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Reflections of a physical science teacher on the philosophical perspectives underpinning the use of computer simulations in a rural South African school

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ABSTRACT

Research consistently demonstrates that computer simulations play a transformative role in teaching and learning in various educational contexts worldwide. These learning tools provide interactive and dynamic environments that individualize learning through the various affordances inherent in their use. Numerous studies have employed various theoretical frameworks, including constructivist, cognitive, and behavioural approaches, to support the integration of simulations into educational practices. However, the discourse often overlooks the philosophical perspectives that inform and shape their use. This article presents insights derived from a study, emphasising the epistemological, ontological, and axiological dimensions that have guided the use of digital technology in a rural school. Adopting a qualitative case study methodology, data were collected through teacher reflective journals and learner focus groups over three years. Findings reveal that computer simulations not only reshape how learners acquire and construct knowledge (epistemology) but they also transform traditional learning environments by merging virtual and physical realities, creating innovative, *elastic* spaces for interaction and exploration (ontology). From an axiological perspective, simulations raise critical questions about the values embedded in teaching practices. The study highlights that recognizing these philosophical perspectives enhances the effective implementation and outcomes of computer simulations in rural classes. However, the study is limited by its single-site design and focus on a single rural context, which may limit the generalizability of the findings. This research contributes to the broader field of computer simulation-based teaching by foregrounding philosophical perspectives and promoting a more intentional, values-aware approach to simulation-enhanced learning.

Keywords: Computer simulations, Epistemology, Ontology, Axiology, Teaching, Learning.

INTRODUCTION

The integration of computer simulations as curriculum materials to leverage teaching and learning in physical sciences creates an educational renaissance.[1] The greatest beneficiaries are, in fact, the schools in rural areas that have been plagued by challenges that threaten the schooling of learners in rural communities for a long time. Research is consistent that computer simulations have a positive impact on

[1] Maria Develaki, "Methodology and Epistemology of Computer Simulations and Implications for Science Education," *Journal of Science Education and Technology* 28, no. 4 (2019): 353–70.

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classroom practices that lead to meaningful learning of science.[2] Meaningful learning occurs when learners engage in authentic practices that are active, intentional, reflective, relational, and emotionally engaging.[3] Although research has consistently highlighted the benefits of using computer simulations in teaching and learning, it has remained largely silent on the philosophical foundations underpinning their use.[4] Philosophical perspectives shape a teacher's stance on teaching and learning, influencing how technology is integrated into pedagogical practice.[5] Therefore, understanding the philosophical perspectives that support the use of computer simulations is essential for their effective and pedagogically sound implementation. Integrating technology into instructional practices that focus on learners has been advocated as a way to promote meaningful learning.[6] Thus, research is needed to understand the philosophical perspectives that support the use of computer simulations to orchestrate learner-centred science education, particularly within the complex realities of rural classrooms.

The effective integration of computer simulations will enhance the quality of education in South Africa, especially in rural schools, a perennial national concern (10). Rural schools have been characterised as disadvantaged due to a lack of teaching and learning materials, specialist rooms (such as science/computer laboratories), broadband connectivity, and libraries.[7] What is perplexing is that the challenges bedevilling rural schools have become issues written in ink, deeply entrenched, and widely acknowledged.[8] The persistent challenges have led researchers to characterize/label rural schools as disadvantaged. The cumulative effect of these limitations significantly undermines the quality of learners' learning experiences. The quality of learning experiences afforded to learners in rural schools has not met the curriculum's expectations. Teachers in rural schools often face challenges delivering engaging and effective lessons due to limited resources and materials.[9] This inadvertently leads teachers to rely on convenient, rote methods that fail to foster deep understanding and application of concepts.[10] Learners in rural schools perform poorly in national examinations compared to their counterparts in urban areas, where schools are better resourced.[11] There are significant disparities in educational outcomes across

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2 Xinxin Fan and David Geelan, "Integrating Information Technology and Science Education for the Future: A Theoretical Review on the Educational Use of Interactive Simulations," *ACEC 2012: It's Time*, 2012; Herbert James Banda and Joseph Nzabahimana, "Effect of Integrating Physics Education Technology Simulations on Students' Conceptual Understanding in Physics: A Review of Literature," *Physical Review Physics Education Research* 17, no. 2 (December 21, 2021): 023108, https://doi.org/10.1103/PhysRevPhysEducRes.17.023108..

3 Emma Kostiainen and Johanna Pöysä-Tarhonen, "Meaningful Learning over the Course of Teacher Education: Students' Reflections," *Teaching and Teacher Education* 168 (2025): 105241.

4 Leonora Kaldaras et al., "Employing Technology-Enhanced Feedback and Scaffolding to Support the Development of Deep Science Understanding Using Computer Simulations," *International Journal of STEM Education* 11, no. 1 (2024): 30; Jonas Kotoka and Jeanne Kriek, "The Impact of Computer Simulations as Interactive Demonstration Tools on the Performance of Grade 11 Learners in Electromagnetism," *African Journal of Research in Mathematics, Science and Technology Education* 18, no. 1 (2014): 100–110; Alejandra J Magana et al., "Scaffolded Team-Based Computational Modeling and Simulation Projects for Promoting Representational Competence and Regulatory Skills," *International Journal of STEM Education* 11, no. 1 (2024): 34; Maxwell Tsoka and Jeanne Kriek, "Grade 11 Rural Science Learners' Descriptions of Their Learning with Computer Simulation," *Journal of Educational Studies* 23, no. 2 (2024): 70–90.

5 Eva Dakich, "Theoretical and Epistemological Foundations of Integrating Digital Technologies in Education in the Second Half of the 20th Century," in *Reflections on the History of Computers in Education: Early Use of Computers and Teaching about Computing in Schools* (Springer, 2014), 150–63.

6 Fan and Geelan, "Integrating Information Technology and Science Education for the Future: A Theoretical Review on the Educational Use of Interactive Simulations."

7 Michael Gardiner, "Education in Rural Areas," *Issues in Education Policy* 4 (2008): 1–33; Merlin John, "Physical Sciences Teaching and Learning in Eastern Cape Rural Schools: Reflections of Pre-Service Teachers," *South African Journal of Education* 39 (2019); Patrick Mafora, "Managing Teacher Retention in a Rural School District in South Africa," *The Australian Educational Researcher* 40, no. 2 (2013): 227–40; Maxwell Tsoka, *Exploring the Use of Computer Simulations as a Technological Pedagogical Reasoning Tool in the Teaching and Learning of Electromagnetism in a Whole-Class Rural Setting* (University of South Africa (South Africa), 2020); Elock Emvula Shikalepo, "Challenges Facing Teaching at Rural Schools: A Review of Related Literature," *International Journal of Research and Innovation in Social Science* 4, no. 5 (2020): 211–18..

8 Shikalepo, "Challenges Facing Teaching at Rural Schools: A Review of Related Literature"; Rekai Zenda, "The Importance of Teaching Resources on Physical Sciences Learners' Academic Achievement in Rural Schools: A Case of South Africa," *Social Education Research*, 2024, 407–20; Gardiner, "Education in Rural Areas."

9 Samantha Hoffman and Rouaan Maarman, "Teachers' Voices and Quality Education in the Basic Education Discourse in South Africa," *Perspectives in Education* 42, no. 4 (2024): 333–48; D. H. Sowetan, "Education Gap Widens – Public Schools Record 41% Bachelor Passes While Private Schools at 89%," 2024, https://www.citizen.co.za/news/south-africa/education/matric/education-gap-widens-public-schools-record-41-bachelor-passes-while-private-schools-at-89/.

10 John, "Physical Sciences Teaching and Learning in Eastern Cape Rural Schools: Reflections of Pre-Service Teachers."

11 Sowetan, "Education Gap Widens – Public Schools Record 41% Bachelor Passes While Private Schools at 89%."

racial groups in South Africa, with many African learners consistently lagging behind their counterparts from other racial and socio-economic backgrounds.[12] With the government's initiative to promote technology-enhanced learning in rural schools by providing digital devices, there is growing optimism that computer simulations will soon become a standard practice in teaching and learning. The transformation of rural pedagogy through such technological innovations has the potential to revive the diminishing culture of learning in many rural schools. This shift could help address several challenges that have eroded educational quality, including the rise in bullying, violence directed at teachers and learners, absenteeism, learner drop-out, teenage pregnancy, drug and substance abuse, and truancy.[13]

Therefore, there is a need for research that not only encourages but also supports rural teachers in harnessing the affordances of computer simulations to enhance teaching and learning. These advantages can be realized from an understanding of how technology can guide instructional decisions and purposes. As the move towards technology-enhanced learning gains momentum, calls are also being made for pre-service teachers to develop the key competencies required to seamlessly integrate digital technologies into their practice.[14] This study aims to explore the use of computer simulations by one teacher in a rural school, with a particular focus on explicating the philosophical perspectives that shape his instructional choices and classroom practices. The study will employ a qualitative research approach grounded in constructivist principles. The following section presents a review of the relevant literature, examining various approaches to integrating computer simulations into teaching and learning. This is followed by a discussion of the theoretical framework that underpins the study and an outline of the methodological approach adopted.

Use of Computer Simulations in Teaching and Learning Physical Sciences

Computer simulations are powerful digital technologies that can potentially reshape the rural classroom to improve science teaching and learning. Tsoka stated that computer simulations are computer-generated applications that mimic or model scientific phenomena or processes.[15] Their design and operations are underpinned by scientific principles that govern system behaviour and by philosophical perspectives that frame how knowledge is represented, interpreted, and constructed through technology. They enable simulation, observation, and exploration of the underlying mechanisms of scientific phenomena in an interactive manner. Their use in teaching science lies at the intersection of them being resources, tools, and technology. Their multifaceted nature underscores the robustness of computer simulations and their transformative potential to enrich science learning. However, the recent and existing literature reveal an exciting trend in research that highlights two dimensions of the use of computer simulations in science teaching and learning. The research reveals the *utility* and *utilisation* of computer simulations in effecting a potential transformation to the way science is currently practiced.[16] By *utility*, we refer to the potential

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[12] Godfrey Chitsauko Muyambi and Philip Kwashi Atiso Ahiaku, "Inequalities and Education in South Africa: A Scoping Review," *International Journal of Educational Research Open* 8 (2025): 100408.

[13] Marvelous Marenyenya, "Delinquent Behaviours Influencing Learners' Academic Achievement at Secondary Schools in Nemanwa Community, Zimbabwe," *International Journal of Studies in Psychology* 3, no. 1 (2023): 13–21; Ntshavheni Nndwayamato Mathoma, "Implications of Substance Abuse on Management of Learner's Academic Performance at Luvuvhu Circuit in Vhembe East District," 2022; Tracy McClinton Appollis et al., "School Dropout, Absenteeism and Coverage of Sexual and Reproductive Health Services in South Africa: Are Those Most at Risk Reached?," *AIDS and Behavior* 28, no. 10 (2024): 3525–42; Michael Nhambura, "Handling of Violent Behaviour of Learners in Secondary Schools: A Case Study of Vryburg Cluster in North-West Province" (North-West University, 2020); Thuto Polonyana and Moeniera Moosa, "Violence in Secondary Schools: Educators' Experiences in Soweto, South Africa," *Perspectives in Education* 42, no. 4 (2024): 24–38; Carien van Zyl and Carlien van Wyk, "Exploring Factors That Could Potentially Have Affected the First 1000 Days of Absent Learners in South Africa: A Qualitative Study," *International Journal of Environmental Research and Public Health* 18, no. 5 (2021): 2768.

[14] Thuthukile Jita, "Pre-Service Teachers' Competence to Teach Science through Information and Communication Technologies in South Africa," *Perspectives in Education* 34, no. 3 (2016): 15–28; Pernilla Nilsson, "From PCK to TPACK-Supporting Student Teachers' Reflections and Use of Digital Technologies in Science Teaching," *Research in Science & Technological Education* 42, no. 3 (2024): 553–77.

[15] Tsoka and Kriek, "Grade 11 Rural Science Learners' Descriptions of Their Learning with Computer Simulation."

[16] Kaldaras et al., "Employing Technology-Enhanced Feedback and Scaffolding to Support the Development of Deep Science Understanding Using Computer Simulations"; Lara Kathleen Smetana and Randy L Bell, "Computer Simulations to Support Science Instruction and Learning: A Critical Review of the Literature," *International Journal of Science Education* 34, no. 9 (2012): 1337–70; Orit Zeichner, "Using Simulations to Improve Achievements and Motivation in ICT Studies," *I-Manager's Journal on School Educational Technology* 16, no. 1 (2020): 11; Herbert James Banda and Joseph Nzabahimana, "The Impact of Physics Education

usefulness, value, or benefit of something. It describes how helpful or functional something is in each context. Thus, the utility of computer simulations refers to the outcomes they produce. *Utilization* refers to the effective use of something or the degree to which something is used. It is more about implementing a resource. Thus, the utilisation of computer simulations refers to the various ways/settings in which they are used. Computer simulations have been used in various educational contexts, both rural and urban, for a range of instructional strategies and learning needs.[17] They can be used effectively in whole-class settings, small groups, or with individual learners, offering flexibility and adaptability to different teaching and learning scenarios.[18]

A meta-analysis of research studies conducted over the last two decades underscores the transformative potential of computer simulations to enhance science teaching and learning.[19] These studies demonstrate that computer simulations provide unique affordances, such as visualising abstract concepts, supporting inquiry-based learning, and fostering active engagement, positioning them as powerful tools in science education. Theoretical frameworks play a crucial role in understanding and optimising the use of computer simulations in science education. Frameworks such as constructivism, connectivism, cultural-historical activity theory (CHAT), distributed cognition, and technological pedagogical content knowledge (TPACK) offer valuable insights.[20] They guide the design, implementation, and evaluation of simulation-based learning experiences to ensure maximum impact. In teaching and learning, the primary focus of computer simulations is not on the technological mechanics behind the tool itself, but on the science of teaching and learning that underlies its use. Technology in education, including computer simulations, is not an end in itself but a vehicle to achieve meaningful educational experiences. There is evidence that teachers' beliefs are central to how they incorporate technology into their teaching.[21] In agreement with Tondeur, we argue that teachers select technological applications that align with their existing beliefs about what meaningful teaching and learning entail.[22] The use of digital technologies in education is not accidental but the result of intentional, well-thought-out decisions grounded in specific philosophical perspectives on teaching and learning. These perspectives influence how teachers integrate technology to create meaningful and transformative learning experiences that align with their pedagogical goals.

Philosophical Perspectives Underpinning the Use of Computer Simulations

Underlying philosophical perspectives guide educational practice.[23] Thus, an approach centred around the teacher or learner is shaped by specific philosophical underpinnings that drive the teaching and learning process. A comparison between teacher-centred and learner-centred approaches reveals fundamentally different philosophical foundations, particularly in their epistemological, ontological, and axiological assumptions. Epistemology deals with what teachers consider valid knowledge and how it is acquired or constructed. On the other hand, the ontology concerns itself with the nature of reality, whether

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Technology (PhET) Interactive Simulation-Based Learning on Motivation and Academic Achievement among Malawian Physics Students," *Journal of Science Education and Technology* 32, no. 1 (2023): 127–41.

[17] Smetana and Bell, "Computer Simulations to Support Science Instruction and Learning: A Critical Review of the Literature"; Nico Rutten, Wouter R Van Joolingen, and Jan T Van Der Veen, "The Learning Effects of Computer Simulations in Science Education," *Computers & Education* 58, no. 1 (2012): 136–53; Samia Khan, "New Pedagogies on Teaching Science with Computer Simulations," *Journal of Science Education and Technology* 20, no. 3 (2011): 215–32.

[18] Tsoka, *Exploring the Use of Computer Simulations as a Technological Pedagogical Reasoning Tool in the Teaching and Learning of Electromagnetism in a Whole-Class Rural Setting*; Smetana and Bell, "Computer Simulations to Support Science Instruction and Learning: A Critical Review of the Literature."

[19] Smetana and Bell, "Computer Simulations to Support Science Instruction and Learning: A Critical Review of the Literature"; Handson Banda, Hlanganipai Ngirande, and Fortune Hogwe, "The Impact of Economic Growth on Unemployment in South Africa: 1994-2012," *Investment Management and Financial Innovations*, no. 13, Iss. 2 (contin1) (2016): 246–55.

[20] Vesna Ferk Savec, "The Opportunities and Challenges for ICT in Science Education," *Teknologia Kemian Opetuksessa* 1, no. 1 (2020): 1; George Siemens, "Connectivism: A Learning Theory Fir the Digital Age," 2005; Lihua Xu and David Clarke, "What Does Distributed Cognition Tell Us about Student Learning of Science?," *Research in Science Education* 42, no. 3 (2012): 491–510; Minhwan Kim, Da Kim, and Taehee Noh, "Analysis of Science Teachers' Guidance of Teaching Practice Using the CHAT," *Journal of The Korean Association For Science Education* 40, no. 2 (2020): 113–26.

[21] A Alvarez et al., "Teachers' Philosophical Views: Towards a Development of Philosophical Framework in Education," *International Journal for Cross-Disciplinary Subjects in Education* 10, no. 3 (2019): 4112–19; Jo Tondeur, "Teachers' Pedagogical Beliefs and Technology Use," in *Encyclopedia of Teacher Education* (Springer, 2022), 1960–64.

[22] Tondeur, "Teachers' Pedagogical Beliefs and Technology Use."

[23] Ruth Heilbronn, "Teacher Educators: Philosophical Perspectives," in *Encyclopedia of Teacher Education* (Springer, 2022), 1834–38.

fixed and objective or dynamic and socially constructed. Axiology concerns values and ethics, addressing what is considered worthwhile or essential in education. This includes the emphasis placed on aspects such as discipline and conformity, learner autonomy, creativity, and social justice. These philosophical dimensions shape practice by informing objectives, guiding instructional approaches, and influencing assessment strategies.

The literature on the use of computer simulations in transforming teaching and learning is increasingly promising, highlighting their potential to enhance both instructional effectiveness and conceptual understanding.[24] These digital tools offer significant pedagogical and epistemic advantages. Empirical research highlights the epistemic affordances of computer simulations, particularly their ability to support knowledge construction by making abstract or complex scientific phenomena observable, manipulable, and testable within virtual environments. By allowing experimentation and promoting inquiry-based learning, simulations foster deeper conceptual understanding and enhance the development of scientific reasoning skills. Pedagogically, computer simulations support new pedagogies that promote learner-centred active learning. We argue that computer simulations hold particular promise in addressing the challenges faced by resource-constrained educational contexts, such as rural schools that often lack access to adequate teaching and learning materials.[25] The lack of adequate teaching resources severely hampers teachers' ability to implement effective instructional practices.[26]

In many cases, this resource deficit has led to teaching approaches being described as weak or limited in their capacity to develop the competencies envisaged by the curriculum, particularly those related to critical thinking, problem-solving, scientific inquiry, and the application of knowledge in real-world contexts. We describe the teaching practices as having a weak residual (pedagogical) effect. Therefore, simulations can serve as cost-effective and scalable alternatives to physical laboratory equipment and textbooks in these settings, allowing learners to engage with scientific concepts through interactive, visual, and experiential means. Beyond addressing material shortages, we argue that computer simulations also contribute to a shift in the philosophical orientation of instruction. These tools have the potential to change how teachers and learners interact, creating new opportunities for both groups.[27] They embody and promote a new social construction of teaching and learning in which digital tools are not seen as supplementary to traditional methods but as transformative agents that redefine teacher-learner relationships and classroom interactions.

Despite a growing body of research documenting the use of computer simulations in education, there remains a noticeable gap in the literature concerning the philosophical underpinnings that shape teachers' use of these tools. Much of the existing scholarship tends to isolate one philosophical dimension, most commonly epistemology, while paying less attention to the integrated influence of epistemology, ontology, and axiology on teaching practice.[28] However, these three perspectives are not discrete or independent; they exist in a triadic relationship, each informing and reinforcing the others in meaningful ways. Epistemology, or one's theory of knowledge, shapes how a teacher views learning and the role of technology in knowledge construction, while ontology influences how teachers perceive learners and their engagement with digital tools. Axiology influences teachers' ethical and pedagogical decisions regarding what is worthwhile or meaningful in education. It is a truism in educational philosophy that these three dimensions collectively influence a teacher's orientation to curriculum, pedagogy, and learner engagement. However, research systematically exploring how these perspectives converge in the context of computer simulation use remains limited, particularly in under-resourced or rural educational settings.

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[24] Kotoka and Kriek, "The Impact of Computer Simulations as Interactive Demonstration Tools on the Performance of Grade 11 Learners in Electromagnetism"; Tsoka, *Exploring the Use of Computer Simulations as a Technological Pedagogical Reasoning Tool in the Teaching and Learning of Electromagnetism in a Whole-Class Rural Setting*; Magana et al., "Scaffolded Team-Based Computational Modeling and Simulation Projects for Promoting Representational Competence and Regulatory Skills"; Banda and Nzabahimana, "The Impact of Physics Education Technology (PhET) Interactive Simulation-Based Learning on Motivation and Academic Achievement among Malawian Physics Students."

[25] Gardiner, "Education in Rural Areas"; John, "Physical Sciences Teaching and Learning in Eastern Cape Rural Schools: Reflections of Pre-Service Teachers"; Shikalepo, "Challenges Facing Teaching at Rural Schools: A Review of Related Literature."

[26] John, "Physical Sciences Teaching and Learning in Eastern Cape Rural Schools: Reflections of Pre-Service Teachers."

[27] Rune Johan Krumsvik, "Ontology, Epistemology and Context–and Our Social Construction of Educational Technology," *Nordic Journal of Digital Literacy* (Universitetsforlaget, 2020).

[28] Ileana M Greca, Eugenia Seoane, and Irene Arriassecq, "Epistemological Issues Concerning Computer Simulations in Science and Their Implications for Science Education," *Science & Education* 23, no. 4 (2014): 897–921.

According to Gamache, 'All practice is rooted in some theoretical framework, if not explicitly, then implicitly'.[29] A focus on philosophical perspectives deepens our understanding of the nuanced ways in which computer simulations transform teaching and learning. In rural schools, where limited resources have historically impeded effective instruction, computer simulations present the potential for an educational renaissance—one that embodies the contemporary zeitgeist of technology-enhanced learning and equitable access to quality education.

THEORETICAL FRAMEWORK

Since this study aimed to construct a picture that delineates the philosophical perspectives that informed the use of computer simulations in my teaching practice, constructivism was identified as the most appropriate theoretical framework to guide the research. Constructivism is a subjective paradigm that assumes multiple realities, emphasising that knowledge does not exist independently of individuals but is actively constructed through their experiences and interactions within their contexts.[30] From this point of view, constructivism views meaning as a personal construct rather than something external and independent of the mind.[31] In the context of this study, it provided a lens through which to explore how both teacher and learner understanding evolved through engagement with technology-enhanced learning tools. By grounding the research in constructivist theory, the study acknowledged the importance of context, prior knowledge, and reflection in shaping how digital technologies, such as computer simulations, are understood, interpreted, and applied in the classroom.

METHODOLOGY

A constructivist epistemology aligns closely with a qualitative research approach, as both prioritise understanding human experience from the perspective of those experiencing it. Constructivism assumes that knowledge is constructed through interaction with the social world rather than discovered.[32] This anti-objective approach rejects the notion of value-free knowledge and instead emphasises context, subjectivity, and the co-construction of meaning between researcher and participants. Consequently, qualitative research within a constructivist paradigm seeks to uncover rich, in-depth insights into people's lived experiences, acknowledging that multiple, equally valid realities exist. Therefore, the study adopted a case study as the research design to explore the nuanced perspectives of the participants as they engaged in a computer simulation-supported environment. According to Kincheloe, a case is a phenomenon bounded in context, defined by space and time frame.[33]

Participants

This research forms part of a broader study by the first author, who aimed to transform his teaching practice by integrating computer simulations in a rural school setting. The researcher had never used these digital tools before. The overarching goal was to enhance learners' conceptual understanding of scientific phenomena by leveraging technology as a pedagogical tool. The PhET simulations downloaded from the internet were used to teach the concept of electromagnetic induction to grade 11 learners during the third quarter in the years 2015-2017. The first author served as teacher-researcher, facilitator, and participant throughout the research process. The researcher also took responsibility for recruiting participants. Learners were invited to participate voluntarily, with the study's purpose and procedures clearly explained beforehand. Written informed consent was obtained from all participants and their guardians, taking into account the school context and the learners' age group.

[29] Paul Gamache, "University Students as Creators of Personal Knowledge: An Alternative Epistemological View," *Teaching in Higher Education* 7, no. 3 (2002): 268.
[30] Norman K. Denzin and Yvonna S. Lincoln, "Transforming Qualitative Research Methods," *Journal of Contemporary Ethnography* 24, no. 3 (October 1, 1995): 349–58, https://doi.org/10.1177/089124195024003006.
[31] J. Kincheloe, *Teachers as Researchers: Qualitative Inquiry as a Path to Empowerment* (London: The Falmer Press, 1991).
[32] R. E. Stake, *The Art of Case Study Research* (SAGE Publications, 1995).
[33] Kincheloe, *Teachers as Researchers: Qualitative Inquiry as a Path to Empowerment*.

Ethics Approval

Ethical clearance for the study was obtained from the relevant Institutional Ethics Committee. The research adhered to standard ethical protocols, including obtaining informed consent, ensuring voluntary participation, maintaining anonymity, and ensuring confidentiality. Participants were informed of their right to withdraw from the study at any time without any negative consequences. Ethical clearance was obtained from the College of Education Research Ethics Review Committee (Ref: 2016/09/14/45341117/01/MC) and the Department of Education (Ref: 14/7/R). In addition, informed consent was obtained from both parents and learners under 18 before their participation in the study. On behalf of all authors, the corresponding author states that there is no conflict of interest. Consent to participate: The study obtained written informed consent from all participants prior to their involvement. Participants were provided with detailed information about the study's purpose, the procedures involved, potential risks and benefits, and their rights, including the option to withdraw at any time without penalty. They were given the opportunity to ask questions and seek clarification before signing the consent form, ensuring their voluntary and informed participation.

Data collection

The researcher maintained a reflective journal throughout the three-year study period (2015–2017). The journal served as a critical tool for reflexivity, allowing the researcher to document personal insights, emerging questions, and methodological decisions. The journal included weekly entries written after classroom sessions, enabling the researcher to capture immediate reflections and evolving interpretations. The reflective journals provided a rich, first-person account of the researcher's evolving thoughts, pedagogical decisions, and classroom experiences as he implemented computer simulations in a rural teaching context. These entries captured not only instructional strategies but also the emotional and intellectual challenges faced during the process of pedagogical transformation.

Focus groups were used as the primary method to collect data on learners' perceptions and experiences with the computer simulations. During the study, three focus groups were conducted, one per year, each comprising six learners. These groups did not overlap; each group was formed with a new cohort of learners who had interacted with the PhET simulations in that specific year. Each focus group session lasted approximately 30-35 minutes, and discussions were audio-recorded and transcribed for analysis. The focus group setting enabled collaborative dialogue among learners, fostering richer data as participants responded to and built on one another's views.

Data analysis

This study employed a deductive thematic analysis that followed an iterative, multiple-step process to examine the data, explicitly guided by three philosophical categories: epistemology, ontology, and axiology. This was done to ensure rigour, transparency, and alignment with the study's aims. The first step was data familiarisation, which involved reading the reflective journals and transcribed focus group discussions several times to gain familiarity and note initial impressions. During this phase, key moments that appeared to reflect philosophical assumptions were highlighted. This was followed by developing a coding framework that was deductively based on the three philosophical categories:

- *Epistemological codes* focused on how knowledge is portrayed or validated in the simulation context.
- *Ontological codes* captured representations of the nature of reality (e.g., whether electromagnetic induction was shown as an objective truth or as model-dependent).
- *Axiological codes* identified references to values such as equity, ethics, or the inclusion of diverse viewpoints.

The following stage involved tagging sections of text with one or more philosophical codes. Numerous quotes are used to capture my views on the ideas, as advocated by Creswell and Poth.[34] The

[34] John W Creswell and Cheryl N Poth, *Qualitative Inquiry and Research Design: Choosing among Five Approaches* (Sage publications, 2016).

final stage involved triangulation and cross-checking. To ensure the coding process's reliability, a critical peer reviewer independently coded a subset of the data. Discrepancies were discussed and resolved through dialogue, with coding definitions refined where necessary. Feedback was incorporated to enhance the authenticity and trustworthiness of the findings.

PRESENTATION OF FINDINGS AND DISCUSSION

This section presents excerpts from reflective journals and focus group discussions to construct the epistemological, ontological, and axiological dimensions engendered by teaching using computer simulations.

Epistemological Perspectives

As Loya suggests, epistemology informs teachers' understanding of what constitutes knowledge and how it is created; it is typically grounded in an ethical stance.[35] An objectivist epistemology, which views knowledge as an objective, universal truth existing independently of the learner, can be contrasted with a constructivist epistemology, where knowledge is not seen as final/fixed but rather as provisional, dynamic, co-constructed, and shaped by learners' experiences, interactions, and reflections. In the presence of computer simulations, a fundamental pedagogical shift occurred in the roles of both teachers and learners. The teacher's functional shift from a knowledge dispenser/gatekeeper to a facilitator, guide, and co-learner was a dimension succinctly captured in the reflective journals and in the focus group discussions. Learners were no longer viewed as passive note-takers, receivers of content, or accumulators of factoids but as active participants in the meaning-making process, engaging with content, peers, and the teacher to co-construct understanding. I present selected excerpts from my reflective journals to substantiate my epistemological stance on the use of computer simulations in teaching and learning. These reflections provide valuable insights into my evolving understanding of how knowledge is constructed within technology-enhanced learning environments. The teacher was not the sole source of knowledge, but rather a participant, along with learners, in constructing knowledge. The teacher facilitated the process by engaging learners in disciplinary practices that construct knowledge. Instead of dictating notes as is the practice in rural schools, the teacher used discussions as a vehicle for active engagement, developing thinking, and collaborative knowledge construction. This approach allowed learners to draw on their own experiences, question ideas, share diverse perspectives, and deepen their understanding through interaction and reflection, rather than passively receiving information.

> *The discussions I had with the learners gave me an opportunity to elicit their ideas and to understand their thinking. I am particularly excited about the communicative power of computer simulations. They provide an environment for exploration through opportunities for dialogue and questioning. When asking a question, I no longer need to evaluate whether the response is correct or incorrect myself; other learners can confirm whether it is correct or incorrect. This makes the teacher no longer the arbiter, but multiple learner voices are allowed to speak. However, where it was necessary, I was called to correct wrong ideas that learners may have (Reflective journal August 2015)*

> *What I enjoy about teaching with computer simulations is that learners are not constrained to understanding the content in the teacher's or textbook author's language. By 'seeing' the content, learners can express it in terms familiar to them. Learners are not reduced to blind consumption of information, as is normally the case during the dictation of notes (Reflective Journal, August 2017).*

Learners reported that learning through computer simulations allowed them to articulate their understanding more freely, using their own words and interpretations, rather than being constrained by the language or explanations provided in a textbook. This relieved them from the practice of cramming, allowing them to meaningfully engage with content in a manner that develops conceptual understanding.

[35] K Loya, "Teaching Philosophy as a Mechanism for a More Inclusive Teaching and Learning Process," *Academia Letters* 409 (2021): 1–5.

Learners asserted that learning with computer simulations saves them from having to imagine, and agreed that imagining abstract things that they have not seen before or do not know is difficult because their imagination might not be accurate (FGD, 2015). According to one learner, Cattie,

> *The computer simulations help summarise what is in the textbook because what will be explained is too much, and some of the words are difficult to understand… most of us learners, when we read a textbook, aim to cram without understanding. When you read from the textbook, it is easy to cram… But if we are observing, like on the projector, it is easy because your understanding when you are seeing it happen is different from when you are imagining; sometimes your imagination might not be correct, but what you see happening is easy to understand, as opposed to when you just read in the textbook. Computer simulations help us to understand the applications of what we will be learning in school (FGD).*
>
> *What I have seen is that when we learn through computer simulations, it is easy for a learner to create their own definition (electromagnetic induction) because they can explain what will happen, but if we are just taught by word of mouth, we are forced to cram without understanding (FGD).*

Supporting the idea of expressing concepts in their own words, one learner described the shape of magnetic field lines around a current-carrying conductor as "expanding" instead of using the scientific term "concentric." Although the term may not be technically precise, it did not diminish the conceptual understanding. Rather, it demonstrated the learner's ability to make sense of the phenomenon in a way that was personally meaningful. This choice of language reflects a process of internalising scientific ideas and translating them into accessible terms, which can serve as a foundation for gradually introducing more formal scientific vocabulary. Thus, computer simulations *equitize* the learning process by providing opportunities for learners to access and express their understanding in their own terms.

Instead of simply delivering pre-packaged information, the teacher became instrumental in selecting appropriate computer simulations to create a memorable learning environment in which learners are actively engaged with simulations to explore concepts, test hypotheses, and construct their understanding. This approach allowed them to appreciate the value of learning science. This is made possible by the advantages of computer simulations.

> *The prompts and cues in some computer simulations are intended to adapt and tailor our lessons to learners' needs. Some computer simulations on the internet are intended for learners in high school as well as students in college or university. (Reflective journal, August 2015)*

As revealed in the excerpt above, computer simulations offered dynamic, interactive learning opportunities that guided the learning process. These actionable elements, known as affordances, are the unique features and opportunities that simulations provide to support learning. Affordances are both inherent properties of computer simulations and the possible actions that can be derived from them. These benefits compel teachers to transform their traditional roles into technology-supported ones, integrating digital tools into their teaching practices to improve learning outcomes.

As a facilitator of learning, the teacher designed and sequenced activities that encouraged inquiry, critical thinking, and problem-solving.[36] They elicit the learner's prior understanding to identify alternative conceptions that hinder meaningful learning of scientific ideas. Computer simulations represent abstract ideas, so teachers must help learners interpret the data generated and draw meaningful conclusions.

> *The use of computer simulations creates an open space for interaction that goes beyond just communication to meaningful engagement. The teacher does not tell learners what is happening; instead, they elicit learners' ideas and demonstrate them. The space of interaction created by computer simulation, which I have termed 'zone of action', promotes certain actions (prompted, directed, or spontaneous) in both the teacher and learners that enhance learning. In the zone of action, the teacher is positioned as a facilitator of learning. At the same time, learners are not*

[36] Charles D Morrison, "From 'Sage on the Stage'to 'Guide on the Side': A Good Start," 2014.

just passive recipients of information but are positioned as active participants (Reflective Journal, 2017).

According to Sarkar Arani et al., (53), teachers scaffold learners' interactions with simulations, helping them stay focused on key learning objectives while fostering curiosity and creativity. They provide prompts, ask open-ended questions, and offer targeted support when learners encounter challenges.

What I did in stopping the simulation helped learners see how the fields around each loop in the solenoid combined to form a resultant magnetic field. This enabled me to explain the magnetic field around a solenoid as the sum of the magnetic fields around its loops (Reflective Journal, August 2015).

As a co-learner, Santosa (54) teachers learn new ways of engaging and interacting with content alongside their learners.

I realised that when I asked the learners what could be done to increase the strength of the magnetic field, I could also ask the same question in a different, more practical way. I then asked the learners what could be done to increase the number of iron filings attracted to the iron nail (referring to the demonstration of the iron nail connected to the cell) (Reflective Journal, August 2016).

Computer simulations are effective graphical representations of scientific phenomena that allow the teacher to engage learners in a reflective discussion in which they verbalise their thoughts, ideas, and feelings. It creates an interactive space where learners and the teacher can talk and think together. I am excited about this because it eliminates my dominance as the teacher in the class. I see this potential as learners become used to learning with this epistemic tool. What is needed for now is to continue to encourage learners to participate (Reflective Journal, August 2015).

The epistemological perspective underpinning the teacher's role as a facilitator, guide, and co-learner is thus rooted in constructivism.[37] This perspective asserts that knowledge is not a fixed/final commodity transmitted from teacher to learner but is co-constructed through active engagement, social interaction, and meaningful participation in learning activities. Knowledge in this context was not simply what the teacher prescribed or dictated, but rather emerged from the matrix of the dynamic interaction among the teacher, the computer simulation, and the learners. It was co-constructed through guided exploration, visualisation, inquiry, and dialogue, in which the simulation served as a mediating epistemic tool that visualised abstract concepts, facilitated experimentation with hypothesised conditions, and invited learners to actively engage with the content using familiar or borrowed words. In this regard, the teacher's role shifted from being a transmitter or dispenser of fixed knowledge to a facilitator of meaning-making, helping learners to interpret, question, and reflect on what they observed. Over time, it became clear that knowledge is not only discovered but rather negotiated, constructed, and validated through shared experiences and collective sense-making in the process of learning. In this process, the teacher, learners, and simulations were *collaborants.*[38] Although the teacher initially believed that the simulations were primarily intended to enhance learners' engagement, it later turned out that they also reshaped the epistemic roles of both learners and the teacher.

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[37] David Cleaver and Julie Ballantyne, "Teachers' Views of Constructivist Theory: A Qualitative Study Illuminating Relationships between Epistemological Understanding and Music Teaching Practice," *International Journal of Music Education* 32, no. 2 (2014): 228–41.

[38] Collaborants refers to the active engagement of the teacher and learners mediated by computer simulations to the co-construction of new understanding.

Ontological Perspectives

As teachers, our epistemological beliefs influence what we regard as reality. Gamache notes that epistemology is based on ontology.[39] Thus, our teaching is objective, subjective, or socially constructed, among other ways, based on how we view the nature of reality. If we consider knowledge to be objective, our teaching focuses on transmitting facts, principles, and universal truths assumed to exist independently of individual perceptions or experiences. This approach emphasises the authoritative presentation of content, where the teacher's role is primarily that of a knowledge expert who delivers accurate information for learners to memorise, understand, and apply in standardised ways. Thus, according to Loya, our ontology is akin to a lens that tints everyone and everything in that world. Since research and curriculum policy documents advocate constructivist approaches to science learning, it is essential to align instructional practices with computer simulations that align with a specific ontology, supporting learners in constructing a subjective reality as they represent, explore, and interpret scientific phenomena.[40] This approach acknowledges that our learners are individuals with social identities, backgrounds, prior knowledge, skills, strengths, challenges, needs, subjectivities, and goals.[41] By adopting a constructivist approach that supports the construction of subjective realities, science learning becomes more inclusive, relevant, and effective.

Using computer simulations, learners are presented with dynamic, interactive, and social opportunities to craft their understanding of scientific ideas. These simulations allow learners to observe abstract phenomena, manipulate variables, measure outcomes, and engage in mediated conversations that foster collaborative meaning-making.

> *The observations made by the learners went a long way to help them to articulate their ideas in a coherent way. The responses elicited from learners demonstrated that they were making sense of what was being taught. The learners were able to identify the variables that affect the bulb's lighting. This was really encouraging. The learners were comfortable with the visual tool, which made them enjoy the lesson (Reflective Journal, August 2015)*
>
> *What I enjoy about teaching with computer simulations is that learners are not constrained to understanding the content in the teacher's or textbook author's language. By 'seeing' the content, learners can express it in terms familiar to them. Learners are not reduced to blind consumption of information, as is normally the case during the dictation of notes. (Reflective Journal, August 2017).*

The social milieu created using computer simulations fosters a community where learners can articulate their ideas, challenge each other's assumptions, and build on collective insights to deepen their understanding of scientific concepts. Mediated conversations guided by the teacher provide a platform for constructing shared knowledge from diverse perspectives while promoting active listening, negotiation, and the co-construction of meaning.

The use of computer simulations is not intended to provide a mere representation of expert knowledge of scientific ideas but to create an environment in which learners actively engage in constructing their understanding of these ideas. Instead of presenting fixed or definitive knowledge, computer simulations offer flexible, interactive scenarios that allow learners to manipulate variables, observe the effects of changes, and draw conclusions from their observations.

> *Learners were able to give valid descriptions of the magnetic field around the current-carrying conductors. One learner provided a description I had not anticipated. He said that the field was non-uniform, as evidenced by the fact that the circles were not equidistant, with the field lines near the conductor very close together, while those far from the conductor were farther apart. He even suggested that the field was therefore stronger near the conductor and weaker far from it (Reflective Journal, August 2015).*

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[39] Gamache, "University Students as Creators of Personal Knowledge: An Alternative Epistemological View."

[40] Mohammad Reza Sarkar Arani et al., "From 'Chalk and Talk' to 'Guide on the Side': A Cross-cultural Analysis of Pedagogy That Drives Customised Teaching for Personalised Learning," *European Journal of Education* 54, no. 2 (2019): 233–49.

[41] Loya, "Teaching Philosophy as a Mechanism for a More Inclusive Teaching and Learning Process."

This approach emphasizes learning science rather than the product, helping students develop a deeper conceptual understanding and critical thinking skills.

I really appreciated the learners' contributions on the factors that affect the induced emf/current. The learners identified factors such as the magnet's strength, the speed of the magnet/coil, the number of coil turns, and the solenoid's diameter. We were able to demonstrate this with the computer simulations. So, instead of reading these in the textbook, they were able to experience their practical demonstration (virtual). Learners were able to accurately interpret visual representations of scientific phenomena, a sense-making practice that is important in learning science (Reflective Journal, August 2015)

By focusing on the learner's interaction with the simulation, the goal is not to replicate experts' knowledge but to enable students to think and act like scientists. They engage in inquiry, experimentation, and analysis, which helps them build transferable skills applicable in academic and real-world contexts. Although the learning experience was engaging, it was not without challenges. The learners initially struggled to accept that the concepts they were exploring were relevant to real life or had practical applications beyond the classroom. Their comments revealed a degree of scepticism toward the graphical representations used in the computer simulations, often perceiving them as overly idealised, unrealistic, and disconnected from everyday experiences. This disconnect highlights a common issue in science education, where learners find it difficult to bridge the gap between theoretical or virtual models and tangible reality. For many, the simulations appeared too utopian to reflect what they might encounter in the physical world, suggesting a lack of familiarity with emerging digital technologies to support conceptual transfer and deepen understanding.

….when you brought those simulations, I didn't believe them. I was just like, "These are the simulations made by scientists." There is no such thing. The one that I didn't believe most was that one, and there was a magnet coming close to the coil and the bulb started lightning, and I was like How come there is no battery? There was nothing. How could such a thing happen, but as you kept on telling us, the magnet can induce a current, so there is a possibility of bulb lightning.

Most of us did not believe that the simulations were true, but when you brought that thing you were winding, the light started to glow, and that's when I started to believe that the simulations were correct.

At first, when you brought those things, I didn't understand what was going on. I think it took me about a week to realise that when a magnet moves towards a coil, light appears, which is why that simulation. I think they were accurate.

While learners acknowledged the epistemic affordances of computer simulations, such as their ability to visualize abstract scientific concepts and support conceptual understanding, they expressed difficulty in accepting the applicability of the reality portrayed in these virtual models, often finding them too detached from real-world contexts and everyday experiences. This skepticism underscores not only a lack of foundational scientific knowledge from prior learning but also limited exposure, particularly among rural learners, to emerging digital learning tools. The unfamiliarity with such technologies may have hindered their ability to relate simulated representations to real-world phenomena, thereby affecting the perceived authenticity and educational value of the simulations. This experience has not only motivated me to incorporate computer simulations into my teaching but also offered valuable insight into the possible thought processes and challenges my learners face. Abstract concepts like electromagnetic induction are counter-intuitive. Learners more readily accept as reality what is tangible and aligns with what they can plausibly imagine. To meaningfully engage with virtual reality as a representation of the real world, it is essential that learners are introduced to these digital tools early in their science education.

Early exposure not only builds familiarity and confidence but also helps learners develop the cognitive skills needed to interpret and relate virtual experiences to real-world scientific phenomena.

Axiological Perspectives

Educational practice as a human activity is not value-free. According to Dewey the child is an organic whole, intellectually, socially, and morally, as well as physically, and the school has the responsibility to provide an education that will give the child such possession of himself that he may take charge of himself and, in so doing, have the power to shape and direct social changes.[42] The science curriculum envisions equipping learners, irrespective of their socio-economic background, race, gender, physical ability, or intellectual ability, with the knowledge, skills, and values necessary for self-fulfillment and meaningful participation in society as citizens of a free country. Therefore, teaching and learning should be grounded in axiological beliefs.[43] According to Loya, axiology prompts us to think about what we consider valuable in teaching.[44] This involves considering power, privilege, difference, objectivity, and subjectivity.[45] In increasingly diverse classrooms, teachers must create learning environments that engender what we refer to *cynefin* (pronounced Kun-eh-vinn), a Welsh word best described as a feeling of belonging and connection to a place and community, so that learners from diverse cultural and linguistic backgrounds feel welcomed, represented, and supported. A more cultural-axiological stance is inclusive and democratises learning by challenging the notion of universal, value-free, rational, objective, and detached ways of teaching and learning.[46]

Although the curriculum policy does not explicitly identify which values should be developed, the study by Roux identified 68 values, with respect (for human rights), integrity, and perseverance/determination ranked as the most important for inclusion in a curriculum.[47] Respect for human rights restores the integrity of learners from severely challenged backgrounds by affirming their dignity, fostering a sense of belonging, and empowering them to persevere in overcoming obstacles to achieve their full potential. Access to quality education is a fundamental human right that upholds the dignity of learners from rural areas, empowering them to overcome challenges and persevere in their pursuit of knowledge and personal growth.[48]

The challenges facing rural communities, such as gender-based violence, substance abuse, poverty, and crime, profoundly impact the development of young people.[49] Learners who live in these communities often face significant barriers that affect their educational outcomes, mental health, and overall well-being. Many of these young individuals carry the weight of societal challenges into the classroom, which can manifest as low self-esteem, difficulty concentrating, absenteeism, or even dropping out of school.[50] The stress of living in environments marked by instability and insecurity often hinders their ability to fully engage with their education or envision a brighter future.

Gender-based violence disproportionately affects girls, limiting their access to education and increasing their vulnerability to early marriages, teenage pregnancies, and exploitation.[51] Substance abuse and exposure to crime further exacerbate the challenges, contributing to a cycle of poverty and

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[42] John Dewey, *Moral Principles in Education* (Houghton Mifflin, 1909).

[43] Department of Education, *Curriculum Assessment Policy Statement (CAPS)* (Pretoria: Government Printers, 2011).

[44] Loya, "Teaching Philosophy as a Mechanism for a More Inclusive Teaching and Learning Process."

[45] Loya, "Teaching Philosophy as a Mechanism for a More Inclusive Teaching and Learning Process."

[46] Loya, "Teaching Philosophy as a Mechanism for a More Inclusive Teaching and Learning Process."

[47] Charl J. Roux and Nazreen Dasoo, "Pre-Service Teachers' Perception of Values Education in the South African Physical Education Curriculum," *South African Journal of Childhood Education* 10, no. 1 (February 11, 2020), https://doi.org/10.4102/sajce.v10i1.717.

[48] Rehaf A Madani, "Analysis of Educational Quality, a Goal of Education for All Policy.," *Higher Education Studies* 9, no. 1 (2019): 100–109; Annalisa Pavan, "UNESCO and the Human Right to Education for All," n.d.

[49] Leoba Nyathi et al., "Social Issues Affecting Social Cohesion in Low-Resource Communities in South Africa," *African Journal of Governance and Development* 13, no. 2 (2024): 135–62; Bep Uink et al., "Socioeconomically Disadvantaged Adolescents with Elevated Externalizing Symptoms Show Heightened Emotion Reactivity to Daily Stress: An Experience Sampling Study," *Child Psychiatry & Human Development* 49, no. 5 (2018): 741–56.

[50] Uink et al., "Socioeconomically Disadvantaged Adolescents with Elevated Externalizing Symptoms Show Heightened Emotion Reactivity to Daily Stress: An Experience Sampling Study."

[51] Florence M Itegi and Felicita W Njuguna, "Gender Based Violence in Educational Institutions and Its Impacts on Girls' Education: A Comparative Study of Selected Countries," *Research Journal in Organizational Psychology & Educational Studies* 2, no. 5 (2013): 276–79; Tripti Bhushan, "Breaking the Chains: Understanding and Combating Early Marriage-Induced Violence against Girls," in *Social, Political, and Health Implications of Early Marriage* (IGI Global Scientific Publishing, 2025), 61–92.

hopelessness.[52] Additionally, inadequate access to resources such as healthcare, transportation, and technology in rural areas compounds these issues, leaving learners at a significant disadvantage compared to their urban counterparts.

Faced with these challenges, schools and teachers should play a key role in creating inclusive environments where learners feel supported, encouraged, and empowered to learn, despite limited resources. This is the tension that teachers in rural areas often face. Teachers often face the difficult tension of striving to provide quality education while navigating systemic constraints. Their role extends beyond instruction; they become advocates, innovators, and mentors committed to bridging the gap between potential and opportunity. Although my learners may not have fully perceived my commitment to enhancing their learning experience, some viewed the time I spent setting up the equipment, connecting the projector to the laptop, raising the screen, and arranging the materials as a waste of valuable instructional time. This was because I had no fixed classroom, but instead had to move from one classroom to another, a process referred to as floating (63). They lamented:

> *What I dislike is that they take time to connect… (Mbof, FGD)*
>
> *They waste time, because they need to be connected in order for them to operate, and it takes approximately 10 minutes to connect them (Tondi, FGD)*
>
> *One thing I hate about computer simulations is that they waste a lot of time; the projector can take up to ten minutes while being prepared up because we do not use those projectors which are [already] installed in every classroom. I think we have only one in the whole school, which means that learning time will be shortened because of the connection (Masala, FGD).*

What they could not immediately see was the intention behind these efforts: to create an engaging and enriched learning environment using available technology. This disconnect highlights a broader challenge in under-resourced settings, where the extra effort required to integrate even basic digital tools can be misinterpreted as inefficiency rather than innovation. It also underscores the importance of helping learners understand not only what we teach, but also how and why we teach the way we do. Despite these sentiments, learners were aware of the opportunities and changes to their attitudes towards learning that the use of computer simulations had facilitated. We provide excerpts from focus group discussions with learners to support the views.

> *The lessons were fine, actually, really interesting, looking at the learning environment. Though we had limited resources, we are glad you made an effort to make it realistic. (Akim, FGD, 2017)*
>
> *They were one of the lessons I actually enjoyed because you tried to make it practical; it wasn't just theory, which was one good thing for us to understand the concepts. (Mushaphi, FGD, 2015)*

Computer simulations can help level the playing field when implemented thoughtfully, ensuring that all learners can access engaging, high-quality learning experiences. By making learning interactive, relevant, and accessible, computer simulations spark curiosity and sustain learners' interest, keeping them engaged and motivated throughout their educational journey.

> *Eh, one thing about that, if computers were used at school, I think those learners who are leaving school will not do so because learners really enjoy technology, so they will, I think, not leave school where computers are used for teaching. No learner will have the arrogance to leave school, because school will be fun, very fun, because everything you are being taught you gonna see it, because they are saying this and that, if you add this and that, you get this, and you gonna see this and be done and be taught things you have never seen. Most learners drop out of school because school subjects become boring, as they have to learn more and more theoretical material without getting the practical side of what really happens in real life. We just focus on books without being taught, like without seeing this, what is this, when is this being said to be like this,*

[52] Valeria Saladino et al., "The Vicious Cycle: Problematic Family Relations, Substance Abuse, and Crime in Adolescence: A Narrative Review," *Frontiers in Psychology* 12 (2021): 673954.

how does it look like …and another thing here is that if they are using computers, we can just take a video when a teacher is teaching so that when are at home you didn't understand well, you can just play a video and see so that you can remember what you have forgotten (Ntaku, FGD, 2017)

The excerpt highlights the values that are fostered when learning is transformed. Learners appreciated that their learning was engaging, meaningful, and enjoyable, suggesting that fun, curiosity, and active participation are essential components of the educational process. The assertion that learners are less likely to drop out when technology is integrated implies that a lack of meaningful engagement increases the risk of dropping out of school. This suggests that incorporating technology can enhance learner engagement, making learning more interactive, relevant, and accessible. Additionally, the excerpt highlights the value learners find in learning that extends beyond textbooks, as it is relevant to real-life applications.

CONCLUSION

To fully appreciate the efficacy and impact of computer simulations, it is essential to engage in a critical and reflective process that examines how these digital technologies shape our ontology (the nature of being), epistemology (the theory of knowledge), and axiology (the study of values). Such reflection not only deepens our understanding of how simulations shape content knowledge but also enriches our interactions with learners, fostering a collaborative and communal approach to knowledge construction. By engaging in this reflection, we can refine our instructional strategies, ensuring that computer simulations align with our educational objectives and foster an environment where all learners are engaged and supported in developing critical thinking and problem-solving skills through their learning content. This innovative approach to integrating digital technology into teaching not only enhances learning but also contributes to the broader discourse on the evolving role of technology in shaping how science is taught. It is no longer possible to imagine teaching science without using digital technology, making it essential to examine the philosophical perspectives that shape and justify its use. Understanding the ontological, epistemological, and axiological foundations of digital tools allows teachers to integrate them more thoughtfully and effectively with greater intentionality and pedagogical sensitivity. By acknowledging the potential challenges, power dynamics, and tensions that may arise from integrating computer simulations, teachers can ensure that technology supports conceptual understanding, learner engagement, and ethically grounded teaching practices.

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