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Alleviation of social injustices in STEM education: Harnessing pedagogical affordances of virtual and augmented reality applications through open learning

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Abstract

This paper explores the extent to which pedagogical affordances of virtual and augmented reality (VAR) applications can be harnessed as a means to alleviate social injustices in science, technology, engineering and mathematics (STEM) education through open learning. The enhancement of epistemic and epistemological access in STEM education requires coherent implementation of appropriate strategic interventions which are essentially geared towards the promotion of pedagogic innovation in its broadest sense. The empirical investigation adopted a qualitative research design located within the interpretivist paradigm. Qualitative data was collected through semi-structured interviews. The study is underpinned by the theory of social justice framework as a theoretical lens. Key findings emanating from the study demonstrated that sustainable integration of VAR applications in STEM education can essentially be harnessed as a catalytic tool to address the articulation gap between school and higher education through parity of participation within the broader South African context. The realisation of this key strategic imperative hinges to a large degree on the critical interrogation of enablers and constraints about sustainable utilisation of VAR applications in STEM teaching and learning.

Keywords: Pedagogical affordances, virtual and augmented reality (VAR), engineering and mathematics (STEM), South African context, teaching and learning

Introduction

Fostering transformative change in South Africa requires the promotion of open learning as a strategy that seeks to address the historical suffocation of educational dreams and limited

access to opportunities. Open learning is described by Paine (1989) as a process that emphasises access to educational opportunities and a philosophy which makes learning more learner-centred. As a pedagogic philosophy, open learning provides learners with the opportunity to choose how to learn, when to learn, where to learn and what to learn as far as possible within the resource constraints of any education and training provision (Paine, 1989). Characterized by principles of flexibility, recognition of prior knowledge, improved access, quality and success, open learning has the potential to transform education and allow for parity of participation. South African diverse and complex Post-School Education and Training (PSET) sector has institutions finding avenues of expression in multiple ways by taking different paths towards different kinds of openness.

In an attempt to foster sustainable integration of technological applications in STEM education, a hub in Virtual and Augmented Reality in STEM Education (VARSTEME) was launched at a South African university in 2021. The hub is envisaged to drive the strategic thrust in empowering pre-service and in-service teachers with knowledge and skills in the use of advanced learning technologies in STEM. In addition, it is envisaged that the hub would also support the pursuit of research studies on the efficacy and pedagogy of virtual and augmented reality. In the long to medium term, the hub would immensely contribute to the promotion of cutting-edge research which can subsequently be disseminated and shared with the global community. The VARSTEME hub seeks to promote access to sustainable utilisation of VAR applications through open learning. As a timely and strategic intervention, a hub in Virtual and Augmented Reality in STEM Education essentially provides meaningful platforms to harness opportunities for open learning in STEM education. To this end, this paper explores the extent to which pedagogical affordances of VAR applications can be harnessed as a means to alleviate social injustices in STEM education through open learning.

Background and contextualisation

The White Paper promulgated by the Department of Higher Education puts considerable emphasis on the importance of Post-School Education and Training (PSET) in meeting the needs of South African society (DHET, 2013). The PSET sector is tasked with addressing the economic demands through the provision of skilled and economically relevant labour force while playing "a vital role in relation to a person's health, quality of life, self-esteem, and the ability of citizens to be actively engaged and empowered" (DHET, 2013, p. 3). These requirements must be met in a national context that is not only plagued by historical

inequalities, but also contending with multiple contemporary challenges, including poor economic growth, fragmented infrastructure development, and political and social disunity as well as the prevalence of COVID-19 pandemic. According to Doyle (2020), a potential consequence of the COVID-19 pandemic is the widening of inequalities in education and skills development.

South Africa has witnessed a dramatic increase in student enrolment in undergraduate programmes across almost all universities (Hornsby & Osman, 2014). In addition, it has also been observed that South African higher education institutions have a particularly dismal track record and poor performing system that is characterised by pervasive discrepancies and other social and economic biases (Scott, Yeld & Hendry, 2007; CHE, 2013). Epistemic and epistemological challenges stifle meaningful enhancement of human capital development within the PSET sector as evidenced by the fact that less than 5 per cent of African and coloured youth succeed in any form of higher education (CHE, 2013). Fundamental challenges encountered in this regard can also be attributed to high levels of failure and dropout rates which have become a characteristic feature of the South African higher education system (Van Zyl, 2013; CHE, 2013). Student under-preparedness for tertiary studies is exacerbated by pervasive knowledge gaps exhibited by most poor students who emerge from disadvantaged contexts and dysfunctional schools (Spaull, 2015). The highlighted systemic challenges underscore the critical need to fundamentally rethink the complexity of the articulation gap between school and higher education within the broader South African context. This arduous task requires the implementation of strategic and innovative interventions which are geared towards the enhancement of the quality of STEM education.

Virtual and augmented reality

Immersive systems can play a pivotal role in the maximisation of students' academic experience. Different types of immersive systems can enable students to maximise their academic experience. These immersive systems include virtual reality (VR), augmented reality (AR), and mixed reality (MR). By their very nature, immersive systems offer the capability to capture new data, create new experiences, and provide new insights by creating virtual elements of physical and imagined worlds. Sacks et al. (2013) define virtual reality as "a technology that uses computers, software, and peripheral hardware to generate a simulated environment for its user" (p.1007). According to Schroeder (1996), a virtual environment or virtual reality technology is "a computer-generated display that allows or compels the user (or

users) to have a sense of being present in an environment other than the one they are actually in and to interact with that environment" (p. 25).

Augmented reality (AR) is distinct from virtual reality. Augmented reality modifies physical surroundings with superimposed virtual elements. Javornik (2016) explains that "this virtual layer, placed between the physical environments and the user, can add textual information, images, videos, or other virtual items to the person's viewing of the physical environment" (p. 252). Augmented reality is defined by Carmigniani et al. (2011) as a real-time direct or indirect view of a physical real-world environment that has been enhanced/augmented by adding virtual computer-generated information to it. This implies that AR is both interactive and registered in 3D as well as combines real and virtual objects. In support of these sentiments, Azuma et al. (2001) posit that AR is essentially a system that "supplements the real world with virtual (computer-generated) objects that appear to coexist in the same space as the real world." (p. 34). The integration of virtual and augmented reality applications in STEM education provides interactive learning environments which can be accessed through open learning as a key pedagogical modality.

Open learning in the South African context

The South African Department of Higher Education and Training (DHET) introduced Open Learning as a transformative response to the many challenges it faced during the apartheid era. DHET has promulgated several policy documents on open learning (DoE, 1997; DHET, 2013); DHET, 2017). Open learning is defined in the White Paper for Post-school Education and Training as an "approach which combines the principles of learner centredness, lifelong learning, the flexibility of learning provision, the removal of barriers to access learning, the recognition for credit of prior learning experience, the provision of learner support, the construction of learning programmes in the expectation that learners can succeed, and the maintenance of rigorous quality assurance over the design of learning materials and support systems" (DHET, 2013, p. 48). This definition is also encapsulated in the Open Learning Policy Framework promulgated by the Department of Higher Education and Training (DHET, 2017).

Open learning is built around four key areas, namely, access, flexibility, quality and success. More specifically, open learning focuses on the development of initiatives to improve performance (Govender & Dhurumraj, 2022). According to Govender and Dhurumraj (2022), access can be addressed through recognition of prior learning experience, the flexibility provided through the provision of tuition and peer engagement through various modes of

learning (i.e. face-to-face, blended and online learning) either synchronously or asynchronously. Quality is supported by the development of learning materials that undergo rigours quality assurance checks. Success is addressed through work-integrated learning (WIL) opportunities for pre-service teachers (DHET, 2013; DHET, 2017). Associated with open learning are Open Educational Resources (OER). Open Educational Resources (OER) are defined as educational resources that are openly available to all at no cost, and under some licences, there is an allowance for the resources to be reused, adapted, and redistributed with no restrictions (Hoosen & Butcher, 2019). Open Educational Resources are believed to have the potential to expand access and promote student success (Cannell, Macintyre, & Hewitt, 2015).

According to Blumenstyk (2017), a massive decline in the textbook market has resulted in the development of Open Educational Resources. Colvard, Watson, and Park (2018) argue that the exorbitant costs of textbooks have resulted in many students not attaining degrees due to the financial impact of exorbitant costs. The prevalence of the COVID-19 pandemic has critically exposed existing socio-economic disparities in South Africa. To mitigate the impact of the COVID-19 pandemic and socio-economic constraints, the use of OER can be adopted as a pedagogical modality to serve as a panacea for prevailing social injustices. Katz (2019) states that the use of OER represents a fundamental paradigm shift in education. Open learning and the concomitant use of OER in the PSET sector allow students to fulfil their higher-order needs as described by Maslow's Theory without compromising their basic needs. An empirical study conducted by Hilton (2019) revealed that students' academic performance is greatly enhanced by the usage of OER than hardcopy texts. VAR applications are essentially open educational resources that can be harnessed for the coherent development of scientific literacy through parity of participation to alleviate social injustices in STEM education.

Parity of participation

Fraser (2005) assigns a generic meaning of justice to "parity of participation". According to Fraser (1996), social arrangements must allow every adult member of society to engage with one another as peers to attain justice for individuals. Educational redistribution can be defined as the provision of resources that require more equitable distribution while including intellectual as well as monetary matters (Fraser, 2003). Fraser (2005) concurs with Hodgkinson-Williams and Trotter (2018) that there are always manifestations of socio-economic injustice during the use of open educational resources. These socioeconomic challenges include but are not limited to a lack of access to the required educational

infrastructure and materials such as functional technological equipment, affordable and stable connectivity and uninterrupted power supply (Hodgkinson-Williams & Trotter, 2018).

The establishment of the VARSTEME hub at a South African university seeks to provide meaningful platforms to confront these socio-economic injustices through parity of participation. The hub allows preservice teachers to make use of OER to enhance their learning experience. However, recurring load shedding in South Africa often restricts teachers' participation and access to interactive learning environments. Consequently, this restriction creates constraints which have an adverse impact on their studies. Hence, Hodgkinson-Williams and Trotter (2018) stress the need for economic redistribution to address maldistribution. Various studies focusing on different higher education institutions demonstrated that open learning and the use of OER is a more cost-effective form of learning for students (e.g., Hilton, Bliss, Robinson, & Wiley, 2013; Ikahihifo, Spring, Rosecrans, & Watson, 2017; Ross, Hendricks & Mowat, 2018). Hence, there is a need for a coordinated and ameliorative response to economic maldistribution.

Educational recognition refers to ensuring access to learners in every lecture as well as every classroom and not just in the rhetoric of policies and plans. The demise of Apartheid meant that an intellectually rich curriculum for learners would now allow for inclusive access that caters for the needs of previously marginalized communities (Fraser, 2003). Fraser (2005) describes parity of participation as the creation of social arrangements for individuals to be able to collaborate. However, success in creating such environments is dependent on knowledge of the students themselves, who they are, where they come from and their equity needs, and the ability to act on this information and tailoring support to address these needs to improve capacity (Keddie, 2012). In South Africa, the domination of western culture in teaching and learning results in cultural injustices. Open learning has the potential to ameliorate cultural injustices by creating opportunities for students to share their contextualised experiences.

Curriculum planning requires the involvement of various stakeholders to ensure equitable representation in curriculum reform. Exclusionary practices engender power asymmetries which lead to political injustices or misrepresentations (Fraser, 2005). According to Fraser (2005), a political dimension of justice brings matters of representation and framing strongly to the fore. Alongside the question of representation, the question of framing arises. Brought into sharp focus by increasing globalization, the porousness of national boundaries,

migrational flows and increased digitization critically exposed fault lines on identity issues (Fraser, 2010).

This paper argues that the implementation of open learning coupled with the concomitant use of available OER would create opportunities for preservice teachers to learn from their primary domain thereby reducing financial constraints and allowing individuals some degree of political power to interpret and share content based on their contextual setting. Fraser (2005) maintains that for "parity of participation" to be achieved, obstacles such as economic structures and the institutionalized hierarchies of cultural values that exist in societies need to be addressed. Hence, an educational curriculum that subscribes to the construct of open learning would ideally create opportunities for interaction among individuals. In support of this assertion, Kennedy (2016) states that curriculum programmes must afford learners opportunities to translate new ideas shared through collaboration into their systems of practice. The realisation of this key imperative requires coherent enhancement of epistemic and epistemological access. The paper further argues that coherent integration of VAR applications in STEM education can potentially provide opportunities for teachers and learners to fully embrace digital transformation as a key feature of the Fourth Industrial Revolution.

Formal access vs epistemological access

Morrow (2007) views epistemology as the theory of knowledge, especially about its methods, validity, and scope, and the distinction between justified belief and opinion. Apartheid policies had an adverse impact on the provision of quality education in South Africa. Morrow (2007) states that Apartheid education generated and perpetuated cycles of epistemological deprivation which deprived many learners of a fair opportunity to gain access to the kind of knowledge that is supposed to be distributed in formal schooling. The key question that we need to grapple with is whether formal access is a precondition for epistemological access. Morrow (1994) argues that there is a fundamental difference between formal access to the institutions that distribute knowledge and epistemological access. In essence, Morrow's argument implies that formal access is not a sufficient condition for epistemological access.

Physical access does not automatically translate into epistemic and epistemological access. Physical access alone is not sufficient according to Morrow (2009) as increased enrolments have historically not translated into equivalent student throughput (Scott, 2009). The integration of VAR applications can catalyze to promote access to disciplinary knowledge. Morrow (2009) defines epistemological access as "access to disciplinary knowledge and the

ways of knowing within a discipline" (p. 36). By its very nature, epistemological access - promotes alignment between institutional values and students' epistemological attributes as it enables a student to confidently and independently access the ways of doing and thinking within a particular discipline (Morrow, 2009). Antia and Dyers 2016 concur with Morrow (2009) and state that epistemological access may also address how new entrants to the system are confronted with epistemic barricades, that may be imposed or self-imposed. Within the broader South African context, various institutions of higher learning grappled with the complexity of the articulation gap between school and higher education through the sustained implementation of extended curriculum programs. However, sustained implementation of extended curriculum programs requires pedagogic innovation which underscores the need for integrating VAR applications in STEM teaching and learning in particular.

Theoretical Framework

The study is underpinned by the theory of social justice framework proposed by Fraser (2005). As a theoretical lens, the framework provided insightful elucidation into the extent to which initiatives promoting access, quality and success respond to historical and contemporary social injustices as well as conditions that enable and constrain success. According to Fraser (2005), social justice can be achieved through "parity of participation" which is defined as the "creation of a space in the learning domain for the equal participation of all individuals through the use of open educational resources" (p.73). Fraser (2005) identifies three dimensions of the social justice domain, namely, economic (maldistribution of resources); cultural (misrecognition of culture and identities); and political (misrepresentation or exclusion of voices). Parity of participation is achieved when these three interwoven domains are met (de Kadt, 2019; Leibowitz & Bozalek, 2016). The social justice framework served as a theoretical lens to demystify barriers that stifle the parity of participation in open learning. The VARSTEME hub mitigated social injustices that stifle meaningful participation in open learning as it promoted parity of participation in STEM education through the provision of access to VAR applications.

Methodology

The study adopted a qualitative research design located within the interpretivist paradigm. McMillan and Schumacher (2010) posit that a qualitative study is meant to be descriptive and interpretive. The qualitative design provided insightful elucidation into the pedagogical affordances of VAR applications as a means to alleviate social injustices in STEM education through open learning. Qualitative data was collected through semi-structured interviews with

purposively selected VARSTEME team members. The VARSTEME team members provided insights into the pedagogical affordances of the integration of VAR applications as a means to develop scientific literacy in STEM education through open learning. The VARSTEME hub development team members further provided insights into the strategic vision that inspired the establishment of the hub itself. Collected data were transcribed verbatim and the emerging themes were generated from participants' narratives. Qualitative data was subsequently thematically analysed using axial coding.

Research findings

Key findings were clustered according to the themes that emerged during data analysis, namely: professional empowerment of pre-service and in-service teachers with knowledge and skills in the use of advanced learning technologies in STEM, pedagogical affordances of VAR applications in STEM education, VAR applications as a means to support academic research endeavours, and the integration of VAR applications as a means to foster epistemic and epistemological access in STEM education.

Theme 1: Professional empowerment of pre-service and in-service teachers with knowledge and skills in the use of advanced learning technologies in STEM

The establishment of the VARSTEME hub was inspired by the critical need to professionally empower pre-service and in-service teachers with knowledge and skills in the use of advanced learning technologies in STEM. The hub provides opportunities for innovative utilisation of VAR applications to develop disciplinary knowledge to address pervasive knowledge gaps in key STEM domains. These sentiments are encapsulated in the following excerpt from the VARSTEME team members.

> Broadening educational pathways in STEM education requires the use of interactive technological applications such as VAR applications to foster pedagogic innovation in STEM teaching and learning. These applications can be harnessed to demystify abstract scientific concepts in key STEM knowledge domains (Participant 1).

Professional empowerment of pre-service and in-service teachers with knowledge and skills in the use of advanced learning technologies in STEM remains a key strategic imperative. The realisation of this key strategic imperative hinges to a large degree on the active involvement of the Department of Basic Education and other key stakeholders in innovative undertakings of this nature as the following excerpt illustrates.

> The VARSTEME hub development team is engaging the Department of Basic Education and other key stakeholders to forge a partnership geared towards the promotion of public awareness of the pedagogical affordances of VAR applications in South African schools. It is envisaged that appropriate arrangements can be made to train teachers on the use of VAR applications as part of the partnership (Participant 2).

Theme 2: Pedagogical affordances of VAR applications in STEM education

The participants highlighted the pedagogical significance of VAR applications in the development of scientific literacy in STEM education. Pedagogical affordances of VAR applications in STEM education are explicated in the following excerpt.

> VAR applications can be used to develop learners' visuo-semiotic reasoning skills and foster interactive learning in science classrooms. In addition, they can be used as semiotic tools to enhance conceptual understanding of abstract scientific concepts (Participant 3).

It is argued in this paper that access to VAR applications can be facilitated through open learning. Demystifying abstract scientific concepts in STEM teaching and learning can be an arduous task. This task can be ameliorated through the sustainable integration of VAR applications in STEM teaching and learning to enable the coherent development of scientific literacy. Therefore, the availability of open educational resources is of critical importance.

Theme 3: VAR applications as a means to support academic research endeavours

While the efficacy of VAR applications in the enhancement of teaching and learning is duly acknowledged, there is a critical need for formal empirical studies on the use of VAR applications within the broader South African context. The following excerpt highlights possible areas of research.

> Teachers' and learners' experiences of VAR applications can be examined as part of formal empirical studies. Pedagogical affordances of domain-specific VAR applications can also be investigated. In addition, the extent to which the use of VAR tools fosters deep learning through the development of higher-order thinking skills merits investigation as well. Other research areas include the use of VAR tools to foster science inquiry-based learning and the exploration of the impact of the use of VAR tools on different individual characteristics (e.g., level of performance, motivation, spatial ability) (Participant 4).

Context-specific exploration of the impact of VAR applications on teaching and learning is of vital significance as this critical endeavour would serve to provide insightful elucidation into the nature of intrinsic and extrinsic contextual factors affecting the sustainable integration of VAR applications in STEM teaching and learning in various educational settings.

Theme 4: The integration of VAR applications as a means to foster epistemic and epistemological access in STEM education

The use of VAR applications can be harnessed as a means to enhance epistemic and epistemological access in STEM education. The South African basic education system is characterised by socio-economic disparities which serve to perpetuate social injustices about the provision of quality education. Innovative use of VAR applications can be adopted as a means to alleviate socio-economic challenges which stifle the provision of quality education in South African schools as the following excerpt illustrates.

> Access to VAR applications can be harnessed as a means to address the complexity of the articulation gap between school and higher education. Enhancing student preparedness for tertiary studies is of crucial significance (Participant 5).

The enhancement of epistemic and epistemological access in STEM education requires a clear and critical understanding of the complexity of the articulation gap between school and higher education. Various institutions of higher learning in South Africa responded to this fundamental challenge through the implementation of extended curriculum programmes which are aimed at addressing student under-preparedness for tertiary studies. Confronting social injustices bedevilling the provision of quality education requires robust intellectual exchanges which disrupt the prevailing status quo. These intellectual exchanges ought to be predicated on a “business unusual approach” and unorthodox philosophical practices.

Discussion

The Covid-19 pandemic critically exposed socio-economic disparities within the South African basic education system. The advent of the Fourth Industrial Revolution (4IR) provided opportunities for teachers and learners to fully embrace digital transformation. However, there is a critical need to develop teachers' professional capacity for meaningful integration of 4IR in STEM teaching and learning using e-learning platforms. VAR applications can be used to develop learners’ visuo-semiotic reasoning skills and foster interactive learning in science classrooms. This assertion is consistent with a research study conducted by Nugroho and Surjono (2018) that demonstrated that an interactive and meaningful learning process is

required for learners to develop science process skills. In particular, interactive learning helps to overcome difficulties of perception and comprehension during the learning process (Tversky, Morrison & Betrancourt, 2002).

In addition, VAR tools can be used as semiotic tools to enhance conceptual understanding of abstract scientific concepts. The communication of any science is mostly through visuo semiotic models such as graphs, tables, diagrams, or simulations (Daniel et al., 2018). Various research studies demonstrated that learners lack representational competencies (e.g., Linder et al., 2014; Strickland et al., 2010; Treagust, 2008). However, it must be pointed out that inappropriate use of visuo semiotic models may lead to poor conceptual understanding (Schönborn & Anderson, 2006). These research findings underscore the need for the development of visuo-semiotic reasoning and representational competencies amongst learners. This mission can be accomplished through meaningful exposure to visualization (Daniel et al., 2018; Trelease, 2016). VAR tools can be used to foster science inquiry-based learning. The impact of the use of VAR tools on different individual characteristics (e.g., level of performance, motivation, spatial ability) can also be explored as part of formal empirical studies. Spatial ability refers to the ability to generate, retain, retrieve, and transform well-structured visual images (Lohman, 1996). By their very nature, STEM subjects require high levels of spatial ability for learners to understand them (Stieff & Uttal, 2015).

The use of VAR applications can be harnessed as a means to enhance epistemic and epistemological access in STEM education. However, the South African basic education system is characterised by socio-economic disparities which serve to perpetuate social injustices about the provision of quality education. Evidence-based solutions are required to adequately address the complexity of the articulation gap between school and higher education within the broader South African context. In support of this assertion, Morrow (2009) posits that epistemological access promotes alignment between institutional values and students' epistemological attributes. According to Antia and Dyers (2016), epistemological access can also serve as a means to address how new entrants to the system are confronted with epistemic barricades that may be imposed or self-imposed.

Professional empowerment of pre-service and in-service teachers with knowledge and skills in the use of advanced learning technologies in STEM remains a key strategic imperative. The realisation of this key strategic imperative hinges to a large degree on the active involvement of the Department of Basic Education and other key stakeholders in innovative

interventions of this nature. Sustainable exposure to the use of VAR applications is commensurate with the implementation of the Coding and Robotics Curriculum by the Department of Basic Education (DBE, 2019). The use of VAR applications can be harnessed to develop disciplinary knowledge to address pervasive knowledge gaps in key STEM domains.

Interpretation of key findings in terms of the adopted theoretical framework

As indicated earlier, the study is underpinned by the theory of social justice framework proposed by Fraser (2005). Embracing digital transformation requires fundamental access to technological resources. A substantial number of schools in South Africa are under-resourced. The general lack of resources perpetuates social injustices in the provision of quality education. Socio-economic disparities characterising the South African education system ought to be addressed to pave the way for sustainable utilisation of VAR applications to enhance the quality of STEM education in schools. Challenges that often stifle meaningful integration of VAR tools in STEM education include technical problems (Kamarainen et al., 2013), cost of devices (Echeverría et al., 2012), usability and complexity of devices (Fidan & Tuncel, 2019) and marker detection problems (Cai et al., 2014). In addition, students can be cognitively overloaded by the large amount of information they encounter, the multiple technological devices they are required to use, and the complex tasks they have to accomplish (Dunleavy et al., 2009). The highlighted challenges should not serve as a deterrent to sustainable integration of VAR tools in STEM teaching and learning.

The use of VAR tools should instead be harnessed as part of key strategic interventions to promote epistemic and epistemological access, quality enhancement and success to provide a coordinated response to historical and contemporary social injustices. This paper advocates for the promotion of social justice through parity of participation in the use of VAR tools which is largely predicated on the need to create spaces in the learning domain for equal participation of all individuals through the use of open educational resources. The realisation of this key strategic imperative requires critical interrogation of enablers and constraints about sustainable utilisation of VAR applications in STEM teaching and learning.

Conclusion

Sustainable integration of VAR applications in STEM education provides a solid basis for the promotion of epistemic and epistemological access to alleviate social injustices bedevilling the provision of quality education. Professional empowerment of pre-service and in-service

teachers with knowledge and skills in the use of advanced learning technologies in STEM remains a key strategic imperative. Meaningful development of scientific literacy in STEM classrooms hinges to a degree on the innovative integration of VAR applications in teaching and learning. There is a need to harness the pedagogical affordances of VAR applications to promote the parity of participants in STEM education. Coherent integration of VAR applications in STEM education can potentially provide opportunities for teachers and learners to fully embrace digital transformation as a key feature of the Fourth Industrial Revolution.

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