work done without doing it in a long way. (P7).

This quotation emphasizes the affordances of drawing from authentic contexts and resources. It is significant that in terms of SDL, the importance of authentic contexts (De Beer and Gravett 2016; Sutiarj et al. 2018) and authentic problems (Havenga 2016) are noted in the literature. Hence, prompting students to address real-life problems can also be supportive of their learning process and their own self-direction.

Finally, the data also showed the importance of active involvement in the online simulation environment. Some of the students noted that they still required further skills to work effectively with this software. The following quotation illustrates this point:

> I realized that I do not have enough skills and knowledge to approach this subject or project of building robotics. I then decided to enroll myself in a short course on how to build a robot so that I can then acquire the knowledge and skills which I might need in the nearest future. (P8).

In this regard, it is also important to note that only through the acquisition of the necessary knowledge of the environment and the elements that make up the tools and processes would students be proficient in building and working with the robot.

Table 10.4 Theme: challenges and perceptions

Choose which robot to design, need to come up with your own robot: not easy at all (P10)
Software: not know where to start, unfamiliar: stress (P2)
GUI: unfriendly, functions disabled (P2)
Challenge: difficult to assemble parts of the robot (P4)
Struggle: few times: how to get block twisted (P6)
Technical knowledge was a difficult part in the design process (P8)
First encounter with LDD: did not know what to do, where to go, unaware to click on the (+) sign, show blocks, (-) to reduce the number of blocks (P10)
Challenging: lots of time trying to connect parts that cannot be connected (P10)
Time consuming: a lot of time putting it together (P8)

Consequently, from an interactional multimodality (Olivier 2020b) point of view, understanding the semiotics of not only the environment and its constituent tools but also the semantics of the programming language would be relevant.

In Table 10.4, a summary is provided regarding the challenges and experiences of students as well as the resources they used.

Table 10.4 highlights some of the challenges that participants experienced. Although a manual was made available, they still had some problems in building the robot.

In retrospect, students evaluated their experiences regarding the construction of a digital artifact. Table 10.5 shows some examples.

Apart from the manual that the lecturer made available to students on the eFundi platform, they also searched for additional open education resources to assist them, as indicated in this theme (Table 10.6).

The challenges experienced by students were also probed in the data collection. Several issues related to students getting to know the environment and using resources within the environment were expressed:

Table 10.5 Theme: evaluation of experiences

Reflection: experience not good: very difficult (P7)
Software: had to familiarize myself with the software, different functions (P9)
Reflect: really learned something new (P8)
Worst part: could not physically move the robot, play with it, hold end product (P6)
LDD cute program: definitely want to use it again in future (P6)
Final product: looks much better than was initially anticipated (P7)
Glad I have tried: can do much better in future: confident, engage with learners: robotics topics (P7)
Great experience: building a robot online was really awesome: first experience (P10)
Willing to learn more about robotics: gained some basic knowledge (P8)
Comprehension: assembling of robots, enhance learning inspiration (P3)
New world of digital & robots: make life easier: introduction robotics in school very interesting (P8)
Software: enjoyed flexible library icons, resize that was suitable for me (P9)
Encourages me to learn new things: always works out for me (P9)
3D design program: enhance learning experience: hands-on exercises (P3)

Table 10.6 Theme: resources

Search: videos to install software (P2), (P7)
YouTube, Internet (P4)
YouTube, Brick System Brother videos: very informative, helpful (P9)
Tutorial: videos support: zoom in/out, to rotate, build robot (P9)
After watching tutorial online: things got better: much easier to work with (P6)
YouTube tutorials: read how to connect two parts: got it right: parts move into each other more easily (P6), (P8)
Websites: hoping to do better with next opportunity: design robot online: make sure to study the websites, and know all features and technicality before starting with design (P8)

> The challenges I experienced were locating the components and locating the right components that would fit into each and every block in the area where we build, though it was locating the relevant blocks the problem came with knowing which blocks to use because there are so many blocks you won't know which ones fit where. (P1).
>
> …that since I do not know where to start, I find it difficult to know what to do because I am not familiar with the software and that stresses me a lot. (P2).
>
> I think that I can say my biggest challenge, was finding the right building materials (components). (P7).

Furthermore, it was noted that students found it difficult to find the software and that it was, according to them, not really user-friendly.

The student's evaluation of their experiences of LDD varied from being very positive to quite negative. Interestingly, one participant noted that it was unfortunate that the physical robot could not be built. It seems the learning curve in terms of the environment and its tools, as well as challenges within the environment, were sometimes experienced as being quite negative, while for some, the overall experience seemed to be more positive, as they learned new things and found it interesting. This aspect would possibly need further investigation as to why different views were prevalent. The following quotations illustrate the divergent views:

> The experience of creating the robot was not too good for me, I found it very difficult to create the robot. My planning on how I wanted to build the robot did not work for me. (P7).
>
> But I am glad I gave it a try, it makes me feel like I can do much better in the future, provided I put the skills into practice and I am confident that I can be able to engage with learners in topics such as robotics in the future. (P7).
>
> The experience I had when I was building my robot was really good, seeing how I can build anything I want online using Lego digital designer was really awesome and this was my first time experience. (P9).

As was noted earlier in terms of SDL, being able to select appropriate resources is an important skill for students. The data also reflected student practices in this regard. It is clear that students had to act proactively in finding additional support for installing and using the software. The following quotations show the student activities in this regard:

> I consulted YouTube and the internet to try to resolve this issue then I found some way yet other parts were not appearing on my software. (P4).

> I was able to get tutorials from the YouTube videos that I watched but unfortunately, there aren't enough videos to watch so that I can come up with some groundbreaking robotics in that instance. (P8).

Consequently, access to appropriate resources seems to be an important prerequisite for effective learning in this context.

10.5 Discussion and Recommendations

The following research question is addressed in this section: How can student teachers develop essential skills for the digital age through robotics simulations? A synthesis of the discussion of the findings is provided, and recommendations are made.

Although the Information Technology student teachers did not have previous knowledge about robotics and the design thereof in an online simulation environment (in this case, LDD), they developed essential skills when working on the robot task. Students were required to manage their own learning processes, take responsibility and be independent learners. For example, they had to learn the software environment, select appropriate resources, and make decisions in planning, designing and evaluating their efforts.

SDL abilities enabled some students to have more success than others. This finding is in line with the findings of Dolenc et al. (2014) which revealed that students displayed similar behavior through robotics activities. Dolenc et al. also found that the activities did not only promote self-direction; the students also seemed motivated. In agreement with Dolenc et al. (2014), it is recommended that teachers or mentors take on the role of facilitator and give students more responsibility in the learning process when engaging in robotics activities. In the literature (Kucuk and Sisman 2018), the importance of motivation in terms of learning robotics is also evident. In addition, the advantages of considering authentic problems also seemed to have a positive effect towards progress in the programming process as well as student SDL. Consequently, opportunities should be created for students to be able to draw on their own experiences, contexts and authentic needs prevalent in this regard.

This research explored the way student teachers develop essential skills for the digital age through robotics simulations. From the data analysis, it is clear that students experienced skills development, as was also the case in the research by Dolenc et al. (2014) and Hudson et al. (2020). In this regard, the student participants in this study identified elements of cognitive and SDL skills as being relevant. This finding also corroborates with the experience related in the research by Lück and Lareau (2016). Despite their narrow view of SDL, it was clear that through their students' interactions with robotics, SDL was promoted. As regards cognitive skills, it is essential to consider that programming requires higher-order cognitive skills, which, according to Yilmaz Ince and Koc (2021), can be supported through robotics in terms of computational thinking skills.

Hence, for future implementation of robotics in similar contexts, supporting cognitive and SDL skills would be recommended. Furthermore, the fostering of computational thinking skills could also—in line with the existing literature (cf. Yilmaz Ince and Koc 2021)—be recommended.

The importance of reflective skills was also evident, and this prompted changes in the way in which students approached their problem-solving. This aspect ties in with the view of Hudson et al. (2020) that learning by reflection is an effective strategy that can be employed within the context of robotics. Furthermore, the environment involved very specific technical skills and innovation through active involvement in online robot simulations on the part of students as they had to navigate their way through a novel environment. It is, therefore, recommended that robotics interventions and the use of such new environments be scaffolded and support be put in place. In this context, a differentiated approach would be useful, as students had varied experiences in this regard.

Useful themes were also derived in terms of students' challenges, experiences and resources used. In this regard, the experiences of students varied greatly, and they had very different needs. The varying levels of difficulty experienced by students in this study also mirrors the research findings of Hudson et al. (2020) which revealed that students reported experiencing programming robots as both easy and hard. However, overall, despite some negativity, most students enjoyed the experience. Students also acted in a very self-directed manner in terms of finding and utilizing additional resources to support their learning.

10.6 Limitations

Notwithstanding the valuable findings from this research, the researchers identified certain limitations. First, the conclusions made from this investigation are not generalizable and relate to a very specific context at a selected South African university and only pertain to a specific group of student teachers. Second, only a small number of participants gave informed consent for their data to be used, and this limited the number of student views that could be considered.

However, despite these issues, this chapter opens up further avenues for future investigation through which real-time student views and perceptions, the role of metacognition and the significance of computational thinking skills, among others, could be explored.

10.7 Conclusion

This chapter explored how student teachers' essential skills for the digital age could be developed through robotics simulations. This multimodal environment lent itself to a space where student teachers could act in a self-directed manner towards developing several skills. Problem-solving in this context relies on knowledge of the semiotic resources utilized in the robotics simulation environment, and certain cognitive and SDL skills, reflective practices as well as unique technical skills and innovation through active involvement in online robot simulations by the students. However, it is also clear that in addition to online resources that can be consulted, lecturers could also provide differentiated support through scaffolded interventions to aid student engagement specifically with the aim of enhancing teacher education for a digital age.

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