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Evaluating the efficacy of simulation-based education in improving blood pressure measurement accuracy among pre-specialised clinical technology students

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ABSTRACT

This study explored whether simulation-based education (SBE) could improve the blood pressure (BP) measurement accuracy of first-year clinical technology students. This study was underpinned by constructivist learning theory, which emphasises that learners actively build knowledge through experience and reflection, particularly in realistic and context-rich environments. The study retrospectively examined data from 51 first-year students. Initially, students were taught using conventional training methods such as lectures and tutorials. The same students were then exposed to a one-hour simulation session. After the traditional and simulation sessions, the accuracy of the students' blood pressure measurements was assessed using a high-fidelity simulation manikin. BP readings measured within ±5 mm Hg of the preset BP were deemed accurate. The McNemar test ($p < 0.05$) was used to compare results before and after the simulation sessions. Before the SBE session, accuracy for systolic, diastolic, and combined BP measurements was 17.6%, 21.6%, and 3.9%, respectively. After the SBE session, accuracy improved to 45.1% for systolic, 37.3% for diastolic, and 19.6% for combined readings. These improvements suggest that SBE had a positive impact on students' measurement accuracy of non-invasive BP. The results indicate that incorporating SBE into clinical technology student training may strengthen practical skills and improve readiness for clinical placements. The study further highlights the benefits of simulation through empirical evidence by contributing to the growing body of scholarship on SBE. By offering a hands-on addition to theory-heavy methods, SBE appears to help students bridge the gap between theory and clinical practice—something traditional approaches may not always achieve.

Keywords: Blood pressure measurement, Simulation-Based Education, Clinical skills, Healthcare training, Work-Integrated Learning.

INTRODUCTION

Accurate blood pressure measurement is critical for healthcare professionals, as it is essential for diagnosing and managing hypertension. Approximately 1.28 billion people between the ages of 30 and 79 globally suffer from hypertension, with the majority (two-thirds) residing in low- and middle-

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income nations.[1] Auscultatory blood pressure measurements are the gold standard when evaluating blood pressure. However, this method of blood pressure measurement requires precise identification of Korotkoff sounds, which can be challenging for students entering clinical practice without proper exposure and experience.[2] The inability to measure blood pressure correctly may lead to misdiagnoses, which emphasises the need for effective training.[3]

Training methods for measuring blood pressure, such as lectures and practical demonstrations, formed part of the traditional training methods of clinical technology students. Research indicated that these traditional training methods often fail to bridge the gap between theoretical knowledge and practical application.[4] Simulation-based education (SBE), on the other hand, offers a controlled environment for experiential learning (EL), enabling inexperienced students to acquire and refine clinical skills through hands-on practice.[5]

This study specifically focused on pre-specialised clinical technology students at a South African University of Technology (SAUoT), where accurate blood pressure measurement is an assessed core competency. SBE had only recently been introduced into the clinical technology curriculum, and this training method's effectiveness in improving the accuracy of blood pressure measurement had not been fully explored. This research aimed to evaluate the impact of SBE on students' ability to measure blood pressure accurately.

LITERATURE REVIEW

Constructivist Learning Theory

Constructivism as a learning theory has proven to successfully bridge the gap between theory and practice. Constructivist learning theory (CLT) not only promotes a scaffolded approach to learning but also problem-solving through critical thinking, which in turn assists with the development of essential skills. Learners are encouraged to actively engage with the learning material and the practical application of these required skills. Through this active participation during their training, students learn how to apply theoretical knowledge to real-world scenarios.[6]

Constructivism is defined as a learning theory and described as a philosophy through which learners enhance their knowledge and skills using a process of construction that is linked to experiences and interaction.[7] The key principles that form the basis of constructivism have their roots embedded in the work of Piaget, Vygotsky, and Bruner. Piaget demonstrated that students are more inclined to assimilate knowledge and skills through active participation than passive observation. Vygotsky, on the other hand, emphasised that positive social interaction among students, peers, and teachers is essential during the learning process. Bruner continued to build on the foundational work of Vygotsky and highlighted that not only the role of the teacher but also the language and mode of instruction will influence the learner's ability to assimilate and construct knowledge.[8]

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The key principles of the CLT may be linked to a learning modality such as SBE through overlapping concepts such as "*reflection*", "*experience*", and "*experimentation*".[9] Constructivism, therefore, as a learning theory, supports SBE, and through its application, students are guided by facilitators during the learning process. Although guided by facilitators, learning is self-directed, with reflection encouraged through structured debriefing sessions. This facilitated and organised learning experience not only promotes critical thinking but also self-awareness.[10] Through these characteristics and practices, SBE lends itself to and clearly demonstrates an affinity for constructivism. CLT not only underpins the interactive and contextual nature of SBE but also the collaborative student engagement and scaffolding associated with this instructional method.[11]

EL, as a theory within the broader philosophy of constructivism, provides insight into "*how*" students learn through constructivism. Both theories require active participation from the students, and EL specifically provides students with an opportunity to be immersed in an experience and directly reflect on their experience.[12] As with constructivism, SBE and its associated characteristics, for example, provision of a concrete experience and debriefing, form a symbiotic relationship with EL and demonstrate how this teaching modality is structured within the four stages of Kolb's EL cycle.[13]

Research explicitly indicates that, through the cyclic nature of Kolb's learning process and by allowing students to "*have an experience*", "*reflect on the experience*", "*learn from the experience*", and finally to adjust and "*implement what they have learnt",* the practical application of simulation in this cycle allows students to establish connections between theory and practice. The physical exposure to an "*experience*", and in the case of simulation, exposure to a realistic scenario, allows the student to strengthen foundational knowledge and implement future learning on a solid foundation.[14]

Traditional Training

Healthcare students in the early 21st century mostly received training through information sessions and practical evaluations. The informative sessions may consist of formal lectures, instructional videos, and practical demonstrations. Occasionally, pupils were also permitted to engage in the required clinical procedure alongside their peers for the sake of experience. In certain programmes, students received instruction through mentorships, in which they physically acquired the necessary skill by practising on a patient under the supervision and guidance of an instructor.[15] This teaching method is usually referred to as the "*see one, do one, teach one*" method and has been validated as a positive teaching method through a process of mentorship and peer-assisted learning, where the student actively participates in the learning process. Unfortunately, in large cohorts of students, mentorship is not always possible due to the one-on-one teacher-student interaction the teaching method requires. In addition, patient safety is also compromised, which raises additional ethical concerns.[16] The theoretical gap between the "*see one*" tier and the "*do one*" tier also needs to be bridged, and this is where simulation has proven to not only assist with overcoming the gap but also promote patient safety. Teaching through simulation has

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proven to enhance skills on both formative and summative platforms.[17] Additional studies confirm that the traditional method of training students in non-invasive BP measurement techniques primarily consisted of formal lectures, supplementary information offered through textbooks, and training videos.[18] A similar training strategy was also the preferred training method for pre-specialised clinical technology students at a local SAUoT.[19]

Simulation-Based Education

Clinical simulation, often also referred to as SBE, encompasses multiple definitions. Generally, the term refers to an instructional method that enables healthcare students to learn, acquire, and practise clinical skills in a setting that closely reflects a real-life situation or clinical environment.[20] It has been widely reported that SBE plays a vital role in the teaching and learning of healthcare students before they enter a real clinical environment.[21] Key educational concepts such as EL, enhanced confidence, improved grasp of abstract concepts, and, most importantly, clinical skill acquisition in the healthcare setting are among the benefits of SBE.[22]

EL, as mentioned rooted in the work of Piaget and aligned with constructivist concepts from Vygotsky, and is an educational philosophy that enables students to actively construct knowledge through experience. Similar to constructivism, EL allows learners to practically apply their theoretical knowledge to real-world situations.[23] The concept of EL is not new in the clinical technology environment, but it is primarily aimed at students specialising in a specific field rather than pre-specialised students.[24] The effect of not being exposed to a clinical environment during their pre-specialised phase of learning resulted in a gap between the theory taught and the ability to perform basic clinical skills.[25] Similar results were observed in other professions, where traditional teaching methods alone did not provide students with the opportunity to think critically and apply theoretical knowledge. SBE, in contrast to previous training methods, demonstrated that it provided these students with the ability to become custodians of their own learning and access learning strategies that they would not traditionally have been exposed to.[26]

Recent research investigating the overall effectiveness of SBE in medical education confirms that this teaching modality positively influences the acquisition and retention of clinical skills when compared to traditional training methods.[27] The ability to acquire new skills also proved to have a positive psychological effect on students. Enhanced confidence through the application of SBE not

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only affects clinical judgement, patient communication, and teamwork but also the performance of clinical tasks. Confidence when performing a newly acquired skill resulted in improved quality of patient care. The effects of this enhanced confidence are exponential and not only influence the ability of the student to perform the clinical procedure but also to trust the information and process.[28]

A meta-analysis found that SBE has an overall positive effect, particularly on skill performance among healthcare professionals. However, the research mainly reported on skill performance in general and primarily focused on nursing students. Information on specific basic skills, such as BP measurement through auscultation, among allied healthcare workers is lacking.[29] This highlights the need for data in an allied healthcare cohort, such as clinical technology.

Research conducted on second-year medical students, however, did show a considerable enhancement in their clinical ability and proficiency in basic skills, such as measuring BP via auscultation. The results of this study are surprisingly not new, particularly in healthcare education systems where SBE is already strongly embedded in the curriculum.[30] Noteworthy findings from research conducted among undergraduate nursing students indicated that even as little as one hour of simulation-based training, in addition to the standard curriculum, significantly improved the students' ability to measure blood pressure accurately.[31]

The question remains whether these acquired skills through SBE are transferable to the clinical environment. Research conducted among preregistered nursing students found that there was an enhanced level of confidence among the participants before engaging in a 40-hour clinical practice rotation. This clinical practice rotation would be very similar to the work integrated learning (WIL) of clinical technology students. The researchers in this study concluded that an extra two hours of tuition through clinical simulation did not enhance the students' ability to accurately measure BP. However, the accuracy of both the control group and the interventional group in the specific study was not assessed before the 40-hour clinical practice but only at the conclusion of the clinical practice rotation. The study also did not report on the exposure the students might have received to BP measurements during their practical rotation. [32]

Key competencies associated with proper and accurate BP measurements may be taught through different teaching modalities; for example, the use of a simulated part-task trainer may be sufficient to expose students to the clinical skill, whereas patient communication may be best suited to be trained through a simulated patient.[33] This research followed the same methodology as similar studies by using a high-fidelity simulation manikin to test how accurately pre-specialised clinical technology students can measure blood pressure by auscultation before and after a clinical simulation session.[34]

METHODOLOGY

Study Design

A retrospective study design was employed to analyse blood pressure measurement accuracy among first-year clinical technology students before and after a single SBE session. The study utilised pre-existing assessment data collected during the students' first year of training. The study was underpinned by constructivist and EL philosophies.

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Participants

Participants included 51 first-year "*clinically naïve*" students enrolled for a specific instrumentation and practical module at the SAUoT. Inclusion criteria included students who completed both traditional and simulation-based training sessions. Exclusion criteria eliminated data from students repeating the module, with prior blood pressure measurement experience, or those not enrolled in the clinical technology programme.

Procedure

Participants underwent traditional blood pressure measurement training, including theoretical lectures and a tutorial video. Subsequently, the learners were exposed to a one-hour SBE session using a high-fidelity manikin. To conduct the research, the same high-fidelity manikin's blood pressure was preset to one of four randomised values (140/90 mm Hg, 100/60 mm Hg, 130/80 mm Hg, or 120/70 mm Hg). Preset blood pressure values were randomised using a simple randomiser generator. Students measured blood pressure on the high-fidelity manikin after the traditional training and again after the SBE session. The blood pressure measurement collected after the traditional training session was captured as the baseline.

Data Collection

Blood pressure measurements were taken using a high-fidelity simulation manikin with four randomised values. Two sets of measurements were collected from students: one after traditional training and another after the SBE session. Students used an institutional rubric to record the values, and the rubrics were anonymised for data collection. Measurements were considered accurate if they were within ±5 mm Hg of the predetermined systolic and diastolic values. Baseline blood pressure readings were taken after traditional training on the same manikin and compared to post-SBE measurements.

Statistical Analysis

Statistical analysis was conducted using Python (version 3.x) with the Statsmodels library (version 0.13.x). The McNemar test was applied to evaluate differences in measurement accuracy between traditional and SBE methods. Statistical significance was set at $p < 0.05$.

Ethical Approval

Ethical approval for the study was obtained from the University of Technology Institutional Planning and Quality Enhancement (IPQE) Committee, where the students were registered for the qualification of Clinical Technology. Special precautions were taken to ensure that no student was identified through their assessment rubrics by allocating each student a participant number. Ethical approval was applied for and granted by the Health Sciences Research Ethics (HSREC) Committee at the University of the Free State (UFS-HSD2024/2217).

As the study involved a retrospective review of pre-existing assessment data collected as part of routine module requirements, no direct interaction with students occurred, and no identifiable personal information was accessed. The HSREC, therefore, granted a waiver of individual informed consent. Module enrolment was mandatory as part of the curriculum and was unrelated to the research; consequently, the concept of voluntary participation did not apply, as students were not recruited into the study.

RESULTS/FINDINGS

Baseline Accuracy

The effectiveness of SBE was evaluated by comparing blood pressure measurement accuracy assessed post-traditional training to blood pressure measurement accuracy assessed post-SBE among clinical technology students (N = 51). The analysis examined three key competencies: systolic pressure measurement, diastolic pressure measurement, and accurate measurement of both pressures.

Following traditional training, baseline accuracy rates were established: 17.6% (9/51) for systolic pressure, 21.6% (11/51) for diastolic pressure, and 3.9% (2/51) for both measurements combined. Post-simulation training, these rates improved to 45.1% (23/51), 37.3% (19/51), and 19.6% (10/51), respectively.

The differences between the pre-training and post-training measurements indicate a relative improvement at 156% for systolic measurements, 73% for diastolic measurements, and 402% for combined accuracy, demonstrating that SBE resulted in significant improvement in competency, especially where initial competency was low.

The marked increase across all three BP measurements suggests that students benefited from the exposure to SBE with its incorporated pedagogical methods, such as immersing students in a realistic experience and purposeful reflection. These methods may reinforce both the procedural and cognitive aspects of accurate BP measurement.

Statistical Analysis

The McNemar test was used to evaluate the differences in measurement accuracy between traditional and SBE methods. For systolic pressure, the test revealed a significant difference (χ^2=7.0, p=0.013), indicating that SBE significantly improved accuracy. For diastolic pressure, no significant difference was observed (χ^2=9.0, p=0.169). However, for the measurement of both pressures, a significant difference was found (χ^2=0.0, p=0.008), suggesting that SBE was more effective in improving accuracy for both measurements.

Irrespective of the non-statistically significant improvement related to the diastolic BP measurements, the upwards trends in accuracy for the specific measurement suggest that with extended or repeated SBE exposure, measurable improvements may possibly be noted. In addition, the difference noted between systolic and diastolic measurements may also demonstrate the perceptual difficulty in identifying certain Korotkoff sounds.

The comparative accuracy rates between traditional and SBE methods demonstrated improved accuracy across all three measurement categories. Notable improvements in accuracy were observed, particularly in systolic blood pressure measurement and combined measurement accuracy, as illustrated in Figure 1 below.

The mentioned results collectively indicate that the incorporation of SBE as part of the training strategy for accurate BP measurement was superior to traditional training alone, assisting novice learners to achieve acceptable clinical competence in an important clinical skill such as BP measurement.

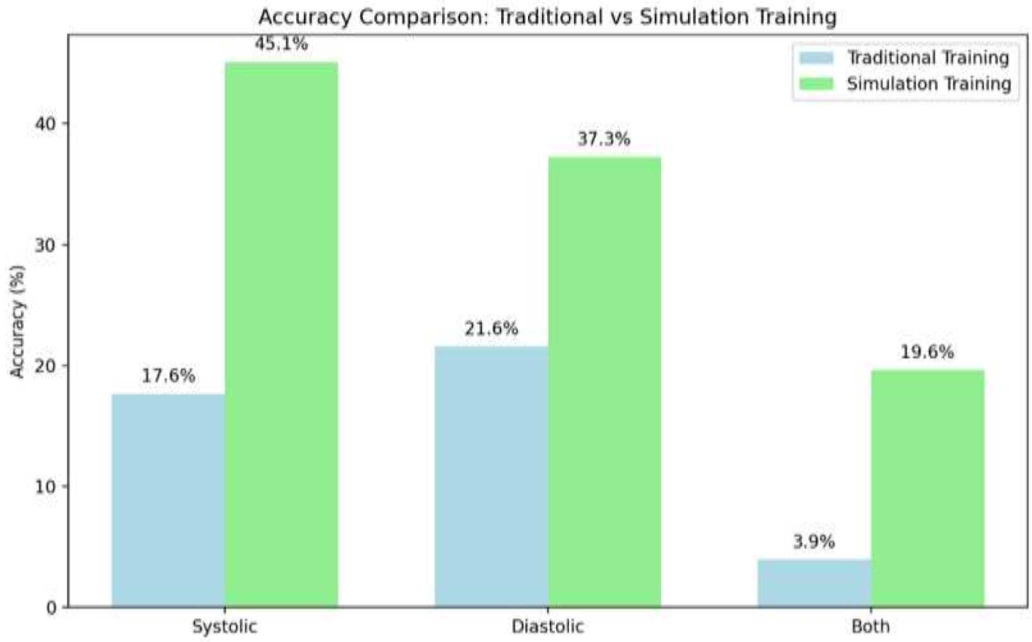

Figure 1: Blood Pressure measurement Accuracy Comparison: Traditional versus Simulation-Based training.

DISCUSSION

Simulation-Based Education: Bridging the Gap

These findings suggest that SBE may be particularly effective in improving students' ability to measure systolic blood pressure accurately. The significant improvement in combined measurement accuracy (both systolic and diastolic) indicates that simulation training may enhance overall blood pressure measurement competency. The non-significant improvement in diastolic measurement accuracy warrants further investigation and may indicate a need for refined training protocols specifically targeting diastolic pressure measurement techniques.

A possible explanation for the significant improvement in systolic BP measurement versus the non-significant improvement in diastolic BP measurement may lie in the fact that the first Korotkoff sound is identified as an audible sound generated by the turbulent flow of blood through the arm when the pressure in the BP cuff is the same as the pressure generated by the heart. In contrast, the fourth and fifth Korotkoff sounds representing the diastolic BP measurement are described as a decreasing and/or absent sound becoming less audible as the pressure in the BP cuff drops below the diastolic pressure. The difference between the two Korotkoff sounds may have the resultant effect of the first Korotkoff sound being more distinct and easier to hear by a novice than the last Korotkoff sounds. [35] Prolonged exposure to SBE specifically targeting the acoustic features of BP measurement may result in the ability of students to significantly differentiate between the various Korotkoff sounds.

These results have important implications for healthcare training, suggesting that the incorporation of SBE could substantially improve clinical students' blood pressure measurement skills. SBE effectively addressed the limitations of traditional training by providing a realistic environment for skill acquisition. The observed improvements in blood pressure measurement accuracy underscore the potential of SBE to enhance allied healthcare students' training, as reported in similar research.[36] By aligning SBE with the constructivist learning theory principles, this teaching method and its environment allow students to implement theoretical concepts in practical exposure, promoting a deeper understanding of the required clinical skill.

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The current findings of the research contribute to the growing body of scholarship supporting SBE as an evidence-based teaching modality, developing necessary skills in clinically naïve students. By focusing on first-year clinical technology students, the study furthermore adds value to a population for whom minimal SBE research exists, expanding the knowledge base of how the exposure and immersion of clinical technology students to SBE may positively influence clinical competencies.

RECOMMENDATIONS

This study highlights the importance of integrating SBE into health training programmes such as clinical technology. By fostering accuracy and confidence, SBE better prepares students for real-world clinical challenges found in clinical environments. It is therefore recommended that SBE be fully incorporated into healthcare students' curricula, such as clinical technology.

To maximise SBE's impact, the clinical technology program should consider embedding simulation throughout the clinical technology curriculum rather than limiting it to specific training sessions. Constant and regular simulation opportunities may not only reinforce psychomotor skills but also assist in reducing skill decay in senior students, ensuring that students across all year groups maintain clinically acceptable levels of competency.

The reflective component and nature of SBE enhance clinical reasoning and consolidate procedural learning, and it is therefore recommended that clinical educators deliberately include structured debriefing sessions as part of the learning process.

Upon the opportunity to restructure the clinical curriculum, a blended learning model should be considered by incorporating simulation, deliberate practice, and continuous competency evaluation to ensure sustainable skill development.

A final recommendation would suggest additional research to further provide insight into the unique cohort of students to determine optimal frequency, duration, and fidelity levels of simulation to ensure positive learning experiences for students in all required clinical learning modules.

CONCLUSION

The integration of SBE significantly improved blood pressure measurement accuracy among pre-specialised clinical technology students. These findings support incorporating SBE into training programmes to enhance students' readiness for WIL and clinical practice. The improved accuracy of BP measurements across systolic, diastolic, and combined values demonstrates that simulation serves as an effective bridge between theoretical concepts and required clinical skills. By providing novice students with the opportunity to practice clinical skills in a safe and controlled environment, these learners are permitted to repeatedly practice clinical tasks without compromising patient safety. The study's contribution to the study of simulation scholarship is evidently demonstrated through the positive competency outcome in inexperienced students, even when exposed to SBE in short but focused sessions. Overall, the findings underscore the value of incorporating deliberate and structured simulation sessions early in the training of healthcare students to not only strengthen foundational skills but also enhance these students' preparedness for the clinical environment.

LIMITATIONS

The retrospective design of the study does result in inherited factors that may influence the outcome of the study due to the inability of the researcher to control outside factors, the difference in how both instructional methods were offered, and the motivation of the students. In addition, the small sample size may influence the study's statistical power and further limit the generalizability of the findings. Future research should incorporate multiple institutions and explore the long-term effects of SBE in a larger, randomised research population.

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