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SIMULATIONS FOR JUNIOR ENGINEERING AND TECHNOLOGY STUDENTS: TEACHERS' ABILITY TO USE DESIGN PROCESS TO PROMOTE PSYCHOMOTOR SKILLS

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Abstract
As an integral part of the 4th industrial revolution, simulation enables engineers and artisans to evaluate the effectiveness of the product before developing the final one. In South Africa, simulation is promoted to support students to develop artefacts that resemble the actual technological solutions. This study used a qualitative research approach and a case study design to explore teachers' ability to use design process to promote contemporary psychomotor skills. Four teachers were purposively sampled considering their experiences. Data was collected through questionnaire and semi-structured interviews and analysed against Maria's Simulation Model and the design process to some extent. The study revealed that teachers were aware of the advantages simulations have in equipping learners with psychomotor skills, however, they did not have means to support students to enact their creative and critical thinking skills. The study recommends a strong pedagogical expertise in dealing with simulations and the design process. Teachers should be conversant with various simulation models and implement them accordingly because technological design process provides effective platform for simulation.

Keywords: Simulation, Fourth industrial revolution, Design process, Technology

1.0 INTRODUCTION

The urgency to continuously prepare students for psychomotor skills which aligns with the Fourth Industrial Revolutions (4IR) is unmatched. The world is changing at a rapid rate due to technological influence that developed from industrialisation to 4IR. And so, simulation is an integral part of the 4IR phenomenon that is categorised by the application of specific technologies such as big data, augmented reality, horizontal or vertical integration, cloud, additive manufacturing, cybersecurity, advanced robotics, and internet of things [1]. By means of these tools, it is now conceivable to simulate business systems and manufacturing process by analysing system inputs and outputs in actual time and acquiring a detailed report about the process being examined. Kenett et al. [2] affirm that it is also possible to construct simulated physical models or animated models for almost any system and these models provide engineers with quantitative data about the effectiveness of the systems. Through simulations, engineers evaluate design alternatives to determine the better technological solutions and support the technological solution for durability, reliability, and safety.

The Department of Basic Education (DBE) in South Africa has introduced the Curriculum and Assessment Statement Policy Statement (CAPS), which promotes simulation as a teaching strategy that enables students to develop their psychomotor skills through real-life context [3]. Simulation is one of many assessment strategies used in the technology senior and further education and training phase to provide competency-based assessment of psychomotor skills. In other words, teachers use this strategy to develop learners' ability to manipulate technological problems and ultimately produce a working physical model that reflects real life scenarios. Although the growing importance of simulation in design is well documented in engineering studies and other fields [4, 5, 6], South African high schools' technology students understanding of this trend is less evident.

As a teaching tool, simulation engages students and allows for deliberate practice. Unlike learning with real artefacts, simulation enables teachers to control the environment and to meet the desired learning objectives [4]. Increasingly, engineering training programmes incorporate modelling and simulation as a teaching modality [5]. Although reports on the usefulness of simulation often focus on procedural skills, little data is presented to support improved educational outcomes [6].

Simulation enables designers to test whether design specifications are met by using virtual rather than physical experiments [5]. These further provide the designer with immediate feedback on design decisions. The use of simulation is also useful for teaching basic technology concepts in mechanical and electronic systems in countries such as United Kingdom, the USA, Canada and Australia [7]. South Africa has a low retention of beginner teachers in the teaching profession, especially those skilled in the use of simulation when teaching psychomotor skills [8]. This trend has serious implications for student outcomes, given the contribution that teachers can make to student achievement.

According to Ndlovu [9], a high school teacher training framework was developed to help teachers to maximise their efficient use of simulation in teaching and learning. Our teachers face many challenges due to a lack of knowledge, training and development, a shortage of resources and so on [4]. One or two, if not all these challenges have, no doubt, contributed to the lower level of simulation among students in classrooms. Govender [10] posit that it is possible that this neglect has contributed to the poor state of teaching and learning in the use of simulation. Unless these problems are addressed, the quality in the use of simulation will remain compromised [11].

Since the introduction of CAPS, technology teachers have been working to incorporate the use of simulation into their classrooms through design process known as "technological process". The reason is obvious, textbook and instructional resources have been the pillars of technology and engineering; however, they fall short in teaching students critical thinking skills and making rapid decisions accurately [12]. There is still a knowledge gap because of limited studies on the use of simulation in design projects [13].

Consequently, the purpose of this study was to understand teachers' knowledge on the importance of preparing students with psychomotor skills through simulation in the design process. We must remember that simulation enables students in technology and engineering subjects to develop cognitive skills such as analysis, synthesis, and evaluation. These skills empower students to determine technological solutions. Hence it was also important to understand technology teachers' perspectives about simulation. Thusly, beneath are the guiding research questions:

1. What is the importance of simulation skill in the design process during the preparation of psychomotor skills?
2. What are the technology teachers' experiences in developing students' psychomotor skills during simulations?

1.1 SOCIAL COGNITIVE THEORY

This study was framed by Bandura's [14] Social Cognitive Theory which describes how people acquire behavioural patterns. This includes the impact of the environment, human behaviour's capability, and their perceived self-efficacy. According to this theory, behavioural competencies, social competencies, and cognitive skills are acquired through observational learning [15]. This theory describes students as dynamic, information processing, problem solving and social organisms. The theory is founded on an agentic perspective operating through forethought, self-regulation and self-reflection as core features of human agency [16].

Bandura [14] proposes four sources of students' self-efficacy, namely: mastery experience, vicarious experience (observing other students and modelling), verbal persuasion, and emotional and physiological states. A mastery experience is considered to be the most influential source of self-efficacy because it provides authentic evidence that students have the ability to succeed in a simulation activity [17]. Self-efficacy beliefs are informed only when experienced events and the results of actions are cognitively appraised [14]. After students have completed a simulation activity, they quite naturally must interpret and evaluate the results obtained. They will then judge their competency according to their interpretations [18]. When students believe that their efforts have been successful, their confidence to successfully accomplish similar or related tasks in the future is increased. Alternatively, when they believe that their efforts have failed to produce the desired effect, the confidence to succeed in similar tasks is [18, 19, 20].

1.2 SIMULATION AND DESIGN PROCESS

The definition of simulation in the technology classroom has become difficult to understand for several reasons. There is no formal conceptual definition that has ever been agreed upon by experts in the field of technology education. Duke [20] defines it as a scientific discipline that is concerned with 'to simulate' or a conscious endeavour to reproduce the central characteristics of a system to understand, experiment with or to predict the behaviour of those systems. Miller [21] describes it as the duplication of the physical and functional characteristic of operational equipment within very tight tolerance specification. However, Gough et al. [22] describes simulation as a strategy that is meant to replace real life, while Badiee and Kaufman [23] explains simulation as a teaching method used for students' safety and a method of facilitating improvement in interdisciplinary communication.

Classroom simulation offers the possibility of enhancing the practicum by providing new opportunities for pre-service teachers to practice their skills. Jeffries [24] and Badiee [23] affirm that simulation is a simplified but accurate, valid and dynamic model of reality implemented as a system. Therefore, the design process in technology involves investigation-design-make-evaluate-communication (IDMEC).

Accordingly, CAPS states that "Investigation" entails a situation to gain information about a problem and context, "Design" concerned with understanding a problem and write a design brief needs to be written. "Make" provides opportunities for students to use tools, equipment and materials to develop a solution to the identified problem, need or opportunity. Students need to "Evaluate" the solutions and the process followed to arrive at the solutions. "Communication" enables students to assess evidence of the processes follow any given project, i.e. the ability to analyse, investigate, plan, design, draw, evaluate and communicate. Simulation could also be used to measure the competency level of the students and monitor their performance, i.e., the unit of participation in the simulation. Students are required to work individually, or as members of a team [25].

1.3 SIMULATION MODEL

According to Maria [26] there are stages of simulation design that are required for students' decision making and they include identifying a problem, formulation of a problem, collect and process real system data, formulate and develop a model, validate the model, document model for future use. As a result. Teachers should demonstrate total understanding of these stages because of their significance in developing learners' psychomotor skills. For instance, it is important to "identify a problem" for simulation and the problem should reflect immediate technological problems that could easily be solved by students [27]. The context problem should be sufficiently identified, and students must understand its fundamental questions clearly [28]. Real problems are those that generate enough dissatisfaction to justify that something should be done to reduce them [29].

Teachers should also assist students to "formulate the problem", that is, show students brainstorming skills, identify the end-users, and define performance measures. Once a student has determined that a problem exists, the problem must be clearly and concisely defined [27]. A student "collects and processes real system data" through the conversion of raw data to meaningful information through a simulation process [25]. At this stage, data is manipulated to produce results that lead to a solution [29]. This is followed by "formulation and development of a model" where students must develop diagrams of the model.

Once the students have a solution to the simulation problem, they should carefully examine (validate) the results to make sure that they make sense of them and check if the solution solves the problems that were identified. The last process would be to "document model for future use". A document model outlines the steps used to complete the model. It is internal, on-going documentation of the process while the occurring-documentation cares more about the 'how' of implementation than the 'what' of model impact [30]. Documenting a model helps students to identify the current state of the problem to know how they can improve it [29].

2.0 METHODOLOGY

A qualitative research approach with quantitative component was adopted in this study using a case study design. Qualitative research design studies people in their natural settings, attempting to make sense of or interpret phenomena in terms of the meanings that people bring to them [31]. He will studied teachers in their natural setting (i.e., classroom). This study purposively sampled four teachers to understand the use of simulation and its importance in the design process. Permission to conduct the study was obtained from the Tubatse Circuit authorities and questionnaires along with interviews were set up within the sampled schools. This was done in order to gain insight into the status quo of simulation and its effectiveness so as to inform remedial efforts. The relevant individuals at the schools were contacted personally to ensure their willingness to participate in the study and to gain consent from the participants.

To reiterate, data was collected through semi-structured interviews with open-ended questions. Open-ended interview questions were asked to four teachers to understand their knowledge and experience of the effective use of simulation. Open-ended questions were used to offer richer and corroborative response to the interview data [32]. Participants were provided with a full explanation of the study and informed that the interview would be audio recorded in order to document their responses to the questions. Interviews helped me to gain insight into the experiences and understanding of the classroom simulation of the participants. Interviews were conducted individually during normal school hours in a vacant classroom to avoid any disruption during the interview session.

The transcripts were analysed using against the simulation model and CAPS technology document [3]. The data from the audio recordings were transcribed in order to make sense of the participants' explanations, and additionally, to identify statements that related to the effective use of simulation in the design process. The finalised set of questions was used to structure the narrative and obtain the participants' views. Participants were identified as Peter, John, James, and Phillip.

3.0 RESULTS AND DISCUSSION

As indicated previously, this study was concerned with the importance of simulation in the design process and technology teachers' experiences in developing students' psychomotor skills on during simulations.

3.1 THE IMPORTANCE OF SIMULATIONS SKILLS IN THE DESIGN PROCESS

According to Maria [26], simulations are significant in a number of ways, however, if the aim is to equip students with psychomotor skills, teachers must display understanding of simulation skills. This includes helping students to identify a problem, formulate the problem, collecting, and processing real system data, formulating and developing a model, validating the model and documenting the model. These skills are crucial for students' decision making to create and analyse a prototype of the physical model and to predict its performance in the real world [26].

The following table (table 1) shows teachers responses with regards to their understanding on the significance of simulation skills in design process.

Table 1: Teachers' responses on simulation skills

Simulation skill for the development of psychomotor skills	**Teachers' responses in (%) frequency**		
	Agree	**Not sure**	**Disagree**
1. Are you able to assist students to identify a context-based problem before they commence with simulations?	100%	-	-
2. Where there are no problem scenarios, do you give students a chance to formulate their own technological problem?	50%	-	50%
3. Do you create opportunity for students to collect and process data that can be valuable for their simulation?	-	100%	-
4. Do you provide adequate and sufficient training sources for students to make physical models?	100%	-	-
5. Do you keep all evidence in a portfolio for the simulations they do?	100%	-	-

In reference to problem solving skill, all teachers agreed to equip learners with problem solving skills during design process. This finding corroborates with some teachers' utterances during interviews about their understanding of that the importance of problem-solving skills in a simulation, see excerpts below;

> "I think the use of simulation in a design process displays the creative mind of students. It gives them better, free, and critical thinking towards any task or project", (Peter).

"Students will be provided with an opportunity to use their mind critically", (John).

"Innovative process is also important in the use of simulation in a design process", (James).

"It improves reasoning skill of a student so that they can be able to identify and solve the problem", (Phillip).

Evidently, the teachers seemed to understand the importance of problem-solving skills in identifying simulation problems. Their statements explained the effect of students' problem-solving skills on identifying simulation problems. The responses also reveal what is needed for students to be able to identify a simulation problem, namely: students' creativity, reasoning skills, innovative thinking skills and critical thinking skills [3, 34]. Teachers should be aware that students need to be creative to be able to identify and solve problems [3].

Interestingly, the current CAPS in Technology allows teachers to allow student to exercise autonomy on the simulations they engage in. This is because technology advocate for creative and critical thinking skills. However, based on numerical results, about fifty percent of teachers were reluctant to give students a chance to formulate their own technological problem. Thusly, they limited learners a chance to enact their creative abilities [3, 34].

When looking at the creation of opportunities for students to collect and process data that can be valuable for their simulation, most teachers were unsure. This was testament to their interview responses where none of the participants mentioned how to involve system specifications, input variables and the performance levels of the existing system while motivating and encouraging students to collect data. We must remember that simulation model (collect and process real system data) involves the collection of data on system specifications, input variables, as well as the performance level of the existing system [6].

In accordance with simulation model, the collection process provides both the baseline from which to measure and a target of what to improve. Resultantly, Technology teachers should provide students with an opportunity to work collaboratively with others [3]. This will allow students to improve their performance. In addition, CAPS document for technology proclaims that students are required to collect and analyse information [3]. Maria [26] states that collecting, analysing and reporting information are also some of the aspects of the effective use of simulation. Data reveal that teachers did not ensure successful problem formulation in the use of simulation. Students needed to be given direction as far as simulation is concerned, see excerpt below; guide and monitor students' performance.

"I will administer students to define performance measures by measuring their effort or progress against a set performance standard", (Peter).

"I can encourage them to show and record everything used and done on paper", (John).

"I will give students a clear guideline about my expectations", (James).

"I will facilitate them to define performance measures", (Phillip).

It is therefore imperative for students to actively participate and for teachers to facilitate them in each learning activity [25].

The common practice for this subject, is that students need to firstly develop a diagram before they can make a physical model. That is why developing a diagram includes three fields: free hand sketches in the design stage, a working drawing in the making stage and artistic impressions in the communication stage [4]. Developing a diagram involves the type of diagram to use, how to use it and how to reason systematically in executing the relevant actions [26]. The participants claimed that they taught students how to develop a diagram that will solve the problem identified, see excerpt below;

"During the training session, I'll make sure that I give them thorough explanation and give them typical examples", (Peter).

"Sometimes I teach my students how to mind-map", (John).

"For now, I advise my students to use mind-mapping and then begin to address the issues

> "on the mind-mapping one after the other", (Phillip).

Indeed, mind-mapping is important for developing students' model solution because students can choose a solution that will contain all the details needed for making the product [4]. Mind-mapping enables students to list the specifications that will help them to develop a solution model. In this regard, Phillip and Peter stated;

> "Advise them to come up with different sketches and the list of some specifications", (Peter).

> "They will also write a design brief with specification which will help them to know the problem and how to solve the problem", (Phillip).

The ability to write a design brief teaches students to give the general outline of the problem to be solved, as well as the purpose of the proposed solutions [3]. Once students are able to write a specification, they should be able to define the problem, materials, end-users of the solution model and safety measures. However, the teachers seemed to understand that drawing skills are important in developing a model. For instance, Peter, John and James commented;

> "Students need to develop drawing skills. I will teach them on how to draw 3D", (Peter).

> "I will advise them to make a drawing in 3D using isometric projection", (John).

> "I will teach them how to present their ideas through drawing", (James).

These responses seem to indicate that the teachers understood that students should be provided with the skills to develop a solution. Drawing skills are necessary in developing a diagram for the model solution [26]. Students should be supported in building their self-efficacy beliefs through a vicarious experience of modelling.

Once, drawing designs are approved, students should engage with training resources to make a physical model, after which its performance will be evaluated. Students should compare the simulation's performance under known conditions with the performance of the real system [26]. Teachers should thus teach students to compare their model with the original one. The teachers acknowledged that there were students in their classrooms who lacked knowledge on comparing models, this is shown in the remarks of Peter, John, James and Phillip;

> "No, I don't think students are able to compare the model's performance with the original data because they lack the necessary knowledge, ideas, and skills to do that", (Peter).

> "No, they don't have knowledge and skills in drawing the original system. They need to know how to draw the original system, to be able to compare it with the model's performance", (John).

> "They lack knowledge on how to use the first step of design process, i.e., 'investigation' to gather information from the original data", (James).

> "My students get confused on how to compare the model's performance because they lack knowledge", (Phillip).

It is evident from the responses that the teachers had problems in getting their students to compare their model's performance with that of the original data. The teachers did, however, understand that there is a need to develop adequate knowledge and skills to ensure the effectiveness of validating a model. "Validating the model" is the fifth stage of Maria's [26] simulation model.

> "They need to be given a comprehensive workshop and training to be able to do that alone without assistance", (Peter).

Following teachers' responses on model's performance, it was necessary to follow-up on their latter statement as a means of allowing the participants to substantiate the way they supported students to validate the model correctly. Thus, they responded in this way;

> "I will seek for help and support from other teachers. Those teachers will tell them the areas where they are weak and give advice on how to improve it", (Peter).

> "Firstly, I will give students time to use their models to do the work the original model could do. This will help to list the areas that need improvement", (John).

"I will assist them to do demonstration in the classroom", (James).

"Let say I am doing the model of a table with my students, and then I will advise them to make different types of tables. They will use those in order to know the table that will solve the problem identified. This simply means that demonstration is very important", (Phillip).

Maria [26] states that testing and examining the model refers to ensuring that the simulation models are correct, complete, and consistent, as well as enhancing confidence in the models. From the responses, it emerged that most of the teachers were aware that demonstration is important for students to be able to discover the model that will solve the problem identified.

There was also a need to understand if teachers kept learners' evidence of the simulations they did in a portfolio. CAPS stipulates that during the design process, students are required to record and present their progress in written and graphical forms on an on-going basis [3]. While investigating the problem, students should also be encouraged to take notes of whatever information they have gathered. This will then be kept by teachers as evidence to the quality assurers like subject advisors and moderators. Data from table 1 indicate that all teachers kept competency-based assessment evidence. Also, teachers acknowledged that they guided students, but that it was not easy to identify strategies that are relevant to recording details of the model. It seems that the participants found it difficult to encourage students to record details of the models for future use.

3.2 TECHNOLOGY TEACHERS' EXPERIENCES IN DEVELOPING STUDENTS' PSYCHOMOTOR SKILLS DURING SIMULATIONS

To understand teachers' experiences, this study categorised the experience in the following way;

- Personal experiences in developing a model that will solve a simulation problem.
- Experience in assisting students in formulating and developing a simulation model.
- Developing students' knowledge in identifying a simulation problem
- Use simulation in the design process

With regards to personal experience, teachers indicated that they are overwhelmed by the process of assisting students to develop a model, see extract below;

"I am still using traditional way of teaching because my students are performing poorly. CAPS require various skills to be used to enabled students to develop a solution model, but I don't see those skills helping my students to develop a model, so I do a lot of work for them", (Phillip).

Le Roux and Steyn [33] detest this practice by stating that teachers should understand that every student should be given a role to play. Pertaining to assisting students in formulating and developing a simulation model, teachers displayed a challenge. Teachers felt that even though they have training equipment, they are not enough to cater for all learning needs of the students and compromise of the provision of psychomotor skills. Also, overcrowding proved to be a long-standing challenge for the teachers, see excerpt below;

"I am unable to check students' work individually because the classroom is overcrowded. For this reason, students are performing poorly", (John).

The above remarks highlight a lack of space for practical as one of the challenges in assisting students to develop a simulation model. It is evident from the response that the conditions for classroom simulations are not conducive to the positive effects of teaching. Moreover, overcrowding has implications for health precautions. Interestingly, teachers seemed to acknowledge that their frustrations and stresses in developing a model were the result of a lack of knowledge, see extract below;

"You cannot provide students with a skill to develop a model if you lack knowledge in developing a model. There is no senior education specialist to train us on how to develop students' skills in developing a model", (Peter).

"There is no adequate knowledge to assist students in developing a model. There are no subject advisors to visit our schools and assist us to improve the results", (John).

"I am not trained on how to teach simulation; as such I lack more knowledge on how to teach students. No workshop on how to teach simulation. As such, I am not sure whether I am doing the correct things or not because there are no government officials to moderate my work", (James).

It is evident from the responses that the teachers had problems, which resulted in students' poor results. It seems that the teachers were aware that there is a need for training and workshop to improve students' performance. The teachers were also of the opinion that more time should be allocated to the use of simulation to improve students' performance in developing a model.

In reference to developing students' knowledge in identifying a simulation problem, teachers seemed unsure about this. These findings match with the responses on the table 1 looking at the same phenomenon. Identifying the problem is the beginning of every problem-solving scenario [26]. Therefore, the accuracy of problem identification greatly affects the acceptability and credibility of the simulation's results [34]. Thus, it is disappointing that teachers were not certain about developing students' knowledge of formulating a simulation problem. The following extract are testament to this;

"My students think that a teacher had to do everything for them in the classroom. I don't see any development with CAPS because it is student-centred", (Peter).

"Changing from teacher-centred to student-centred is not easy. My students are not doing well. They don't participate actively in identifying the simulation problem", (John).

"They think is good for teachers to prepare notes for them. My students are happy if the chalkboard is full of notes", (James).

"They think is the teachers' responsibility to give everything in the classroom", (Phillip).

On the use of simulation in the design process, teachers were aware that it is important to understand the simulation problem and the knowledge of the design process, see evidence below;

"Firstly, I explain the importance of the design process. I'll explain the design process one by one", (Peter).

"Students should know the problem first. Knowing the problem will enable them to know the cause of the problem", (John).

"I think it is very important to assist students on how to get the problem first. Students can never solve the problem if they don't know how to get the problem and where the problem derived from", (James).

The design process is a fundamental technique used in technology to solve simulation problems [35]. Teachers' response indicate that the concept of 'explanation' is essential as teachers should be able to explain the design process thoroughly. As the students' progress through their simulation activity, they must be taught how to associate knowledge and skills to design and create a problem solution [3]. From the participants' responses, it appears that the teachers used the same approach when teaching students how to identify the problem.

4.0 CONCLUSION

One of the 4IR components that must be included in our curriculum, especially in technology and engineering subjects, is simulation. Technology teachers owe it to their students to embrace simulation and assist in the development of psychomotor skills using realistic models. Instead of studying simulation, students should develop their own models. According to Bandura, simulation fosters self-efficacy. This study emphasizes the need for teachers to identify appropriate problem situations in order to enhance students' psychomotor skills even if they are aware of what to expect from students through the use of simulation. When students believe that their efforts have been successful, their confidence to successfully accomplish the task is raised. However, if the students are unable to identify the end-users of a simulation model, then they will not be able to present the solution effectively.

It is important that technology teachers possess the knowledge and abilities necessary to effectively employ simulation. Students should be taught how to recognize and state a problem, gather data, construct a model, validate the model, and record the model for later use. Teachers should not be the exclusive source of guidance or motivation for their students; instead, they should encourage them through the use of rewards and incentives to encourage active participation in the classroom simulation. The design process offers teachers the ideal platform to help students enhance their simulation abilities. Teachers' positive perception towards supporting students to succeed in simulation is rather imperative. If students are not supported to participate actively the fourth industrial revolution, then Africa is likely to continue to lag in terms of knowledge and skills development.

5.0 LIMITATIONS AND RECOMMENDATIONS

The participants emphasized that there are no resources to encourage simulations, which was a drawback of the study due to the congested nature of the sampled schools. The researchers were unable to make any observations due to a lack of resources. Future research is advised to look at simulation carried out in a well-designated classroom with all essential tools and resources, as well as the degree to which schools adopt the 4IR.

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