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Editorial Special Issue April 2024

Reimagining the Teaching of STEM Subjects Through Arts-Based and Participatory Methodologies

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This special issue of *Educational Research for Social Change* focuses on rethinking the teaching of science, technology, engineering, arts, and mathematics (STEM) subjects through integrating creative arts-based (thus, STEAM) and participatory methodologies in classrooms. Methods of teaching of STEM subjects, mostly using traditional teaching methods (e.g. lectures, question-and-answer, practical work) have worked to some extent. They have however, been found to present knowledge that students only meet in formal institutions, and through strategies that have little relevance to the students' lives. These strategies and knowledge ultimately leave some students alienated from the intended learning of STEM subjects. And this, in turn, undermines the purpose of education—to enable each learner to develop their talents to the full and to realise their full creative potential including responsibility for their own lives and achievement of their personal aims, goals, and objectives.

The aim of the United Nations' Sustainable Development Goal #4 (Global Goals, n.d.) is to facilitate quality education at individual, societal, and global levels in order to foster sustainable development. Good quality STEAM education therefore helps learners to attain well-being by creating conditions for flourishing—that is, the continuing development of their optimal potential and living as human beings. It means learners should be engaged in relationships and activities that are meaningful to them (de Ruyter, et. al., 2022). These engagements should thus be aligned with an individual's own values and humanistic values, which enables them to achieve well-being in the learning of STEAM subjects. This calls for the reimagining of educational processes that promote human flourishing through education.

Approaches to the teaching of STEAM must involve transformative approaches to the teaching and learning. Transformative teaching and learning approaches can humanise subjects by showing their connections to other aspects of learners' lives. Humanising knowledge commonises it, rather than making it a privilege for the few who can understand it (Bollier, 2020). Transformative teaching and learning approaches facilitate epistemological access, which reduces the alienation perpetuated by traditional teaching methods. Furthermore, transformative methodologies that enable epistemological access assist with the decolonisation of the discourse of STEAM subjects.

In this issue, Caleb Mandikonza explores transformative approaches to teaching using arts-based teaching approaches in natural sciences education in his article, "Using Arts-Based Methodologies: Facilitating First-Year Pre-Service Teachers' Collaborative Teaching of Cell Biology." His students worked in small groups to present on teaching cell biology concepts of their choice, using strategies such as dance, drama, music, poetry, and drawing as stimulus for learning the concepts.

Tholani Tshuma and Eunice Nyamupangedengu's article, "Drama in the Science Classroom: Reimagining the Teaching of Natural and Life Sciences" demonstrates how the integration of arts-based, participatory, and humanistic methodologies in the teaching of science subjects has potential to stimulate student interest, facilitate epistemological access, and improve their performance. Through self-study research, these two teacher educators share and reflect on their observations and experiences of using drama in teaching science concepts (diffusion, DNA structure, meiosis) and a socio-scientific issue (albinism) to pre-service teachers training to be high school teachers. Data were in the form of drama scripts, journaling of observations, reflections, and discussions with a critical friend.

The next article is "A Formative Study Towards the Inclusion of Indigenous Technologies and Knowledge Practices in Science, Technology, Engineering, Arts, and Mathematics (STEAM) Curriculum Settings" by Rob O'Donoghue, Wilma van Staden, John Bhurekeni, Janet Snow-Macleod, and Lindiwe Ndlamlenze. These authors use a cultural-historical approach to examine three collaborative case studies through formative research on the pedagogic tools for including Indigenous technologies and knowledge practices in teacher education (these practices are generally excluded in the contemporary classroom). They found that although teachers are highly interested in their Indigenous knowledge heritage, they do not have the knowledge to include this in their teaching—and their learners tend to prioritise modernity over indigenous heritage and technologies, often undervaluing the latter as forgotten past.

Drawing from the project, Mentoring as a Method to Promote Women's Health in the Context of HIV-Prevention and Unequal Gender Relations, Mathabo Khau's article reports on "Using Drama Pedagogy to Enhance Understanding of HIV Transmission, Infection, and Prevention Among Third-Year Student Teachers." The data were generated through the arts-based activity, drama, to teach about HIV transmission to student teachers in a bid to equip them with alternative ways of teaching learners about HIV and AIDS. Her findings disclose the student teachers' lived experiences, and how they shaped their perceptions of HIV infection and living with AIDS, and that the arts-based pedagogy allowed for their enhanced understanding of complex phenomena.

In her position paper, "Enabling STE(A)M in Sustainability Education Through Dialogic/Dialectic Reconciliation," Ingrid Schudel uses illustrative examples of a broad range of arts to explore possibilities for STEAM education with an education for sustainable development focus that counters disciplinary alienations between the arts and the STEM disciplines. This author posits that unnecessary alienations between cultural-emblematic and mathematical-logical epistemes, especially those linked to narrow interpretations and restricted developments in dialogism and dialectics respectively, are

influenced by restricted understandings of epistemological, ontological, and praxiological philosophical drivers in meaning making and responsive action. Her paper further develops a series of philosophical principles that could underpin STEAM education practices.

Next, is the article "Exploring Design Principles for STEAM Learning Activities Development by Science and Technology Teachers" by Maria Tsakeni. Following the design-based research stages of needs analysis, development, testing, and reflection, her study produced design principles underpinned by the learning theory of constructionism. These principles include design thinking, finding solutions for learning problems, creativity, and innovation applied to instructional design. Her study recommends the use of design thinking pedagogies in developing teacher knowledge on STEAM classroom practice

Eunice Nyamupangedengu and Constance Khupe's article, "Turning the Art of Karanga Beer Brewing Into a Science: An Example of Humanising Biology Teaching and Learning" demonstrates how Indigenous knowledges can be incorporated into STEM subject content. They argue that humanising the teaching of STEM subjects by building on Indigenous knowledges can make these subjects attractive, accessible to, and relevant for students—especially given that many children are engaged in subsistence-based knowledge economic practices and activities that are rooted in Indigenous practices.

The book reviewed in this issue is *Against Racial Capitalism: Selected Writings, Neville Alexander* (Vally & Motala, 2023). According to Nadeema Musthan, this carefully curated collection of Neville Alexander's writing is the latest contribution to ongoing collective efforts to honour who Alexander was, acknowledge and interrogate the vital intellectual contributions he made (particularly in reference to contemporary struggles), and recognise the indelible mark he left—not just in South Africa but globally. This edited selection of Neville Alexander's writing was complied by two of his long-standing friends, Salim Vally and Enver Motala, who have individually and collectively, struggled and continue to work tirelessly in workers' education, community struggles, political, worker and student organisations, and globally in anti-colonial struggles of various kinds. This contribution not only introduces Neville Alexander to another generation of activists and engaged intellectuals but also serves as an expression of radical love, which encourages us to build critical communities, insist on and engage in dialogical spaces, and develop critical reflective practices oriented towards human dignity and a more just world.

This special issue ends with Logamurthie Athiemoolam's report on the 10th South African Education Research Association conference hosted by Rhodes University from 30 October to 3 November 2023, with the theme *Education(al) Foundations, Education(al) Futures.* The conference was well attended with over 300 delegates from across the spectrum of higher education institutions in South Africa and from some international universities too, including Sweden. A noteworthy feature of the conference was that it offered a rich, diverse programme that included plenary presentations by renowned educational researchers, workshops, parallel sessions, book launches, poster presentations, and ample opportunities for networking during the conference. Participants believed the conference shed light on important issues affecting education at large, and contributed positively to their ongoing personal, professional, and academic development within the contexts of the higher education institutions. The sense of sharing common issues, challenges, and concerns in a collaborative, collegial, and supportive space—especially for novice and emerging academics—signified hope for the next generation of academics.

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Using Arts-Based Methodologies: Facilitating First-Year Pre-Service Teachers' Collaborative Teaching of Cell Biology

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Abstract

Even with well-prepared lectures, some of my students still struggled to understand some of the concepts of cell biology. I therefore wondered if an exploration of teaching methods involving the arts would help them to engage with the subject content in ways that made it more accessible, and help them to understand the concepts better. Building on earlier approaches of using collaborative learning, I requested students to discuss, plan, and present to each other on cell biology concepts using arts-based teaching methods. In groups of 4–6 members, they could use any strategy such as dance, drama, music, poetry, and drawing to teach the concepts. The students collaboratively prepared content for a concept of their choice and presented it using their chosen and developed teaching strategy. Some of the strategies that students seemed to enjoy using included rapping the concepts, songs, dance, role play, and poetry. A few students resorted to individual PowerPoint presentations. The hope was that the enjoyment would translate into students' familiarisation with and understanding of the concepts better than through traditional teaching. Although the approach demonstrated that students could teach these concepts in versatile and fun ways, it did not assess their understanding of the concepts presented.

Keywords: arts-based methodologies, STEAM, STEM, teaching strategies, lecturer-designed task, micro-teaching, epistemological access, reflective narrative, flipped classroom

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Introduction

Can students learn concepts of cell biology better through arts-based activities such as song, dance, drawings, and poetry? How can an educator facilitate students to engage with everyday arts activities such as song and dance to learn concepts in life sciences? Life sciences is one of the science, technology, engineering, and mathematics (STEM) disciplines that are also grouped as science,

technology, engineering, arts, and mathematics (STEAM) subjects (Aguilera & Ortiz-Revilla, 2021; Xanthoudaki, 2017).

The disciplines that constitute STEM are similar in their knowledge discourse and structure and are deemed to have connections between them. Bernstein (1999, p.159) described them as having "a coherent, explicit, and systematically principled structure, hierarchically organized, as in the sciences." These similarities and connections (Uştu et al., 2021) gave them the potential for an interdisciplinary approach to teaching the subjects. The STEM approach to education thus promises curricula as a meta-discipline where interdisciplinary bridges bring together what the traditional curricula have taken as separate disciplines (Uştu et al., 2021). Experiences of real life are complex, multifaceted, and constantly evolving in context. Disciplinary teaching and intended learning view science knowledge as static and fixed and as such, easy to understand because it is governed by laws and principles (Henriksen, 2014). Disciplinary knowledge in STEM subjects is also specialised and hierarchical (Maton, 2013), which makes their interaction with other forms of knowing discrete from each other and from human experiences and particularly, seemingly distant from the lived experiences of the students who are expected to learn, understand, and make use of the knowledge.

Interdisciplinary approaches can help educators to create learning opportunities through pedagogical approaches that mimic real life situations, which are often complex and ill-defined. Interdisciplinarity has been shown to foster creativity in students (Kubat & Guray, 2018). An interdisciplinary approach to teaching STEM subjects also provides students with increased motivation because authentic learning opportunities are meaningful and have a clear purpose to which students can relate. To engage in interdisciplinarity, students must first understand the concepts and then will they be able to relate to them. This study did not delve into interdisciplinarity but explored how students relate to the content through different lenses.

The poor performance of learners in general, in STEM subjects is due to the perception that they are difficult to teach and to learn (Winberg et al., 2019). They are difficult to learn because the knowledge is distant from learners' lives. STEM subjects are also perceived to be difficult to learn because the curricular and teaching approaches used often decontextualise the students from the knowledge and ultimately, alienate students from the intended knowledge (McKenna & Boughey, 2016). Students do not find any relationship with the knowledge because of its nature, how it is presented to them, and expectations relating to assessment. This alienation is associated with how the students are cultured into the university. The university culture is rigid and cannot accommodate students' prior knowledge and experiences of life and of learning. McKenna and Boughey (2016) argued for academic literacies, including scientific literacies, to homogenise university literacies with student culture—rather than depending on university literacies alone in classroom settings. This was echoed by Muller (2014) who asserted that the culture of teaching affected the achievement of students and hence, their success rate. This alienation results in lower enrolment and ensuing performance, particularly of women at tertiary level (Anaya et al., 2022), including teacher training.

Ultimately, those few students who do enrol for STEM subjects do not all complete their respective courses. Students need to be enculturated into the university so that their learning interactions are not divorced from their lives; the culture of teaching and learning must not exclude but recognise them so that they can also recognise themselves in the knowledge gained in STEM classrooms. The perception that STEM subjects are difficult also partly emanates from the poor epistemological access, which is ascribed to classroom-based factors including pedagogical approaches that alienate learners from the subjects and affect their self-efficacy and their beliefs about their abilities (Middleton et al., 2019). Bozalek et al. (2011, p. 2) noted:

> *Normative theories of student learning suggest that the lecturer needs to expose students to knowledge in the field and students will, on their own, be able to piece together how it works. In this autonomous model, students intuitively discover and understand the mechanics of the taught field, and are thus able, given that they apply themselves diligently enough, to both understand and even, at higher levels, produce knowledge in the field. When students find this difficult or even impossible to do then the fault must lie with the student; students may be cognitively unable or just too underprepared to grasp the concepts in the field.*

In this ubiquitous model of teaching in university settings, students are expected to be autonomous individuals who function by making sense of knowledge, and are able to cope with the demands of a course if exposed to its knowledge. This expected outcome is not always the case and the model is the cause of poor performance. According to Muller (2014), epistemological access has its roots in "what it means to teach" (p. 255). The implication is that teaching needs to be guided by the purpose to enable students to understand the knowledge intended for them in STEM subjects. Maniram and Maistry (2018) defined epistemological access as how students negotiate and access disciplinary knowledge, including the ways of knowing that influence their knowledge within a discipline.

This position challenges lecturers who have the pedagogic responsibility to be responsive to students' learning contexts, and to achieve epistemological assess for their students—particularly in STEM subjects. Muller (2014, p. 264) posited that a balanced and contextually nuanced mix of three aspects of epistemological access is appropriate for developing understanding of knowledge and meaning making, namely:

- Knowledge of theoretical propositions and theoretical systems, which focuses on theoretical, conceptual. and dispositional knowledge.
- Knowledge of things themselves, which implies knowledge of physical things and phenomena that constitute the things.
- A practice, its associated rules, norms, and customary moves. This aspect propounds that knowledge can be understood as practice and can be expanded through practice in a community, as suggested by Vygotsky (1978) and developed by Wenger et al. (2002).

Epistemological access is intertwined with the notion of *learning as connection*. Shumba and Kampamba (2012) suggested that the learning of science happens at the nexus of concept and context. This implies the student's social-cultural, socioecological, personal, familial, and other real-life situations and experiences in the community are relevant for meaningful learning. This is particularly important in STEM subjects, which seem distant from the lived lives of students. The lecturer should design teaching that will enable students to draw from the various tools in their lives to make meaning of the knowledge.

This study sought to draw from students' experiences of the arts to enable them to show their understanding of cell biology concepts. In so doing, the teaching was hoped to be humanistic and help with the *commoning* (making common) of the knowledge (Freire, 1970; UNESCO, 2015). Carter et al. (2021) thought the STEAM approach has potential to challenge existing identities of students, teachers, and researchers on how they view the nature and dominance of their home disciplines, their knowledge base, and nurtured abilities to handle the knowledge of these disciplines. STEAM therefore has potential to open and enable different spaces, skills, and competencies without converting artists

into scientists or scientists into artists. It should only end at the point of enabling students to appreciate the interconnected (rather than the disciplinary) nature of knowledge.

Teacher educators therefore are tasked with preparing pre-service teachers to teach STEM subjects in a manner that makes them interesting and fun for learners such that there is an improvement in their performance and consequent increased uptake of STEM specialisations. Arts-based methodologies entail the use of arts subjects and methodologies for teaching (Carter et al., 2021). Thus, this article explores the use of arts-based and participatory methodologies in the teaching of life sciences, a STEM subject. This perspective has the potential to generate capabilities and competences that enable new, deeper, meaningful, as well as humanistic learning experiences—thus, a STEAM approach. Therefore, rather than exploring only the teaching of STEM, the investigated approach explores the pedagogical link between STEM and some forms of arts. The main research question for this study was: "How can a lecturer facilitate arts-based collaborative student interactions for STEM teaching in a life sciences classroom?"

The following sub-questions guided the study:

- How do pre-service teachers present the concepts using the chosen strategies?
- What are the emerging insights on the students' use of arts-based methodologies to present the chosen organelles?

This study was conducted in a first-year life sciences pre-service teacher context.

Literature Review

The key concern for this study was the employment of an alternative teaching method that would help students to collaboratively make sense of the concepts of cell biology in meaningful and engaging ways using arts of choice in microteaching activities. Mandikonza (2022) has demonstrated that pre-service teachers appreciated working collaboratively to develop an understanding of the cell biology concepts. Further to this, working collaboratively to understand the arts through using the arts is likely to enhance students' creativity and facilitate them to unlock their intelligences (Carter et al., 2021; Talib et al., 2019; Zhbanova, 2019). An assumption is that while engaging the arts for teaching science, students would also understand the arts better. Engaging the arts can be a creative process as students use them for their intended purposes. Zhbanova (2019) contended that the creative process emerges from observation, finding patterns, creating mental images, and making conclusions, all of which make learning more meaningful. In this case, it was hoped that facilitating students to engage with science concepts by using the arts would be a creative process but more important, would improve their ability to relate the arts to science concepts.

Stohlmann et al. (2012) suggested that among other practices for teaching math and science at high school, cooperative learning was important with the educator as facilitator. To achieve this, the teacher should build on students' prior knowledge to enable knowledge to be advanced through social discourse. Knowledge building should be understood as a social process in context, that is, it involves social interactions. This assertion agrees with sociocultural approaches to teaching and learning as propounded by Vygotsky (1978) who argued that the learning process should engage the individual in meaningful social learning processes. Carter et al. (2021) identified STEAM as a social practice that is increasing ecological awareness because learning is in context. Therefore, students' ability to construct new knowledge of science using what they already know, and what relates to their experiences, is paramount for learning. This means the ability of students to contextualise knowledge is important for

knowledge development. Zhu (2020) foregrounded student-centred active learning as the key outcome of an integrated STEAM approach to teaching. That means students are engaged throughout the learning sessions. Student-centred active learning was also proposed by Taber (2018), who argued for mediation of social learning processes within students' zone of proximal development (ZPD).

Zhu (2020) further identified interactive lectures, blended learning, and individualised instruction as key elements for STEAM teaching and learning. Interactive lectures include question-and-answer activities that engage both educator and students in developing concepts. According to Zhu (2020), blended learning involves online and face-to-face interactions. The flipped classroom is a key component of this approach. The flipped classroom is when students are given a task to do away from the classroom, and then bring their task response to the classroom. The lesson can be conducted online or face-to-face. Lesson content is developed through facilitation of the students' responses (Church et al., 2021).

Henriksen (2014) described how a teacher requested students to create visual images of a concept (visual art used to teach a concept or idea). The teacher in question asked students to design an advertisement to sell a cellular organelle. Students drew on advertisement, artistry, and the intended cell biology knowledge to come up with the visual presentation. This teacher also asked students to write songs about cell concepts and sing them in class. This is similar to the approach I used, but I left it open for students to choose any strategy they wanted to use to teach any selected concept.

Research Methodology

This article presents a reflective narrative of my attempt at enhancing epistemological access by engaging first-year students on concepts on the topic of cell biology through the explorative use of arts-based teaching and participatory methodologies at a South African university. All first-year sciences students take the Natural Sciences 1 course. Cell Biology is the first topic in the Life Sciences component of Natural Sciences 1, and forms the basis of Life Sciences in the four-year teacher education programme.

First, I taught the general structure of the cell, and presented the general structure of both plant and animal cells as seen through the light microscope on PowerPoint. This showed the outline of the cell and a few organelles including the cell membrane, the nucleus, and the cytoplasm. This was to familiarise the students with the high school diagrams and introduce them to the images of plant and animal cells that they would observe with the light microscope during their practical sessions in the laboratories. I further used PowerPoint to introduce the ultrastructure of the cell as seen under the electron microscope. I used diagrams presented on PowerPoint to show details of the contents of the nucleus and of the cytoplasm. Further to the PowerPoint presentations, I played YouTube video clips that showed the general ultrastructures of the plant and animal cells, respectively. I used the nucleus and the cell membrane to introduce students to how the structure of organelles is related to their function in the cell, and I taught about these few organelles. In this study, as a teaching method, pre-service teachers were tasked to work in small groups of between four and six members to design a 10–15-minute micro lesson using any method of their choice among song, rap, poetry, role play, drawing, and PowerPoint to teach the structure and function of an organelle of their choice and to present this to their colleagues in class.

Corrégé and Michinov (2021) found that a group size of four members was effective for students because they provided adequate conditions for discussion and collaboration leading to *learning gain*—a term that implies learning. Blatchford and Russell (2020) thought small groups of four to six allowed for student interactions and provided opportunities for the teacher to assist individual students. Enu

et al. (2015) pointed out that although cooperative learning was enhanced in small group settings, group size itself was not important—it is the strategies used to engage groups that are important in driving learning of concepts. My decision for four to six students was conscious and deliberate; the information on each of the organelles was very brief and did not need more presenters. And, small groups were ideal because collaborating members of a group tend to present together, and the time available would give each one a chance to present and receive comments from the lecturer on their part. The prompt for the students' task was:

> *Work in groups of 4–6 members to use any of the strategies such as dance, drama, music, poetry, and drawings to teach the structure and function of cellular organelles of your choice. The lesson presentation will be for 10–15 minutes.*

This article reports on that task by means of vignettes of students' work and lecturer reflections to establish the efficacy of the exploration. The quality of students' presentations is used here as a proxy for success of the method. Quality was determined by the appropriateness of the method or strategy used, the correctness of the content, the learning support materials used to present, and how innovating and captivating the strategy was for the audience. A qualitative, interpretive, and reflective narrative case study was used. Qualitative research focuses on understanding real-life problems, including concepts, opinions, emotions, or experiences, and relationships of research participants without using numbers (Mohajan, 2018). In this instance, I present the case of my experiences with students using arts-based methodologies to present on cell biology concepts. I studied these experiences by establishing if the approach used to give students a task to present on organelles was appropriate for teaching about the cell structure and function. Students' groups presented online during online sessions. Research participants were the Natural Sciences 1 student teachers and me. The data generated from online lessons were recorded on the Canvas Ulwazi institutional platform. The data therefore were in the form of audio-visual recordings. Because an interpretive approach permits subjective and multiple perspectives, the researcher can explore human experiences in their socio-ecological contexts. Thus, I could study my own experiences of facilitating the use of arts-based methodologies to teach topics in cell biology. These were presented as vignettes in this report.

An interpretivist paradigm was appropriate for this study because it provided for the researcher to study social reality, which is viewed as not singular or objective but is rather shaped by human experiences and social contexts (Tracy, 2013). Therefore, it is appropriate to subjectively study the phenomenon of using of arts-based methodologies in social contexts and classroom teaching processes. Knowledge is developed through communication and practice is mediated by the researcher (Tracy, 2013). The case study was appropriate for this study because it allowed for the study of the contemporary phenomenon, the use of arts-based methodologies, in participants' natural setting. The natural setting was the interactions in a teacher education classroom (Johansson, 2005). Data for the study were in the form of PowerPoint presentations, lecturer's notes, and students' notes and the artefacts they produced for and during presentations.

Narrative enquiry was appropriate because it is a form of qualitative research where accounts are the raw data (Chambers, 2003; Wolgemuth & Agosto, 2019). Narrative studies discern meaning by analysing stories about individuals and the societies in which they live. They also present interactions within the societies by studying how these stories are constructed. Therefore, narrative enquiry is suitable for a qualitative interpretivist study because it allows for the development of subjective and contextualised knowledge (Butina, 2015; Creswell, 2007; Wolgemuth & Agosto, 2019). A biographical account of the processes and struggles involved in the practice of teaching cell biology allowed me to interrogate nuanced experiences of the phenomenon. This interrogation of practice is in line with Clandinin and Connelly (2000), who posited that narrative enquiry can be conducted within formal institutions, including classrooms in schools. The narrations themselves, being an analytical artefact,

are accompanied by a process of reflection. This reflective process elicits reflection-in-action (the reflections on practice development that took place during lessons) as well as reflection-on-action—investigating the unfolding of the teaching practice and its effect on conceptual development, as well as the affective dimension of the phenomenon after the lesson (Chambers, 2003).

At the beginning of the year, students were invited to participate in research processes aimed at improving my teaching practice. Students were invited to complete consent forms and were informed of the voluntary participation clause, which provided that should they change their mind at any time during the year, they were free to withdraw or to withhold their participation in any of the studies. Data were analysed inductively, and the analysis was guided by the key concepts in the literature and the research questions. It was notable to examine the accounts presented in the vignettes and establish what they meant for the research questions.

Results

The class had 270 students. These pre-service teachers worked in self-organised groups of between four and six participants. It was not possible to establish the exact number of student groups that shared an organelle because only a few of them presented due to time constraints, and they tended to repeat the organelles. Only two or three groups could present on the same organelle. Groups that shared an organelle were asked to provide input by adding information the presenters had missed. Table 1 shows the distribution of groups per organelle presented.

Table 1

Distribution of Groups per Organelle Presented

Group Size	No. of Groups	Organelle	Strategy Chosen
5	3	Nucleus	PowerPoint, pictures, and video
20	1	Cell/plasma membrane	Role-play/drama, song, and video
6	3	Rough endoplasmic reticulum	Poetry, PowerPoint, and video
6	2	Golgi body	Poetry
4	2	Lysosomes	Song
6	2	Mitochondria	PowerPoint and video
5	2	Ribosomes	Song
5	2	Plant cell wall	PowerPoint image
6	2	Chloroplast	PowerPoint image and video

For the PowerPoint presentations shown in Table 1, one member of the group acted as organiser and conductor of the presentation and guided the others. They introduced the members and the layout of the presentation. The other members presented a few lines of the script notes of the organelle, in turn.

Group members therefore chose sections of the scripts that they would present, however, they all worked on the same script. That implies that in their preparation, students would have familiarised themselves with their respective scripts. This allowed for smooth transition from one presenter to the next and if there was a diagram, they all referred to the same one. My thinking is that students collaboratively helped each other to understand the organelle prior to presentation. Although an observer could not conclusively say that the students had learnt and understood structure and function of the organelle, there is evidence that there were social processes when students interacted on the organelle.

When presenting in song, members of the group participated simultaneously, with participants taking different roles. Some members hummed the tune as others presented the notes as lyrics of the song. This choice of presentation was different from the previous one where students took turns to present from one script—here, they contributed together by providing lyrics and the sound.

Because there were fewer organelles than groups, two or three groups sometimes prepared to present on one organelle. Over and above the organelles, students could also cover the topic of the general structure of the cell itself, which I had covered in class. Six groups chose to use song and poetry, 10 groups used PowerPoint presentations, and one group used role-play (drama). Due to time constraints, not all groups could present and so those that shared an organelle had one group presenting and the others added comments on what was missing, and whether and how the strategy used was effective for teaching the organelle.

Only songs, role-play, and PowerPoint are highlighted in this research report to illustrate the creativity that pre-service teachers have, and can show, if the lecturer gives them a chance to explore collaborative teaching using unconventional strategies.

Songs

One of the songs that six pre-service teachers composed was on the cell membrane, and is presented in Excerpt 1.

Excerpt 1

Lyrics for a Song on the Cell Membrane

The Plasma membrane
-the plasma membrane is the membrane enclosing the cell
-another name for the plasma membrane is the cell membrane
-it is found in all cells and it separates the interior of the cell from the exterior environment
The plasma membrane has got proteins which stick outside of it that allow for cells to interact with one another.
-These membrane proteins have got different functions, one them being the Junctions which serve as a connection between two cells joined together.
-There are Gap junctions and also Tight functions
-Their function is to help cells communicate with one another and be able to receive and also transfer different materials between each other.
-Another function served by membrane proteins is Enzymes function
-The enzymatic activity is to localise metabolic pathways fixed to membranes,

membrane embedded enzymes catalyse chemical reactions occurring within the cell.
Transport protein takes important substances from one side of the membrane to the other side,
Important substances like ions(sodium and potassium)sugars(glucose), messenger molecules and many more.
We have two different types of transport protein
1. activated diffusion
2. Active transport

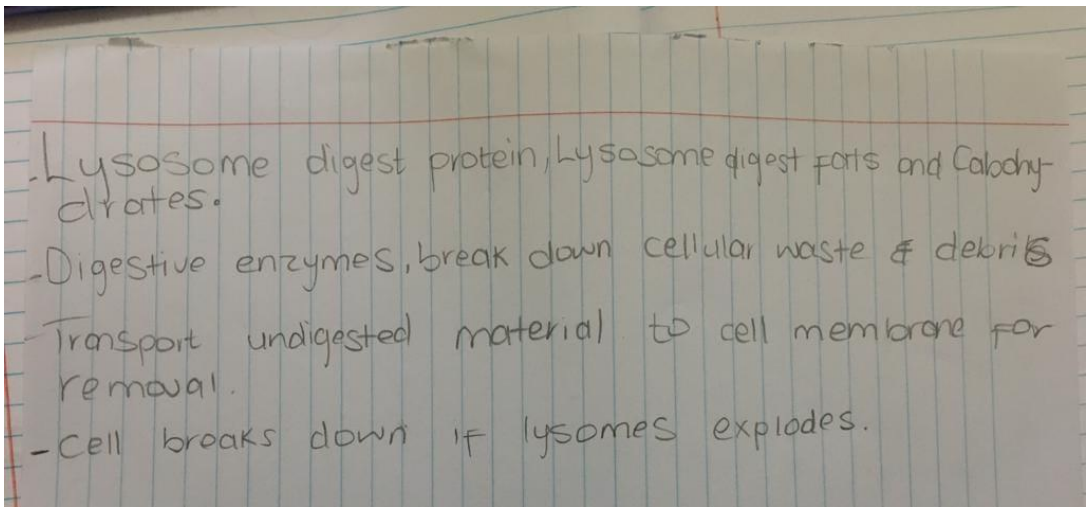
Four group members each narrated a few lines in turn, while the others hummed a tune and performed a slow swing dance. While they sang, I took note of what was missing and what needed to be corrected. After the presentation, I asked the other students to comment on how appropriate the strategy chosen was, how it was implemented, and the correctness and depth of the content. The melody was very beautiful; it was a mix of a capella and rap. The group received resounding applause from the rest of the class.

I proceeded to illustrate where the cell membrane is located, and how it relates to the structure and functions of the cell. Because the students had sung the song, they did not have an illustration of where exactly the cell membrane was. Therefore, I consolidated their presentation by referring to an image of the generalised structure of the cell to show the location of the cell membrane. I then presented the fluid mosaic model of the cell membrane to show the different components, including the bilipid layer, the intrinsic and extrinsic proteins, glycolipids, glycoproteins, cholesterol, and phosphorins to illustrate some of the concepts on the architecture of the cell membrane that were alluded to in the song.

Another group of six presented an a capella song with the following lyrics about the lysosome (Excerpt 2).

Excerpt 2

Lyrics for the Song on Lysosomes



One member sang the lyrics soulfully while the others hummed a background sound. They combined this song with a PowerPoint image of the structure of the lysosome, which they showed to the class during their song. Their visual presentation shifted from the singers to the PowerPoint presentation that showed the structure of the lysosome. They combined the singing with a slow swing dance as they

hummed. The presentation was therefore multimodal—the song, its lyrics, and the image. Given the time available for each group presentation and the brevity of their notes, this group repeated their song thrice. Of note, was that although the dance was not related to the organelle in question, it made the presentation interesting to watch and listen to. The content presented on structure and function of the lysosome was correct, and the method chosen was appropriate for the teaching. I consolidated this by showing a YouTube video of the lysosome. I also noted that the students had not distinguished between primary and secondary lysosomes and therefore used the presentation as a background on which to build content on primary and secondary lysosomes. And I linked these to phagocytosis, phagocytic vesicles, pinocytosis, and pinocytotic vesicles to result in secondary lysosomes. It was also important for me to distinguish lysosomes from other single membrane bound organelles, the peroxisomes. The presentation therefore demonstrated the knowledge that could develop through collaboration and zones of proximal development (Vygotsky, 1978). I acted as a more knowledgeable other to expand students' knowledge to show relationships between lysosomes and other organelles.

Role-Play

One group designed a role-play for the fluid mosaic model of the cell membrane and transmembrane transport. They organised themselves into a bigger group of 20 members by combining four groups. Some members faced each other in a line and held hands to represent the phospholipids. Some with labels on their shirts stood between them to represent transmembrane proteins, and others with different labels on their shirts represented extra membrane proteins and yet others with labels on their shirts represented the particles that were to move across the membrane (including water, alcohol, lipid molecules, and cholesterol). The particles were labelled as polar and non-polar particles. One participant was a narrator and at each stage, she narrated the structure and behaviour of the membrane and the particles.

Although the fluidity of the membrane was not illustrated, the correct content of the basic structure of the membrane was demonstrated through the role-play. Students were able to illustrate the bilipid layer and transmembrane proteins. This presentation was supported by a PowerPoint picture and a video animation after the role-play. The activity took almost 30 minutes, which was thrice the length of the designated period. The labels on students' shirts and the combination of role-play, PowerPoint, and closing animation consolidated a very informative activity.

The rest of the class applauded the presenters in acknowledgement of the quality of their work. I then asked the class if this method of teaching was appropriate, and whether the content was correct. Students had appreciated the method, and examples of their comments include:

> *This was awesome, the group managed to show the structure of the cell membrane.*
>
> *The way they thought about representing the transmembrane proteins made the membrane structure visual and this helped me to understand movement across the membrane. For example, the high concentration of particles on the outside and them moving through the pores showed diffusion. The group failed to convince me about active transport.*

This student appreciated one illustration of passive transport and how it is related to the porous nature of the membrane, however, the demonstration of the notion of active transport was not well received by the student.

To consolidate the presentation, I used my prior PowerPoint presentation of the ultrastructure of the cell to show where the cell membrane is in plant and animal cells and how it relates to other organelles

and to the functions of the cell. The other organelles that relate to the cell membrane include the cell wall and cell-to-cell junctions. I further presented the fluid mosaic model, and how it was discovered through freeze-fracture and the use of a scanning electron microscope. This led to distinction of the different functions of two main electron microscopes, the transmission electron microscope, and the scanning electron microscope. The role-play had served as background for building other concepts relating to the cell membrane.

PowerPoint Presentations

As in Mandikonza (2022), a few individuals decided not to collaborate with others. They instead decided to make individual lecture-based PowerPoint presentations. They argued that they could benefit from working in groups and preferred individual work. They presented fairly comprehensive PowerPoint-based lectures with pictures and notes. These students indicated that in high school, they were taught to be independent and found that they understood and completed tasks better when working alone:

> *At high school, we mostly worked independently and we kind of competed against each other. We were encouraged to work in groups, but the final result was yours alone. We therefore had to work minimally with others and then work very hard alone. I personally only looked for others when I needed specific help when the teacher was not there. You help someone, and they beat you in class.*

Therefore, high school practices influence students' socio-cultural abilities. As an educator, I have ideas about how students learn best but I think that it is important to allow them to work in the ways they think best for them to succeed. Nonetheless, the educator should continue to encourage students to collaborate in the activities that they engage in during lessons. I left these students to work alone but encouraged them to collaborate through informal assessment activities such as 5–10-minute discussions during my lessons.

Those students were also not patient with the back-and-forth that takes place when working in groups. They offered comments such as:

> *Group work is very slow and boring. Students argue, at times over simple things and that takes so much time. Working in groups delays because time is spent on deciding how to do the group activity rather than doing the activity itself. By the time you agree on anything, you will have forgotten why you got together after all.*

These students thought the deliberation that happens in group tasks slowed their work. They also thought the deliberations distracted them from the actual task. All group activities involve setting the rules of engagement first before embarking on the actual task, which is what these students felt they did not have time for.

Student Responses to Using Arts in Group Work

Some students thought teaching through the arts did not give the science content the seriousness that it demands. They noted:

> *Students spend a lot of time to think about the strategy to use and they spent a lot of time rehearsing their presentation. That time could have been used to study the organelles. The effort was spread on both the content and the strategy instead of the content alone.*

Thus, they saw the importance of content, but they did not see how the strategy facilitated epistemological access—by working collaboratively and learning from each other or by organising the notes used during presentations. This contrasts with most students who thought learning biological concepts through non-formal teaching and learning strategies was fun, and made learning of the concepts easier and lighter.

Many pre-service teachers expressed that they enjoyed preparing for and presenting the collaborative microteaching lessons and besides getting a better understanding of the concepts, they also got to know each other. Comments included:

> *Our group was made up members from our residence. We know each other from the classroom but had not talked a lot to each other before this task. Once we formed the group, we agreed that one of us make the notes. We came together and she taught us about the organelle. When we understood it, we discussed on the method of presenting. We shared some tunes from songs that we each like. We agreed on one and then we added the notes to the tune.*

Therefore, students ended up adapting songs that they already enjoyed and sang to for the task. Further, they said:

> *It was fun because we got to know each other's names, the songs that others liked, and we also we taught each other. We mostly used our smart phones to get the information and the images of the organelle.*

Vygotsky (1978) asserted that learning is social, and in the third generation of cultural activity theory, Engeström (1987) suggested that mediation of learning an object (content in this study), entailed participants working in a community. My students used tools including psychological tools, such as the task, as well as their knowledge of songs. Students interacted on developing understanding of the concepts. The group task was a mediation tool for learning the intended concepts. It also emerged that students' responses were a form of informal assessment that the teacher educator could use to assess the affective and cognitive outcomes of the teaching process. These pre-service teachers appreciated the teaching method, and the teacher educator for the teaching approach, which was new to them.

Discussion

My study interest was how student teachers responding to a lecturer-generated task, and working collaboratively, would present information on chosen organelles and their choice of strategy. Students decided inter alia, on the use of song, drama, and PowerPoint pictures. The task they responded to acted as a stimulus and mediating tool (Engeström, 1987; Vygotsky, 1978). I facilitated students to engage their creativity through the mediation tool. The students showed that when motivated, they can come up with innovating and interesting teaching methods. But, in using these methods, a lecturer has to illustrate the nature of content to be taught by giving a good background before giving the task.

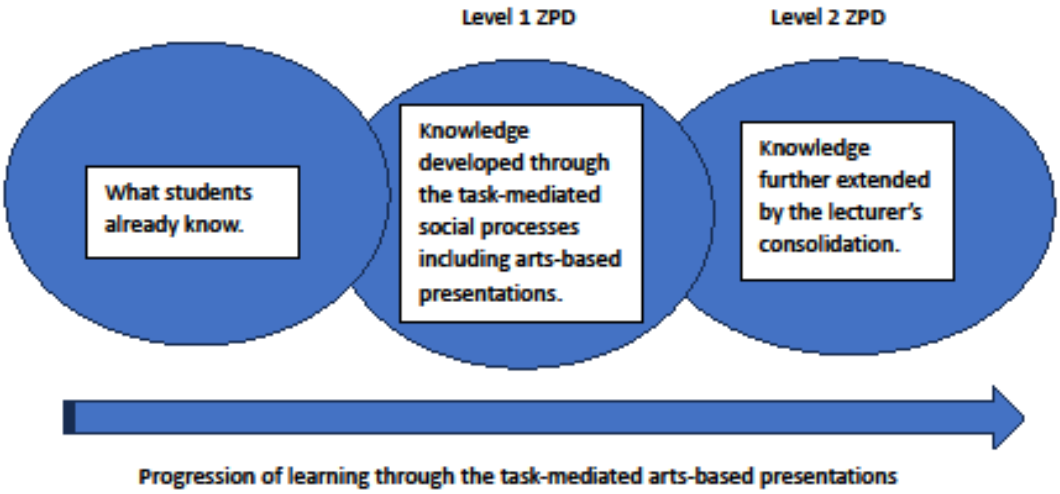
Further, Talib et al. (2019), Zhbanova (2019), and Carter et al. (2021) asserted that students who engage in arts-based methodologies demonstrate creativity. This methodological space allowed students to explore their inner selves and to find links between their everyday lives and the disciplinary content. Although the links shown in the activities do not point to their understanding of content, they illustrate how they could relate the teaching of cell biology content to music and visual arts such as role-play (Henriksen, 2014).

The flipped classroom approach was central to this whole activity. Through this classroom strategy, pre-service teachers were able to engage with the concepts and choose the one they wanted to collaborate on. Some pre-service teachers engaged with concepts that were easy for them and that would give them flexibility to design the way to teach it. Others chose an organelle they thought was difficult for them to understand so that in the process of conducting the task, they might understand it better. These students therefore used the opportunity to study it in-depth and assist each other to understand it. Thus, sociocultural learning processes helped the pre-service teachers to expand their zone of proximal development (Engeström, 1987; Vygotsky, 1978). In working together, some pre-service teachers were the "more knowledgeable" who helped others to understand the intended concepts before sharing them with the class. Every group had an active leader who organised the students to collaboratively engage with the task. The task was therefore a scaffolding tool for the flipped classroom, including pre-service teachers' interaction among themselves, with the intended knowledge, and for how they interacted during in-classroom activities. Taber (2018) who emphasised Vygotsky's work, proposed that the teachers who wish to scaffold their students' learning in their ZPD need to design appropriate learning activities and support materials. Students were challenged to explore presentation of concepts with the hope that they would understand them better using the arts, which are part of the tools in their ZPD.

Taber (2018) also suggested that during scaffolding, the teacher's role must wane. This was evident with a lecturer who introduced the topic of structure and function of cells including cellular organelles, and then designed a task for students to pick up from where he left off. Further, the lecturer only came in to consolidate the presentations, giving more autonomy to the students. This approach of facilitating students to engage in flipped classroom tasks allows the teacher to intervene as a second level mediation process where he scaffolds students from what they presented, to another level in learning the concepts. The students therefore undergo two levels of the ZPD as shown in Figure 1.

Figure 1

Stepwise Expansion of the ZPD in Class



The first level is where the students collaboratively engage in arts-based strategies to develop understanding and to present to their colleagues. The second level is where the lecturer intervenes to consolidate the students' presentations and use concepts presented as the starting point for other related concepts. In the first socio-cultural process, students learn from each other and in the second,

students learn mainly from the lecturer. Using arts-based teaching strategies to present concepts on cellular organelles created a platform for students to engage with concepts and for the lecturer to use these as a starting point to mediate his own teaching and expand the students' ZPD more meaningfully.

Conclusion

It is possible to facilitate students to work collaboratively to present to each other on cell biology concepts provided the students are given a task to guide them. The task is a mediation tool that mediates students' interactions among themselves and their interactions with knowledge. This was illustrated by those students who expressed that they were able to learn the concepts through the interactions.

The flipped classroom was shown to be a successful mediating approach for arts-based STEAM collaborative learning processes. The lecturer-generated task facilitated pre-service teachers to interact and deliberate with each other and with biology concepts in interesting and less formal ways, pointing to their ability to familiarise these would-be strange and difficult concepts that tended to be outside their lived lives. That the pre-service teachers managed to link the pedagogy of concepts to aspects of their lives that they enjoy, is evidence of the success of facilitating epistemological access and the knowledge commoning intent of the teaching strategy. Therefore, if lecturers provide pre-service teachers with the platform, they can innovate the teaching of concepts in ways that link the arts and science through pedagogy while developing understanding of the same concepts. Ultimately, social learning activities tend to provide conditions for collaborative learning and creativity pursuits for attaining quality STEAM education as per Sustainable Development Goal 4. The integration of collaborative arts-based strategies makes the lesson STEAM-focused because students explore the meaning of sciences concepts through socio-cultural processes—and they learn other attributes including social interactions and collaboration.

For this teaching strategy to be successful, the lecturer needs to generate an appropriate task for students to work on collaboratively away from the classroom. There must be adequate time for students to make their presentations, therefore, time management is crucial. The activity could also be assessed, which would stimulate greater engagement. Even though these lessons are primarily for student presentations, the lecturer must be prepared to mediate those.

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Drama in the Science Classroom: Reimagining the Teaching of Natural and Life Sciences[1]

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Abstract

The low levels of interest by students in science, technology, engineering, and mathematics (STEM)-related subjects and work is a challenge that needs to be resolved. And research has shown that arts-based, participatory, and humanistic methodologies—when integrated with the teaching of STEM subjects—have the potential to stimulate student interest, facilitate epistemological access, and hence, improve performance. Thus, in this self-study research paper, two science teacher educators share and reflect on their observations and experiences of using an arts-based teaching methodology (drama) in teaching science concepts and socio-scientific issues to pre-service teachers training to be high school teachers. Drama activities were used to teach the concepts of diffusion, DNA structure, meiosis, and a socio-scientific issue associated with albinism in African communities. Data were collected through the development of drama scripts, journaling observations, reflections, and discussions with a critical friend. Insights from the study show that the integration of drama into the science classroom creates opportunities for social interaction, for recognising students' active participation in their own learning, for power sharing, and for promoting engagement (cognitive, affective, and physical) that leads to the construction of new knowledge. In addition, drama pedagogy humanises science subject matter by showing its relevance and catering for varied learning styles. And drama ignites enthusiasm in students by invoking their innate sense of wonder. Consequently, adopting a STEAM (science, technology, engineering, arts, and mathematics) approach to teaching STEM subjects enriches epistemological access to scientific disciplines because such unconventional pedagogical strategies humanise abstract concepts, thereby increasing the likelihood of student success in these fields. There is, however, a need for heightened alertness in the teacher in order to pick up any misunderstandings and misconceptions about the science concepts that may manifest in the drama presentations.

Keywords: drama in science, science pre-service teachers, self-study, socio-scientific issue, participatory methodologies

[1] Ethical clearance number: H17/09/44

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Introduction and Background

We are two self-study scholars who teach natural and life sciences to pre-service teachers training to be secondary school teachers. We use drama, a participatory teaching methodology, in our teaching with the aim of exploring new ways of promoting student engagement. According to Abed (2016), drama can be an inspiring and powerful method of teaching science, which can improve students' understanding of scientific concepts as well as sharpen their aesthetic experience of science. In addition, using drama in science learning can promote the engagement of learners in science activities and help them to grasp challenging ideas (McGregor, 2012). As asserted by Alrutz (2004), drama accommodates students' multiple learning styles and interests. In an earlier paper based on this study (Nyamupangedengu, 2020), students' experiences of drama-based teaching and learning activities were reported on. In this paper, we turn the focus to us as teacher educators, and reflect on our experiences of using drama to teach science concepts for insights on how (if at all) drama can humanise and, in turn, promote inclusivity in the teaching and learning of STEM subjects that focus on natural and life sciences. The questions that guided our reflections are:

- What are our experiences of using drama when teaching natural and life science concepts to pre-service teachers?
- How can we as teacher educators use drama to humanise the teaching of natural and life sciences for enhanced student engagement, interest, and learning?

Literature Review

Teaching in ways that distance science content from students' reality, social life, and everyday context has resulted in a blind embracing of the notion that science, technology, engineering, and mathematics (STEM)-related fields are difficult and therefore not appropriate for everyone. This stereotyping has resulted in many students being prematurely excluded from STEM-related fields and work options (van Tuijl & van der Molen, 2016). Thus, appropriate all-inclusive teacher practices that involve concretising abstract STEM subjects' content could help build a strong foundation for students to find their footing early in their learning of these subjects, and thereby dispel controversial ability beliefs and the notion that some students are inherently born to be excluded from STEM subjects (Muijs & Reynolds, 2015). The early building of children's self-concept in STEM fields through designing suitable participatory learning activities is crucial because this can inform their career decisions and choices as young adults (van Tuijl & van der Molen, 2016). The early building of children's self-concept can also help address the concern that most STEM students do not perceive their courses (or their ability to complete those courses successfully) in as positive a way as do students in non-STEM subjects (Owston et al., 2020). Further, hands-on participatory teaching approaches in STEM subjects have been found to influence students' interest (Han et al., 2021) and future career prospects in these disciplines (Ching et al., 2019).

Notion of Arts-Based Education

Arts-based teaching methodologies are rooted in the use of arts subjects and methodologies for teaching STEM subjects as STEAM (science, technology, engineering, arts, and mathematics; Razi & Zhou, 2022), for example, using drama during the teaching of science as articulated in this article. Arts-based teaching approaches are based on the premise that because young children's responses to the world are mainly aesthetic and sensory, teaching strategies based on the arts have unlimited potential to captivate their interest, and enhance their motivation to learn and their cognitive engagement with the content as they play (Han et al., 2021). Thus, the rationale for embedding the arts in STEM subjects as articulated in this article is threefold. Firstly, human beings need the arts in order for their holistic development to be realised, and this innate human need for aesthetics should inform the design of curricula. Secondly, many attempts to integrate the arts with other areas of learning have occurred in the past, and further insights need to be unveiled in that direction. Thirdly and finally, a more robust and clearly articulated conceptualisation of the arts-based teaching and learning of specific content needs to be interrogated, modelled, and exemplified in STEAM subjects because children learn better in ways that are naturally suited to their motivational imperatives (Han et al., 2021). In the research literature, dramatisation has been found to be a crucial empirical aspect of student learning for three main reasons (Salimi et al., 2011). Firstly, students were found to learn from and through what they were doing in given specific drama episodes. This in line with the constructivist theory of learning, which purports that students learn better through their own manipulation of their immediate environment (Berger & Luckmann, 2011). Secondly, through dramatisation, students become active participants in their learning, compared to the passive role they play when traditional methods of talk, chalk, and board are used. Lastly, the arts encompass aesthetic components that are important for human well-being and cognitive development (Nutbrown, 2013).

The Notion of Drama Pedagogy

The use of drama as a pedagogy has been tried in many educational setups, and many benefits have emerged from it. In a study of Indian students by Alam et al. (2020), it was shown that modern classrooms need teaching approaches that can foster the learning process much more easily. In addition, the authors showed that the use of drama as a pedagogy improves reception of, and engagement with, the content for learning. Furthermore, through dramatic play, individuals develop valuable skills and abilities during their learning of educational concepts (Eisner, 2002). Drama pedagogies were found to not only be an art but could also be viewed as a science that was of aesthetic value to the participants. Furthermore, unique learning opportunities and insights are offered for the participants who learn new subject content from using drama pedagogies (Eisner, 2002). It has also emerged that drama pedagogy helps lay strong foundations for new and unique teaching and learning alternatives that uphold physicality, and are based on *performative experience* (Schewe, 2013). Research evidence has also shown that the use of drama pedagogies is a natural way of having students learn in the way that they live, that is, learning from simple concepts to complex. For instance, Schewe (2013) unveiled the notion that human life is a rolling play, and that we come to understand the complexities we face in life and life itself better through play. Corroboration of this notion arose from empirical evidence by Dunn and Stinson (2011), who concluded that there was a strong connection between dramatic play and living, teaching, and learning. In another inquiry, which examined the role reversal when players changed dramatising roles, it emerged that the students began to empathise with others' point of views; this happened even in instances where the students were not in agreement (Blatner, 1995).

Although research has shown that the use of drama can promote student engagement with content and hence learning, there is need to note that how the drama pedagogy is enacted has an impact on its effectiveness. For example, Dunn and Stinson (2011) asserted that for students to experience deeper understanding of the content to be taught, the drama pedagogies must be based on what they

termed sound *teacher artistry*. This artistry involves teachers being aware of dramatic form and able to "effectively manage the four roles of actor, director, playwright, and teacher, across both the macro and micro levels of planning and implementation" (Dunn & Stinson, 2011, p. 630).

Drama Pedagogies During Science Teaching

The choice of drama in this study was motivated by research that has shown that the use of drama improves student learning of science ideas. For example, a study by Najami et al. (2019) showed that learning chemistry through drama pedagogies contributed positively to students' achievements, their interest in chemistry, and their achievements. Elsewhere, Peleg and Baram-Tsabari (2015) found that drama pedagogies helped students perceive science as a social human experience, which enhanced and motivated their understanding of science concepts. Ødegaard (2003) revealed that the use of drama and theatre are humanistic ways of penetrating core difficult science concepts because the process of transforming and viewing textbook ideas as three-dimensional models that are alive requires rethinking and re-conceptualising knowledge. That rethinking of textbook ideas promotes unique ways of understanding the content. A study by Lerman (2003) showed that teaching through the sculpture and painting of abstract science concepts rendered them concrete and easier for the students to understand. Further, performing a dance that represented the combination and separation of chromosomes during mitotic cell division, and performing a television theatre based on Ozone the Clown enhanced the learning of mitosis and the ozone layer, respectively.

In a study in Turkey, the use of drama pedagogies revealed that learning about electrolysis through drama positively impacted those middle-school students' scores and overall achievement (Saricayir, 2010). In a later study conducted in Denmark, it emerged that students who took part in physics dramatic performances showed an increased interest in physics (Peleg & Baram-Tsabari, 2015). However, other studies on the use of drama in science teaching and learning have shown that drama activities do not necessarily assist with factual recall (e.g. Ødegaard, 2003) even though they lead to a deeper conceptual understanding of the learned science topic (e.g. Arieli, 2007).

Theoretical Framework

This research work draws from and uses the opportunities, recognition, interaction, and models (ORIM)-Arts framework (Nutbrown et al., 1996) as a theoretical lens. This theory postulates that for any arts-based learning (from children in the kindergarten to adult training), the person in the position of authority (e.g. informed adult, teacher, parent, or trainer) should provide four things for development or learning to occur: opportunities, recognition, interaction, and models.

Opportunities

In a typical arts-based learning classroom situation, teachers should provide many opportunities for students to express themselves (Nutbrown et al., 1996).

Recognition

In any social grouping, people need recognition because they are social beings. For children and adults, the authoritative others can show recognition in many ways (Hannon, 1995; Nutbrown et al., 1996), for example, praising good efforts, telling others what the individual has done well, celebrating and acknowledging their successes, and taking an interest in and following their unfolding activities.

Interaction

Human beings need social interaction with the more informed others for aesthetic reasons and for cognitive development or learning new things (Nutbrown et al., 1996). We interact with each other through, for example, talking, playing games, demonstrating, or even getting involved in real group tasks and projects. Through such social interactions, those more informed can assist the less informed to achieve more than they could do as individuals (Vygotsky, 1978). Furthermore, as the students interact in arts-based learning such as group dramatisation, they can also be exposed to individual constructivism of the STEM content embedded within the dramatisation (Berger & Luckmann, 2011).

Models

The more informed others can act as powerful role models for the less informed or novices to imitate that which they see unfolding in given different social contexts (Hannon 1995; Nutbrown et al., 1996) such as drama plays when teaching and learning in STEAM setups. Thus, being aware of and exploiting the power of the adult more-informed model is crucial for cognitive growth or learning to take place in arts-based learning fora. In this work, the role of the teacher is crucial when it comes to issues such as knowledge of the content to be represented as drama plays, and demonstrations of how a drama should unfold.

Research Design

The Methodology of Self-Study

This study took the form of a self-study in which we reflected on our use of drama in the teaching of natural and life science concepts. Self-study is a study of the self by the self. It is a methodology for studying professional practice (Loughran, 2007). It is about researching practice by teachers/teacher educators interested in better understanding and developing their knowledge of practice (Berry, 2008). Five principal characteristics typify self-study methodology. These five characteristics are that the work is self-initiated and focused; the work is improvement aimed; it is interactive; it uses multiple, primarily qualitative methods; and validity is exemplar based. Self-initiated and focused means that the teachers or teacher educators are both the researchers and the researched (Samaras, 2011). In this study, we the two authors were the participants and the researchers. However, students in the courses in which we implemented the drama pedagogy also became participants by virtue of being registered in those courses. Consent was therefore sought from those students. Improvement aimed means that the work of the teacher educators is aimed at the improvement not only of themselves but also of their students, their students' students, and their institutions and social contexts (LaBoskey, 2004). Given that in self-study, the researcher and the researched are one and the same, the study is interactive at one or more stages of the process. The interactive nature of self-study describes the monitoring process whereby critical friends, colleagues, and students are involved in the self-study project (Samaras & Freese, 2006). A critical friend is an individual in self-study who is invited to act as a sounding board (LaBoskey, 2004). Critical friends probe, prompt, and ask challenging questions with the aim of supporting the self-study scholar's reframing of events. Critical friends, therefore, join the professional learning experience so that they can adequately engage with the events, the activities, and the ideas being implemented in the study. The two authors in this study acted as critical friends to each other's work. Self-study methodology uses multiple, primarily qualitative, methods for gathering data. The use of multiple methods provides opportunities for the self-study researcher and for others to gain different angles or viewpoints on the educational processes being investigated thereby providing a more comprehensive view of the process. Validity being exemplar based means that validation is achieved through "the construction, testing, sharing and re-testing of exemplars of teaching practice" (LaBoskey, 2004, p. 859). Exemplars of practice are concrete documents and examples of practice that are presented as exhibits to allow members of a relevant research

community to judge for themselves the trustwothiness and validity of the observations and interpretations.

Participants

The main participants in this study were we, the two authors, and we chose to investigate the use of drama in the courses that we teach for ease of access and of planning. Tholani teaches a natural science course to 1st-year students and Eunice teaches genetics to 4th-year students training to be secondary school teachers. In addition, because we have been teaching these courses for several years now, we were familiar with the topics in the course, and the concepts that we find challenging to engage students in. Our students for that year, 150 1st-year students in Tholani's class, and 80 4th-year students in Eunice's class also became participants by virtue of being registered for the courses in which the class activities were planned. Eunice applied for ethics at her university because she was the lead investigator in the project. Students' consent were sought although the focus of the study was on the authors' following roles: play writer (which would manifest in producing the scripts), director (which would manifest in directing the actual acting by the students), and the teacher (which would manifest in providing the four things for development or learning to occur as explained earlier—opportunities, recognition, interaction, and modelling during both the planning and enactment of the drama activities).

The following four concepts were dramatised: diffusion, the structure of DNA, meiosis, and a socio-scientific issue. The concept of diffusion was dramatised in Tholani's class and the other three concepts in Eunice's class. Tholani chose the topic of diffusion because he had struggled to concretise the movement of molecules during diffusion to promote student understanding. Eunice chose the three aspects dramatised in her class for the following reasons. She chose to have the structure of DNA dramatised because even though the structure can be concretised through use of models, describing the structure of DNA introduces challenging content and many unfamiliar terms, which overwhelms students, making it difficult for them internalise its structure. The excerpt below is a short example of the challenging content and terminology that is presented to students when teaching about the DNA structure:

> *DNA is a nucleic acid macromolecule. The basic building blocks of DNA are called nucleotides. Each nucleotide consists of a sugar (deoxyribose), one of four bases (cytosine (C), thymine (T), adenine (A), guanine (G)), and a phosphate. Cytosine and thymine are pyrimidine bases and are single ringed, while Adenine and guanine are purine bases and are double ringed. DNA is made up of 2 strands/double stranded. Each strand is made up of a string of nucleotide molecules. The 2 strands are anti-parallel i.e. they run in opposite directions and have a sugar phosphate back-bone. A purine base pairs with a pyrimidine i.e. Thymine with adenine and guanine with cytosine. The 2 strands are joined by hydrogen bonds. The sugar phosphates are joined by covalent bonds. (Eunice, personal notes based on ideas by Reece et al., 2017)*

As can be seen in the excerpt above, the content is dense with terminology and descriptions that need to be understood in order to visualising the structure. Eunice therefore wanted to explore how (if at all) dramatising the DNA structure would allow students to engage with the concept without becoming overwhelmed. Meiosis is the second concept that was dramatised in Eunice's class. Meiosis is a biological process but it is represented in textbooks as static stages, making it challenging for students to visualise. Therefore, Eunice wanted to explore whether drama could bring the static stages to life. The third aspect dramatised in Eunice's class was a socio-scientific issue around the genetic condition, albinism. She teaches about genetic disorders in her genetics course, including their impact on individuals, on families, and on communities at large. This drama was based on a true story she had witnessed in her home village. She wanted to expose students to this story through drama, and find

out what lessons the students could take away from it. No changes were made to the content or structure of the two courses. The only change was the introduction of drama pedagogy to the teaching and learning activities.

Sources of Data

As is required in self-study, multiple forms of data were collected. These comprised scripts (i.e. descriptions of drama activities), journal entries of our discussions of the drama activities, and journal entries from our reflexivity. Four scripts were produced—the descriptions of the four drama activities we used to teach the concepts of diffusion, DNA, meiosis, and the socio-scientific issue, respectively. Next, we offer five examples of various data forms that were generated.

1. Drama Script: Socio-Scientific Issue, a Child With Albinism Born to Parents with Melanin Skin Pigment

> *In the rural village of Nyanga, there is a couple who after getting married the wife got pregnant and gave birth to their first child. The birth was celebrated by the whole family. The wife got pregnant again and gave birth to an albino child. The husband's relatives and even hers accused the woman of infidelity because there has never been an albino in the history of the family. They wanted their son to divorce the woman. The husband was sure that his wife did not cheat him. He however could not explain how they could possibly have an albino child. The birth of this child therefore brought division and misery in a once happy family. A social worker at a local clinic then suggested that the family go for genetic counseling and DNA tests. The genetic tests showed that both parents and the normal boy were all carriers of albinism. Because of the tension and the charged atmosphere within this family, it was decided that the results of the DNA tests be presented and explained at the chief's compound.*

2. Eunice's Journal Entry of Part of the Discussion of her Drama Script With her Critical Friend

Tholani: What motivated you to come up with this story around albinism?

> *Eunice: I was teaching the topic genetic disorders, which included teaching about genetic tests and genetic counselling. When I am teaching biology, I want my students to always appreciate the relevance of the knowledge that they are learning. Therefore, in this case, I wanted them to see why it is important for them to have knowledge of albinism as a representative case as well as knowledge of the importance of the associated concepts of genetic tests and of genetic counselling etc. The story is based on a real-life story. . . . The actors were the Chief and his policeman, the social worker, the couple with the albino child, the wife's relatives including her parents, the husband's relatives also including his parents, and people from the husband's village where they lived. The class was divided into two groups that dramatised the script.*

Tholani: Why did you decide to get it dramatised?

> *Eunice: Most socio-scientific issues are controversial and impact individuals and families. Therefore, I was of the idea that dramatising the issue would provide opportunities for the class to engage in and possibly experience the human suffering that may arise when family and/or community members are not familiar with the science behind manifestation of the albinism condition.*

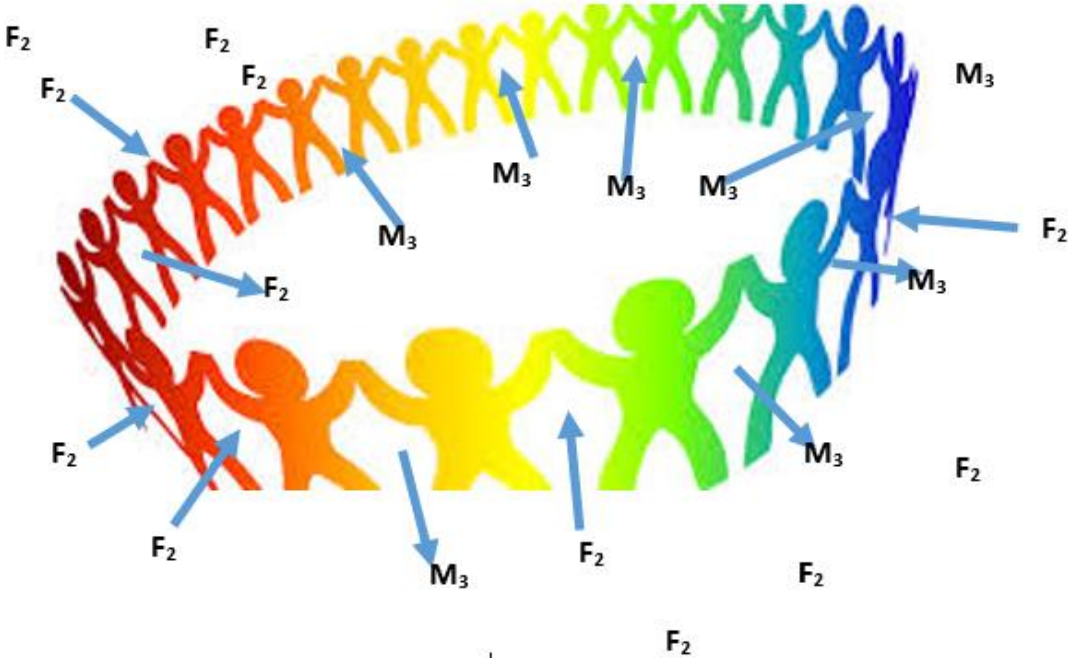
3. Drama Script in Tholani's Course: Diffusion in the Alveolus

In Tholani's class, the students were required to dramatise the process of diffusion as it happens in the alveolus. The students therefore, were to dramatise the behaviour and movement of oxygen and carbon dioxide into and out of the alveolus down their concentration gradients, respectively. Description of the drama activity:

> *A few students will form a circle as shown in Figure 1 below from the drama script. The drama will be done in an open space of the soccer field, the 60 female students (F) will represent oxygen, and will all be dressed in white coats. Ninety male students will represent carbon dioxide as follows: a third of them will be dressed in blue to denote the carbon in carbon dioxide structure, and the other two thirds (60) will be dressed in white coats to represent the two oxygen atoms on the CO_2 molecule. The female students will join hands in pairs to denote an oxygen molecule (O_2), which is a diatomic molecule. The male students will join hands in a ratio of two in white and one in blue to denote carbon dioxide (O=C=O) as also depicted in Figure 1. A whistle will be blown to indicate that "diffusion" should start. When the whistle is blown, music will be playing in the background and the dramatisation will begin with students in their respective pairs and groups (males or females) attempting to move from where their kind are many to where they are few. This movement will be allowed to continue for about half a minute until the whistle is blown again and the slow tune of the music turned off.*

Figure 1

Diagram Depicting the Dramatisation of Gaseous Exchange in the Alveolus



4. Tholani's Journal Entry of Part of the Discussion of his Drama Script With his Critical Friend

Eunice: What motivated you to use drama for teaching this content?

> *Tholani: Over the years when teaching the topic of gaseous exchange, I struggled to explain in concrete terms what happens at atomic and molecular level. This is because I struggled to have real-life examples to refer to when teaching the issue of atoms and*

molecules making up oxygen and carbon dioxide. I envisaged that it is quite abstract for the students to visualise things they only read in books and have not seen in everyday life. My pedagogical reasoning was that having the students acting as atoms and molecules, with some background music playing, would provide something to relate to when learning about this topic.

5. Example of a Journal Entry of Tholani's Observations During the Dramatisation of Diffusion

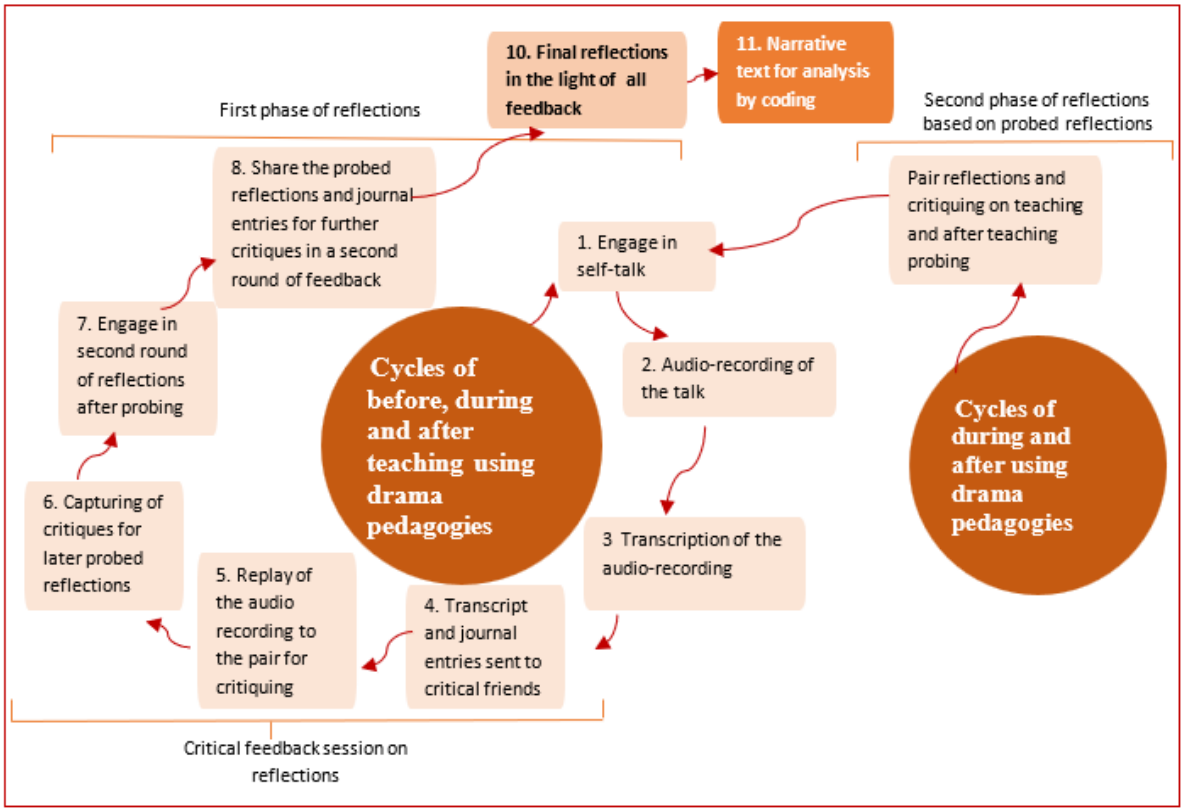
Some students danced to the rhythm as they move in a gliding style. The students had to move in relation to the slow tone/beat of the rhythm. The rationale for using the country music beat was to have the students move at a flowing pace the way oxygen and carbon dioxide gases enter and leave the alveolus. After the whistle was blown, and the music stopped, the numbers of pairs and groups of students, both male and female were counted on both sides. Seemingly, after the movement, some female student pairs were inside the circle and some still outside. The male students were also distributed randomly both inside and outside. After four phases of blowing the whistle and stopping, most of the female students were inside the circle and most male students were outside the circle.

Data Analysis: Engagement in Reflexivity

Data analysis in this study followed what Samaras (2011) described as a "hermeneutic process" (p. 197), whereby data collection and analysis happen concurrently and continually back and forth. We engaged in reflexivity that entailed three phases: before, during, and after the drama activities. The purpose of engaging in reflexivity was to document our individual thoughts on how the drama activities had unfolded—including challenges and any insights on how to represent content for teaching through drama pedagogies. Our documentation kept a trail (Samaras, 2011) of the pedagogical reasoning and actions of each of us throughout the inquiry. The documented trail made it easy to share our thoughts and ideas about the use of drama pedagogies when teaching natural and life sciences. The reflexivity entailed 11 steps as depicted in Figure 2 below. The rationale for engaging in these steps was to maximise the validation of our research findings.

Figure 2

Reflexivity Phases Engaged in During This Investigation (based on ideas by Tshuma, 2023)



Reflections Before, During, and After Teaching

The first phase entailed two steps: a) journal entries and free flow reflections on our individual perceptions about drama pedagogies, and b) we then exchanged our journal entries and reflection transcripts in order to look at each other's work and write probing critical comments. During the critical feedback, we posed critical comments to the reflections and journal entries we had shared. This was a crucial validation step because it assisted us to view drama pedagogical issues beyond our personal biases and limitations. We each captured the critiques to use to re-engage with our actions, views, and experiences in a second phase of reflections or probed reflections as shown in Figure 2, Step 8.

In the second phase of reflections, we shared reflections on how we had responded to each other's critiques raised in the initial feedback session. These cycles of reflection and feedback took centre stage at every step of this inquiry in the repetitive style shown in Figure 2. After the teaching and all the feedback sessions, we engaged in the final reflection sessions where we produced narrative descriptions of our observations and experiences including lessons learnt throughout the entire study for thematic coding as also depicted in Figure 2.

Analysis of Narratives From the Reflexivity Cycles

The last of the reflexivity phases shown in Figure 2 (Step 11) was the generation of narrative texts for thematic analysis. Below, we present examples of three coded narrative texts—two from Eunice, followed by one from Tholani.

1. Coded Extract From the Narrative Description of the Drama on Meiosis

> *The meiosis process was the first to be dramatised at the time of introducing drama as part of the activities in the biology course. I had to use some authority (lecturer uses authority) to get students to engage in the drama activities as some students could not see immediate relevance of the drama activities to the learning of science concepts. However, once students had gone through the script, the drama idea began to make sense and they engaged in the discussions assigning roles to each other in their groups (opportunities created for social interaction). Those with a good understanding of the phases and events were also observed explaining to the group and demonstrating the behaviour of chromosomes (opportunities created for more knowledgeable other [MKO] mediation). To accurately dramatise the process, students were seen referring to their notes and searching the internet to acquaint themselves more with the content they were about to act out (opportunities created for engagement with content). As the discussions were proceeding, I would move between the groups, listening to the explanations, acknowledging (opportunities for teacher to recognise-recognition) the correct explanations as well as prompting them to think further, where I could see that they are missing key aspects of the process (opportunities created for MKO mediation). The different groups began to add their own ideas to the scripts including more roles (engagement and social interaction). Therefore, two groups out of four were eventually agreed upon. Individuals from the dismantled groups got added to the two groups as they needed more people to effectively dramatise the process.*

2. Coded Extract From the Narrative Description of the Drama on a Feud Within an African Family After the Birth of a Child With Albinism

> *Unlike the drama on meiosis, which was based on content only, this one included both science and social aspects. While the meiosis one was prepared and acted on the same day during a 3h practical session, the socio-scientific issue drama required more time as there was need for research on both the science content and the social aspects e.g. the roles and responsibilities of the chief and his policemen. Students needed to think through how to explain how it is possible for normal parents to give birth to a child with albinism to lay people, what genetic counselling entails etc. The script therefore provided opportunities for students to do research as it alerted students to what they didn't know. During the dramatisation, students engaged with scientific- concepts such as DNA, genes, alleles, genetic tests, paternity tests (students engaged with science concepts) as they were explaining them during the "hearing" at the chief's compound. Misunderstandings got exposed in both the talk and the actions (misunderstandings exposed in the social exchanges). Many African students identified with the issue (relevance). Some white students were fascinated by the set-up and indicated that they had learnt something about the African culture (diversity). There was both cognitive and affective engagement during the drama as participants intensely brainstormed the dilemma that the birth of this child had brought to this African family (cognitive and affective engagement). Participants had to also think out of the box to come up with understandable ways of representing scientific concepts.*

3. Narrative Text From Tholani

> *When representing alveolus gaseous exchange content through drama, I included music to cater for those students who enjoy music as they learn (knowledge of pedagogy). I also had in mind that there is a child in every adult, and thus, I envisaged that playful learning could invoke deep-seated understanding of abstract concepts. I observed that some of the students were reluctant to play as kindergarten kids before the dramatisation started. This is because when I asked them to leave the lecture hall for the spots field, some of them*

seemed reluctant. However, when in the field and the drama unfolding, I could see that I had awoken the little kindergarten kids within them (excitement ignited). I noted that they would all pay attention so that they hear the whistle blow so that they navigate in limited spaces between groups to make as much progress towards their targeted direction (physical engagement). Because the students were joining hands as pairs and groups, their movement was slowed down as they would bump into each other the way diffusion molecules will also not flow smoothly. The students seemed excited as they played like small children and some of them danced as they move.

Presentation of Findings

The following themes came out of the analysis of our narrative texts:

- Opportunities for social interaction.
- Opportunities for recognition.
- Opportunities for power-sharing.
- Opportunities for engagement (cognitive, affective, and physical), which led to construction of new knowledge.
- Relevance of the science subject matter.
- Varied number of learning styles catered for.
- Opportunities for constructivist ways of learning.
- Tensions.

Discussion of Findings

Drama, by its nature, requires collaboration because it is a collective activity. Every participant is assigned a role to play. As a result, dramatising the natural and life sciences concepts promoted social interaction (Vygotsky, 1978) because each student was continually engaging with their environment—that is, other students, with us their lecturers, and with the content—(Khoza & Nyamupangedengu, 2018). Further, this social interaction in turn promoted all three forms of engagement (cognitive, affective, and physical), which led to the construction of new knowledge. The students came up with their own understanding of content as they dramatised the science content in the company of each other. For instance, one student came up with insights about issues of molecular sizes as excerpted below:

Rose: I did not know that carbon dioxide molecule is bigger that oxygen molecule, I just thought they were gases.

Tholani's reflection: The comment by Rose was an eye-opener in relation to what I wished to see happening in the classroom, I thus quizzed the student to find out the details behind the conclusion: "What is it that makes you say carbon dioxide is a bigger molecule than oxygen?"

Rose: Male students were in larger small groups than the female students, as they even struggled to move around.

Rose's response is evidence that students construct their own understanding of the abstract science content as they actively dramatise that content during the teaching and learning process. This corroborates the theory of constructionism of knowledge as put forth by Berger and Luckmann (2011).

The social interaction provided a unique opportunity for students to internalise the content in relation to their participation involving that content. This is because they had opportunity to visualise the abstract concepts in the social plane of their playful encounters and, in some instances, to take on the role of more knowledgeable others as they taught and learnt from each other. For instance, during the alveoli gaseous exchange drama, one member of the group of the male students suggested to his group how they could navigate or "diffuse" faster out of the circle:

> *Jack: For us to move faster, let us not hold hands and walk side by side, but let us hold hands and move in a file one behind the other.*
>
> *Journal entry: This statement by Jack alludes to factors that affect the rate of diffusion in general and in the alveolus in particular. I am going to use this suggestion by Jack to initiate a class discussion in the next class.*

In addition, the use of drama pedagogy led to us relinquishing power because we were no longer the only sources of knowledge. Providing open scripts that students could add to, allowed them to make choices on how they wanted to present the content they were dramatising. In this way, power was shared between us the lecturers and our students. Dramatising the concepts also brought relevance to the science subject matter, which in turn, humanised the concepts. Many African students identified with what was enacted in the albinism drama and some of them shared their experiences of how children with this condition are badly treated in their own communities because of lack of knowledge by members of the community. Many students appreciated the importance of science knowledge in everyday life. The drama also provided a window into less known professions and services like social workers and counselling services, and the roles of chiefs.

> *Kate: I have always wondered what the role of chiefs is.*
>
> *Thabiso: I now have an idea of what social workers' work involve.*

As can be seen in the utterances above, Kate was a white student and the drama gave her a glimpse into the roles of a chief and how they conduct their business:

> Ma'am, this is so fascinating. The chief was very patient and listened to everyone but when *he* began to speak, he spoke with authority but at *the* same time merciful understanding. He seemed to know what causes albinism. So, are all chiefs learned?

Thabiso, an African student acknowledged that in Black African communities, professions like social work are hardly spoken about: "I had no idea what they really do." Therefore, drama activities such as this one, if done at high school level, can not only humanise life sciences concepts, but also increase students' awareness of careers associated with the discipline beyond mainstream ones, and possibly influence their interest (Han et al., 2021) and future career prospects in these disciplines (Ching et al., 2019).

Tensions From Use of Drama Pedagogy

Although there were many positives arising from the use of drama in the teaching of natural and life sciences concepts, there were also some tensions. See excerpts below from each of our journals:

In today's drama, Tom seems to have forgotten that genes and allele are different concepts, and explaining them is crucial for a better understanding of albinism. I had no choice but to intervene. My intervention however seemed to have derailed Tom's enthusiasm. Do I need to desist from interfering when incorrect statements are made? At what point was I to get involved? Will the drama bring the understanding that I was expecting it to bring? At what point should I correct misunderstandings and misconceptions? (Eunice)

During the drama, I itched to stop the drama and comment on what was unfolding in relation to the content of alveoli gaseous exchange. This is because we were outside, and that unusual learning environment seemed to excite the students to focus on their next drama more. I felt I was missing out on good opportunities to explain and have the students see the link between the content being learnt and their drama moves. I had these questions at the back of my mind: What is the best time to highlight the link between the unfolding drama episode and the actual science content? Will stopping the drama to explain issues not disturb the fun and flow of the drama and have the "children" in them being switched to the "adult" in them? (Tholani)

Those are some of the tensions that we grappled with, and are still grappling with. This is because even though our observations in this study showed that students gain a lot (relevance, social interaction, knowledge of the concept), in a few cases, the incorrect explanations stick with the students and sometimes, just as with any use of models, there is a misinterpretation of the represented structures—leading to misconceptions.

Conclusions

Although drama is usually common in the domains of language, this study has shown that bringing it into the science classroom creates opportunities for social interaction, for recognising students' active participation in their own learning, for power-sharing, for promoting engagement (cognitive, affective, and physical) that leads to construction of new knowledge, relevance of the science subject matter, and catering for varied learning styles. In addition, drama pedagogy sparks excitement amongst students because it awakens the kindergarten children in them. The excitement during playful learning elicits deep concentration that is crucial for grasping abstract concepts. Thus, the approach of teaching STEM subjects as STEAM improves epistemological access to the sciences subjects. This is because such unusual pedagogical approaches humanise the science subject matter. Furthermore, whilst it calls for a deep understanding of content to represent it in the form of a drama episode, the use of drama allows for power sharing. This power sharing provides students with opportunities to act as more knowledgeable others to each other and, in turn, takes from the teacher, the burden of being the only one to explain abstract science content to the students. The teacher must, however, be alert in order to clarify any misconceptions and misunderstandings that can arise from the dramatisation activities.

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A Formative Study Towards the Inclusion of Indigenous Technologies and Knowledge Practices in Science, Technology, Engineering, Arts, and Mathematics (STEAM) Curriculum Settings

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Abstract

This work on STEAM and education for sustainable development was undertaken across a series of collaborative case studies as formative research on the inclusion of Indigenous technologies and knowledge practices in teacher education. We noted that, despite the current academic imperative to decolonise southern African education, one seldom finds the inclusion of Indigenous technologies and Indigenous heritage practices in the contemporary classroom. Teachers we worked with were highly interested in their Indigenous knowledge heritage. Yet, they reported that they, and the young teachers they work with, simply do not have the heritage knowledge capital to include Indigenous knowledge systems in their teaching. Other challenges they face are the time it takes to engage community knowledge holders, and to find knowledge relating to school subject disciplines. The teachers observed that students prioritise modernity over Indigenous heritage and technologies, often undervaluing the latter as a forgotten past. Three exploratory cases delved into teacher education's response to challenges through co-engaged work, and this paper synthesises the

emerging evidence—aiming to refine pedagogical tools for integrating Indigenous knowledge into STEAM education. A cultural-historical approach was used to frame the study and to derive insights and inferences in co-engaged lesson design research with teachers.

Keywords: Indigenous knowledge systems, Indigenous knowledge, Indigenous heritage, STEAM

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Background

There is a great need to strengthen the South African curriculum by integrating Indigenous knowledge systems (IKS)[1] into science, technology, engineering, arts, and mathematics (STEAM) education. Godson et al. (2024) noted the role of IKS in enriching education and its potential contribution to scientific knowledge through integration into STEM (science, technology, engineering, and mathematics) education, which focuses on emphasising technical skills and problem solving.

STEAM education takes this process one step further by integrating the arts into the framework, emphasising creativity and interdisciplinary thinking and fostering creativity, critical thinking, and innovation through the arts. STEAM encourages active transformative education by nurturing holistic learning experiences where students engage in real-world problems, think creatively, and develop empathy. By incorporating the arts, students can approach challenges from multiple perspectives, leading to more innovative solutions and a deeper understanding of complex issues, making STEAM education ideal for fostering active transformative learning through integrating IKS.

The research comprised three case studies conducted with teachers in 2023 as part of the Fundisa for Change (https://fundisaforchange.co.za/) teacher education programme. The collaborative work took the form of course-mediated lesson planning work with teachers who explored the inclusion of Indigenous technologies (artefacts) and knowledge practices in their subject teaching in the Intermediate and Foundation Phases of the CAPS curriculum.

An Opening Review to Inform the Studies

The inclusion of IKS in curriculum policy emerged and developed within an opposing of African Indigenous and Western knowledge systems. This epistemic dialectic, being repetitively influenced by the continuities of coloniality (Bhurekeni, 2020), is found in the works of Jegede and Aikenhead (1999), Odora-Hoppers (2001), and Nagara (2017), for example, and has developed as a characterising feature of IKS as a decolonising field of study and practice. Survey research has also opened up the field, and IKS has emerged as a developing concern that, despite education policy imperatives, it is not yet widely evident in school curriculum settings in the southern African region (Mkosi, 2005; Ngulube et al., 2015).

[1] IKS is read as Indigenous knowledge practices and technologies that can situate and frame STEAM to reappropriate Indigenous technologies and practices in ways that enhance the relevance of learning in these curriculum subjects.

The developing discourses have, in a variety of ways, called for inclusion, a transcending of boundaries on the epistemic front (Jegede & Aikenhead, 1999) and an expanding of narrow perspectives in curriculum settings so that the plural character of heritage knowledge systems (Nagara, 2017) is reflected in teaching and learning. When viewed through this lens, the modern classroom can be interpreted as a nexus of knowledge systems including the contemporary knowledge found in modern institutions, which is frequently manifested in the formal curriculum as school subject disciplines.

As noted earlier, despite a proliferation of Indigenous knowledge (IK) literature and its integration within a widening field of IKS, we did not find clear cases where IK is included in classroom teaching in ways that heritage might articulate with modern subjects relating to the needs and life experiences of the people today. A noted unique feature of IKS in curriculum and pedagogic innovation is that these are often transmitted orally, through observation and practice, in a dynamic process that meets the needs of a particular community (Cláudio da Silva et al., 2023). This calls for changes in curriculum policy and we thus outline here, an approach to the inclusion of IK.

Towards a Collaborative Research Design

The evidence in the brief literature review pointed to a need for framing theory-informed research on the inclusion of Indigenous technologies and knowledge to enhance the relevance of learning to enrich and transform conventional classroom teaching. A primary purpose of this research was thus to clarify models of process towards the inclusion of Indigenous technologies and knowledge to strengthen the current knowledge-mediated curriculum through more inclusive lesson design research with teachers. In this context, we will present three case studies:

- The inclusion of heritage knowledge in course-supported lesson design work (2021–23 field notes by Snow and O'Donoghue, as reported in Schudel et al., 2021).
- Activating heritage knowledge in an online teacher education programme (2023 evaluation notes by O'Donoghue and van Staden).
- Deliberative work to surface IK in science education (Ndlamlenze & O'Donoghue, 2023).

The research was centred on the abductive development of inferences that might better inform the inclusion of Indigenous technologies and knowledge practices in conventional subject teaching. These collaborative studies were thus located in our teacher education work and centred on the derivation of abductive inferences where abduction involves reinterpretation as researchers begin with a theoretical framework, thereby reinterpreting and attributing new meaning or significance to the phenomenon being studied or constructing theory through its application in new context (Bergene, 2007). The case evidence from the three cases is drawn together in this exploratory review of the successive design research undertaken with teachers. As a Fundisa for Change process of teacher professional development, we explored the inclusion of Indigenous technologies and knowledge practices within Education for Sustainable Development (ESD) as a reflexive process of transformative learning. The imperatives to include IKS and ESD in curriculum strengthening are now being treated as cross-cutting concerns by the South African Department of Basic Education (2023).

Clarifying Co-Engaged Design Research Methodology

Figure 1 reflects the 4-phase lesson design research methodology against the generic model for educational design research after McKenney and Reeves (2012). The focal topic for the small-scale

case studies with teachers was the inclusion of Indigenous technologies and knowledge practices in lesson planning. The study drew on contemporary cultural-historical and language studies approaches that accommodated the inclusion of IK and transformative competences informing education for sustainable development (ESD). The suggested Handprints for Change learning progressions included a 4-phased learning progression developing around start-up story sharing, inquiry, data analysis, and the application of knowledge in change challenges (O'Donoghue et al., 2020).

Figure 1

A Developmental Concept Map of the Task Sequencing Design Process and the Qualitative Assessment of Learning Transactions (Adapted From McKenney & Reeves, 2012)

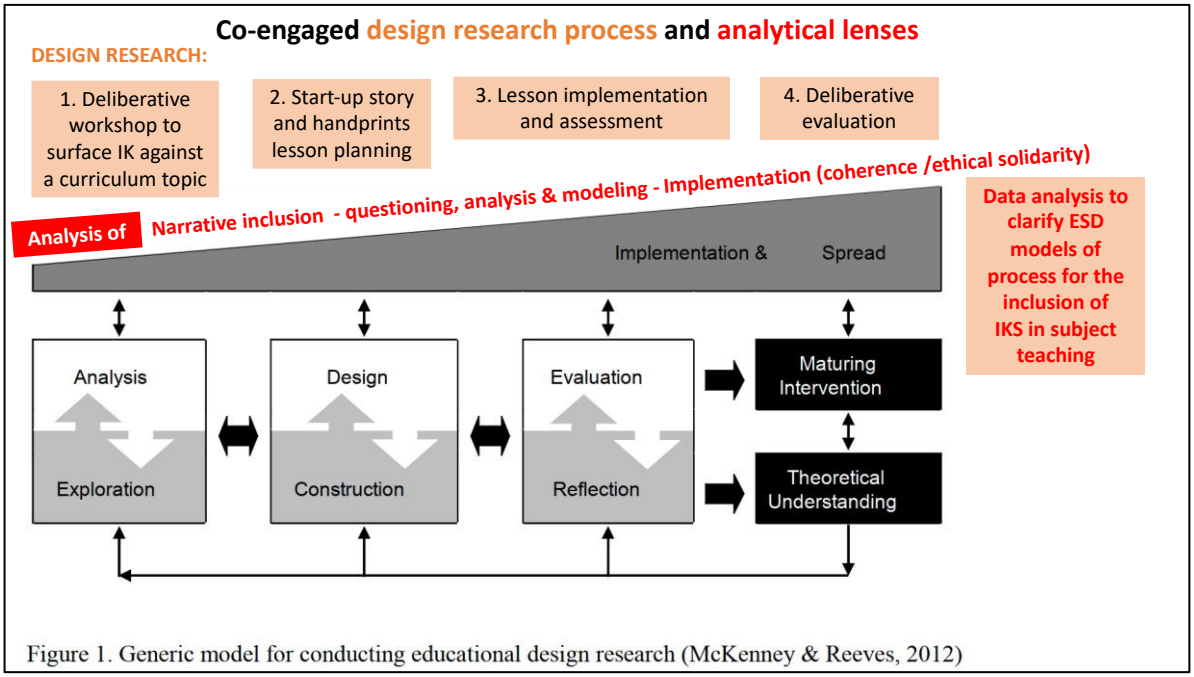


Figure 1. Generic model for conducting educational design research (McKenney & Reeves, 2012)

To frame ESD as a transformative progression of process skills, we worked with an expansive learning cycle after Engeström and Sannino (2020) and the 4-quadrant Vygotskian task sequencing of Edwards (2014), as shown in Figure 2. Here, Sannino and Engeström (2017) provided a formative intervention model of process as an analytical lens for the deliberative mediation of learning-led change.

Figure 2

Planning ESD as Real-World Transformative Learning

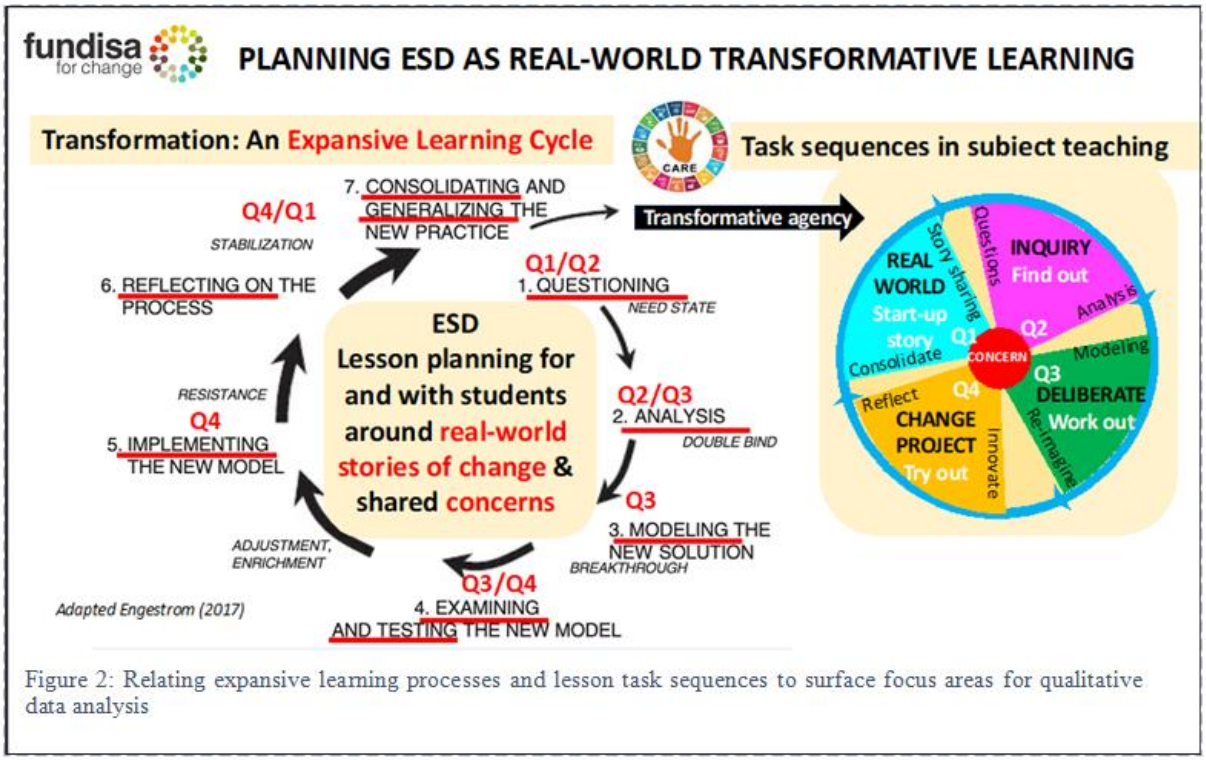


Figure 2: Relating expansive learning processes and lesson task sequences to surface focus areas for qualitative data analysis

The close coupling of social learning theory and lesson task sequences in Figure 2 enabled us to frame a knowledge-mediated action research process for our course-supported work with teachers. Here, our attention was centred on Indigenous technologies and knowledge practices as an intergenerational platform to raise questions to guide inquiry-based learning. Through the task sequences, teachers could mediate, track, and assess learning as an expansive process in relation to the matter of concern.

Working in this way to explore a cyclical process of transformative learning within a pedagogical process of unfolding task sequences, we were able to deliberate and review:

- the lesson design and its mediating pedagogy as an ESD process and
- the inclusion of Indigenous technologies and knowledge practices to activate heritage learning.

Our research concern here was thus both the inclusive mediation of a heritage-activated learning process and the development of the necessary models of process to support this. During the pilot studies, teachers were co-design researchers within a teacher education programme working together to develop lesson plans around IK heritage. Working in this way, we were able to review inclusive learning transactions through the qualitative tracking and analysis of a developing learning programme, namely, the practical coherence of knowledge within an ethical consensus, and abductive inferences evident within a co-engaged design research methodology. Here, evidence of inclusion was verified within the lesson design submissions of participants and in their reports on lesson implementation.

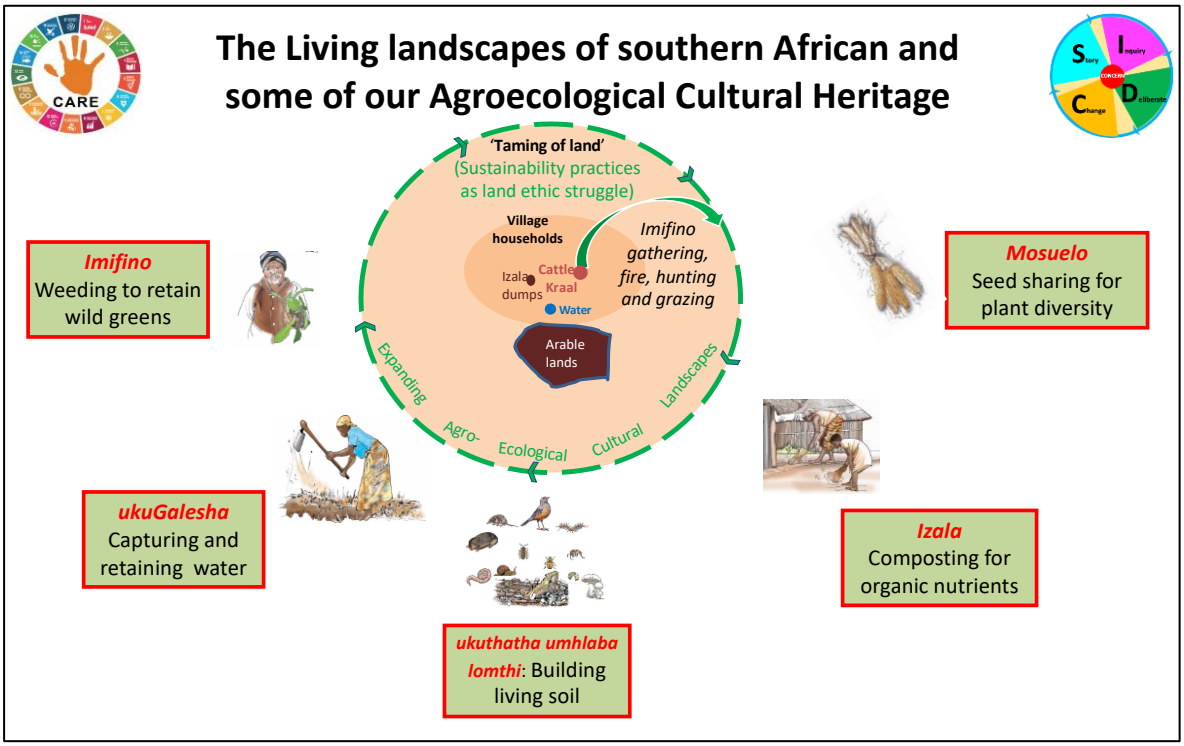
The Course-Mediated and Deliberative Uncovering of Indigenous Heritage Knowledge

The framing theory for the pilot studies reported in this paper was centred on the outcomes of the first stage of a course-mediated design research process, namely, the surfacing of IK and real-world story materials for opening up questions in relation to local matters of concern.

The cases reported here necessitated a decolonising of the prevailing environmental histories of the region. Colonial environmental histories inscribed Indigenous peoples as both the fallen "children of nature" (Walker & Richards, 1975) and destroyers of nature (Pringle, 1982). A revised living-landscape perspective uncovered how Indigenous peoples' agroecological practices have shaped and enabled them to live within the extreme climate in the living landscapes of southern Africa. The weight of evidence supporting this decolonising shift means that the landscapes of southern Africa cannot be read as natural ecosystems that were successively degraded by Indigenous peoples.

Figure 3

Land Taming as an Evolving Process of Agroecological Land-Case Practices on the Living Landscapes of Southern Africa



These insights reframe readings of how the practices of the Indigenous peoples of southern Africa were primitive, crude, and destructive to the environment. This demonisation of Indigenous peoples is found in early chitemene agriculture, which was taught as a destructive process of slash-and-burn contributing to biodiversity loss and soil erosion. Contrary to this colonial reading of early woodland farming practices, we now know that burning was a way of controlling soil fauna like armyworms, and releasing important nutrients in leached forest soils. There is also evidence of a cyclical use of forested areas with a long fallow period that allowed habitats to recover so that they could be tilled again (O'Donoghue et al., 2013). Further, this pattern of land tenure was a sustained cultural practice in the Miombo, where centuries of change *tamed the land* (Chigwedere, 2016) to shape a mosaic mix of open

woodland and savanna that came to support cattle, people, and the herds of wildlife that the colonial eye of ecologists attributed to nature.

In order to challenge these colonial inscriptions, we revisited genealogical records, where the development of a settled land for agriculture was described as land taming. A re-examination of the historical record highlighted how these seasonal practices evolved as diverse forms of bio-cultural land care (refer the circular model of process in Figure 3 for further details).

We thus explored how the current environmental crisis could be understood as an outcome of modernity, and the IKS topics we explored were developed around sustainable food production. This topic surfaced Indigenous heritage practices like *izalene* (composting), *imifino* (green leafy vegetables) harvesting, and other seasonal agricultural practices found in southern African cultural settings (see the IK practices in Figure 3). Cultural artefacts were used to start up story-sharing conversations that had been reframed within a cultural perspective, and which overturned and displaced the dominant discourses of colonial modernity with a love for Africa and being African in the intergenerational company of others.

Case Studies of Design Research Lesson Planning With Teachers

The three case studies reported here were undertaken in 2023 as an exploratory process of collaborative learning towards the inclusion of Indigenous heritage technologies and knowledge in lesson planning. It is important to note that South African classrooms are sites of multicultural learning with a knowledge-mediated curriculum that has yet to fully develop a plural and inclusive ethos at the level of knowledge. The current curriculum strengthening process is intent on this so we are finding ourselves working on both the uncovering of Indigenous African heritage and the inclusion of other cultural knowledge capital in multicultural classroom settings. In the food security and agroecological focus of our work with teachers, we found ourselves giving attention to plural knowledge practices against the backdrop of African historiographies on living landscapes and the sustainability challenges that now confront all of us in modernity.

Case 1: The Inclusion of IK in Lesson Design Work With Teachers

In 2014, the Fundisa for Change team thought that IK would be a popular addition to teacher education courses, so Soul Shava and Rob O'Donoghue (2014) were asked to write up a course text for the inclusion of IK in the primary school curriculum. This course material remained unused in a formal course for several years until teachers in the KwaZulu-Natal Midlands expressed an interest in IK. We did some informal work on Fundisa for Change courses in 2020 and then brought IK into a series of ESD courses and research activities with teachers between 2021 and 2023.

Across these courses, where we included a focus on IK, there was a high level of interest. Yet the teachers reported that they did not have the knowledge to include IK in their teaching. They also reported that including community knowledge holders had limitations and that local knowledge topics did not always relate well to the school subjects they taught. Many teachers also noted that some learners were not interested because they did not value heritage knowledge.

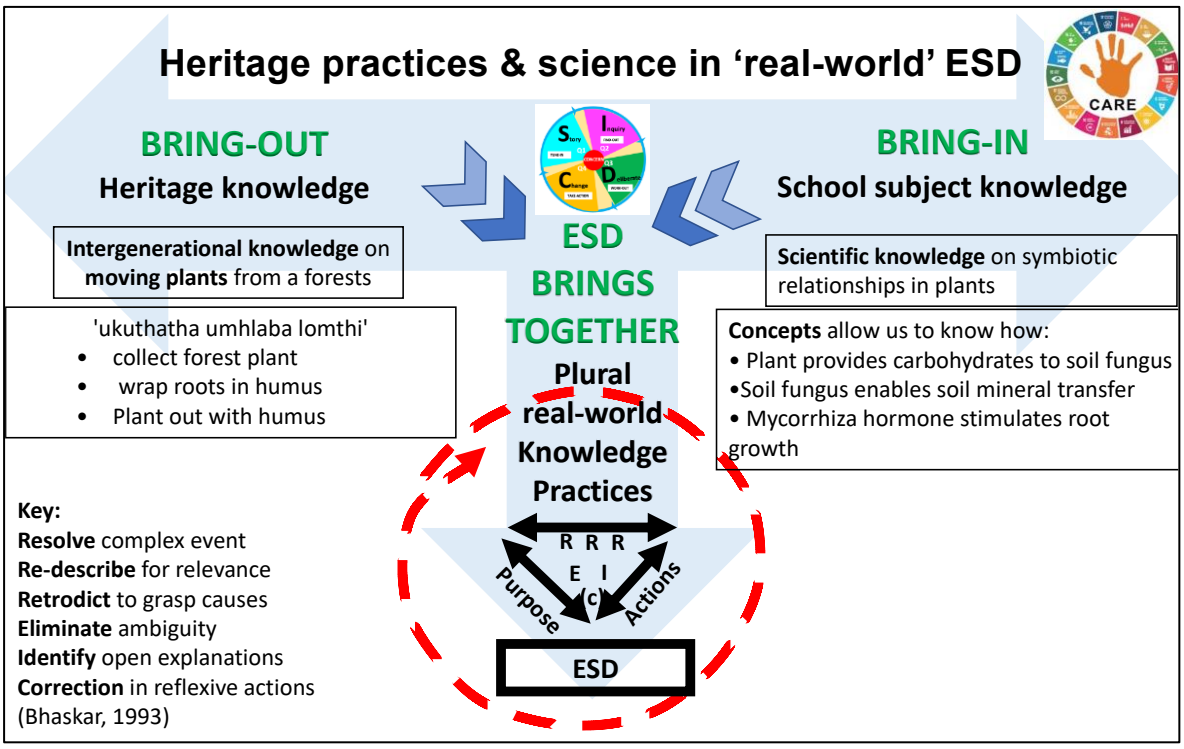
Therefore, in the courses, we used artefacts and accounts of Indigenous technologies and knowledge practices to support teachers in uncovering and recovering IK that had curriculum relevance. There was an enthusiastic response from teachers who set out to include IK in their lesson planning. This was our first formal design research experience on IK with primary school educators working in a diverse range of subject areas.

Outcomes

Contrary to the opposing of Indigenous and Western as differing epistemic processes, we found that in curriculum settings, the heritage knowledges related to real-world contexts of teaching and learning were not explicit because teachers foregrounded the concepts that needed to be taught and learned. We used a critical realist tool to review the contextualising and integration of knowledge in the real-world contexts of heritage food gardening. Here, our primary research interest was the interplay of heritage practices and scientific propositions. An exemplar of the analytical schema is provided in Figure 4. This is illustrated by the heritage planting of forest trees and the explanatory insights of modern scientific concepts related to mycorrhiza. Here, we used Bhaskar's (2016) RRREI(c) schema to enable an depth analysis of situated and expansive learning.

Figure 4

Critical Realism as an Analytical Tool Across Knowledge Systems



Bhaskar's dialectic critical realism comes with a reframing of the Hegelian dialectic around the identification and resolving of absences that render things incomplete and open to reframing. This insight and his RRREI(c) schema allowed us to juxtapose knowledges to create learning spaces where absence could be resolved and learning expanded. Notable here is how the ecological sciences have excluded people, and how these absences created ecology as an oppressive science until the recent advent of the environmental sciences, where the concept of people-as-part-of natural systems and processes opened up STEAM as an arena of learning to unlearn the practices that are incomplete and in need of revision. Using these tools, we were able to support teachers in planning lesson progressions for mediating learning across IK practices and the scientific propositions in the school curriculum, as shown in Figure 4.

Navigating through the process proved to be a daunting task. The lesson plans primarily focused on teaching about waste and topics related to school gardens. These became foundations for widening links with other curriculum content. Engaging with lesson plans in the sciences posed challenges because the knowledge presented itself from an external viewpoint comprising abstract concepts and processes to memorise. Confronted by these lesson design challenges, we encouraged teachers to work with heritage artefacts as a foundation for understanding scientific processes. Further investigation into this method is justified in future research. For recent insights on the integration of IK in STEM and transformative learning, refer to Godson et al. (2024), as well as the work by Lotz-Sisitka et al. (2015).

Notable here, however, is how the sharing of knowledge in their mother tongue enabled students to describe a heritage practice like *amasi* (souring milk) and how this opened up cultural similarities in the making of curds (in India) and yoghurt and relating these products with the science of fermentation. Once again, we saw that there was an accumulation of deep insights into cultural knowledges and that the sharing of these in the mother tongue brought richness and excitement into teaching and learning. In their lessons, teachers reported children working with IK practices in their mother tongue with simultaneous translation by another speaker of that mother tongue, allowing teachers to explore how this opened up the past, cultural pride, and depth of understanding across past, present, and future (O'Donoghue et al., 2021) as a learning pathway to knowledge-informed innovation.

We were also confronted by the challenge that cultural histories and knowledges other than Indigenous African knowledge needed to be included. This was particularly the case with the Indian knowledge heritage that developed historically in market gardening in the Durban area when indentured labour arrived from India. The historical record of oppression and struggle and the family histories of participants revealed that Indian peoples had learned about *imifino* from the Zulu, had brought their own wild herbs, and came to develop heritage knowledge for market gardening in the Durban area that reaches into the present day.

Insights

There was a high level of interest amongst teachers, but engaging modern learners was not always easy. Despite this, all cultures have heritage knowledge practices that can enhance the relevance of learning as well as stimulate respect for the past and a developing capacity for intercultural learning. We also noted that heritage practices and the modern sciences could be brought together in lesson planning in learning sequences that promoted interest and learning.

The inclusion of knowledge on *izalene* (litter management and composting) was particularly significant for waste management, with teachers reporting that learners were proud of and inspired by this Zulu heritage practice. Teachers noted that students identified with how creating artefacts from waste brought new sustainability challenges relating to plastics. Here, we noted that working with this knowledge practice and a wheel representing the Sustainable Development Goals (UNESCO, 2015) brought a sense of pride and enabled the students to link to health and well-being in the life skills curriculum (O'Donoghue et al., 2021). Across the courses, it was evident that the incorporation of Indigenous technologies and knowledge led to increasingly profound insights into the nuances of IK practices and how the neglect of heritage in curriculum settings was inhibiting learning with understanding, and developing pride and identity with being African, and having a developing love of Africa (Bhurekeni, 2021). The most significant revelations that came from the participating teachers were that the learners identified with their cultural knowledge practices, recognised diversity and cultural similarities, and developed an ability to see their knowledge in the world around them (O'Donoghue et al., 2021).

Case 2: Activating IK in an Online Teacher Education Course

Following the experience of working with IK practices and opening up the plural knowledge environment associated with this work, we developed schematic tools and exemplars that could be used to frame a teacher education course in STEAM curriculum settings. The Indigenous heritage materials and insights enable us to design a hybrid (contact and online) course for 37 foundation phase student teachers at Rhodes University. Its purpose was to explore cultural historical methodologies for surfacing IKS, associated learning theory, and analytical tools. Here, students worked with a series of practical kits around which we deliberated heritage knowledge as a foundation for story-sharing and small-scale social innovations to promote sustainable lifestyles and livelihoods related to local food gardening. This was supported by a monograph on early environmental work with IK (O'Donoghue et al., 1999) and a later work on Indigenous knowledge and social innovation (O'Donoghue et al., 2013). Figure 3 reflected the Nguni knowledge practices covered, and the student teachers explored how these knowledge practices could be deployed to restore family and community food gardening.

Outcomes

The student teachers raised concerns about the relevance of IK in our modern times but became engaged in how the colonial environmental narratives had maligned Indigenous peoples and marginalised their knowledge in curriculum settings. They worked well with IK in practical activities, and many began deliberations on the value of Indigenous practices to illuminate and engage the problems in the present day. After an initial scepticism about the value of IK in modern times, a wide range of restorative social justice and decolonising perspectives were explored. Here, the practical work on composting heritage and the natural sciences opened up a wide range of learning pathways that could be mediated with an IK foundation. Composting and *imifino* were particularly relevant because they related to anaemia (iron deficiency) in women, which has come with the modern diet.

Insights

This work began to affirm how heritage practices could be a foil for in-depth engagement on sustainability concerns in relation to livelihood and lifestyle practices. Much of the knowledge that surfaced in the story was expanded and related to local concerns through classroom deliberations and group tasks that were built into the programme. Because the programme was a STEAM teacher education programme, the student teachers did not develop specific lesson plans as in Case 1 but were challenged to use the heritage knowledge. This work affirmed the key role that conversation and deliberation played in the surfacing of knowledge and concerns that could be engaged with IK—work that was taken further with teachers in the KwaZulu-Natal Midlands by Lindiwe Ndlamlenze.

Case 3: The Deliberative Surfacing of IK With Teachers

Flowing from the development of online material and the experience of the earlier work with teachers on the inclusion of Indigenous heritage in lesson planning, we noted that one of the main stumbling blocks to the inclusion of IK in curriculum settings was the activation of Indigenous heritage amongst teachers and within school-in-community settings. Case 3 was a workshop with teachers in the KwaZulu-Natal Midlands, that was convened by Lindiwe Ndlamlenze and Rob O'Donoghue. Here teachers worked with artefacts to deliberate indigenous knowledge practices and their curriculum significance in the teaching of scientific concepts. Lindiwe's focus was to use artefacts to explore IK practices that could be included in the science curriculum. The topic she used to convene the workshop was, Separation of Liquids. Working with artefacts, we opened up food and nutrition topics beyond the food gardening scope of the first two exploratory case studies with teachers. The workshop task was for the teachers to develop lesson plans where IK practices could be used to teach the scientific process skills associated with the separation of liquids. Researching these processes with teachers was then taken up in Lindiwe's continuing academic studies.

The calabash was a notable technology that was puzzling to the teachers because they all knew *amasi* from their youth, but most now ate flavoured yoghurt in preference to the soured milk, and none soured their own milk at home. We opened with the story with an anecdote about how Nelson Mandela would eat *amasi* for breakfast and how healthy this was. We noted how he particularly favoured homemade *amasi* because it was more creamy and richer than that bought in a supermarket. It was a good conversation starter because many of the teachers recalled experiences from their youth, and the conversation developed as the calabash was passed around. We explored the practice of inoculating the calabash with yeast from the fermentation of sorghum, done with a special grass spoon that was used to gather the yeast froth in a small bowl for use in the souring of porridge. Everyone had stories to recount about soured porridge. This opened up insights into how the Nguni were masters of fermentation because they had developed their mastery over centuries of extracting nutrition from sorghum and millet. The conversation returned to *amasi* and the calabash as a fermentation chamber to which warm milk was added. The hidden element of the calabash technology in the fermenting of milk is a small hole in the lower side of the chamber. Before the milk is added, it is blocked with a small grass stem that swells when the liquid is added, and serves to seal any leakage. At this stage, we were able to pose the question: "Why is supermarket *amasi* slightly sour, whereas *amasi* made in the traditional way is smooth, sweet and creamy?" We came to the answer through conversation and demonstration of the separation of whey by tilting the calabash and allowing the liquid to drain out into a small bowl to be used for souring porridge. Working in similar ways, we looked at winnowing, the weeding hoe, and the lifting of ferments using the grass spoon.

Outcomes

The workshop affirmed much of the earlier work with teachers, adding substance to the articulation between Indigenous heritage practices and the acquisition of scientific knowledge as an expansive learning process in which work with heritage could be explored for its potential to enhance relevance. Following the workshop, the teachers did a curriculum analysis to identify how Indigenous heritage practices could become a foundation for enhancing the relevance of the science curriculum. Lindiwe supported and analysed this work as part of her as yet unpublished study on IK and science.

Insights

A key insight that emerged was how the heritage knowledge surfaced in conversation that activated and recovered shared fragments of memory that were then woven together in deliberative conversation. What also came to light was how an ethic of care and respect was embedded in the deliberative learning processes, a key outcome of research on Afrophilia conducted by Bhurekeni (2020).

Synthesis and Discussion

The three successive periods of work on heritage artefacts, technologies, and knowledge practices with teachers raised a range of questions that needed to be taken into account in our teacher education work to strengthen social learning in school-in-community settings. Here, ethics-led learning was a cross-cutting concern that surfaced in all cases and informed the reframing of the colonial narratives of exclusion and oppression. The work of John Bhurekeni (2022) was relevant here, notably his focus on Afrophilia—a shared love of Africa and love of self as an African. This was particularly notable in the affirming sense of identity, being, and pride that came with the overturning of colonial environmental narratives, and an African sense of belonging and land care associated with the living landscape of southern Africa as a heritage from which to contemplate more just and sustainable futures together.

Across the emerging case evidence and developing insights reflected above, we were able to begin to give attention to the diverse ways in which Indigenous heritage technologies and knowledge and life

experience were key processes to be considered for the strengthening of learning in curriculum settings within the southern African region. This allowed us to contemplate a deliberative schema for a school-in-community approach to the deliberative activation and inclusion of heritage knowledge in modern schooling and ESD

Conclusions

The use of the schematic research design tools enabled us to design the course to surface IK for start-up story materials for introducing science lessons in more culturally situated and historically relevant ways. The ESD learning progression bridged heritage and scientific knowledge with the inclusion of scientific process skills related to inquiry and data analysis, using a critical realist perspective. These and other outcomes of the exploratory research are being used to inform the design of an online learning programme for teachers. In this context, we discovered that a legacy of exclusion, and a favouring of everything modern, appear to be key drivers of how work with Indigenous technologies and knowledge practices situated in IKS have been slow to find their way into modern classroom and curriculum settings. There are many intertwined factors that can account for this, but none is currently giving adequate insights into how to work with IKs in the plural cultural settings of the modern classroom. The key insights emerging through this work we are doing with the teachers are that, with heritage knowledge, teachers are able to situate learning and enhance relevance in ways that enable learning-led change. This paper thus begins to uncover how the open-ended STEAM curriculum could be a key area where teachers will be able to work with Indigenous knowledge practices. This would require them to work with plural knowledges in learning transactions that recognise plural perspectives and practices. The study points to how teachers can recover and be enriched with IK insights, which they can use to create learning environments, and mediate insights that mirror how things were—and how things have changed. These processes can be a platform for STEAM innovation towards more sustainable ways of being and doing things together.

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Using Drama Pedagogy to Enhance Understanding of HIV Transmission, Infection, and Prevention Among Third-Year Student Teachers

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Abstract

Thirty-eight years into the HIV and AIDS pandemic, the world is still striving to reduce global HIV infections towards zero new infections and AIDS-related deaths by 2030. Sub-Saharan Africa continues to carry the burden of global HIV infections as governmental and non-governmental agencies try out different prevention strategies (UNAIDS, 2024b). Several scholars have argued that comprehensive sexuality education (CSE) is the best preventive strategy to reach youth and key populations with factual information regarding HIV and AIDS. This paper draws from the project, Mentoring as a Method to Promote Women's Health in the Context of HIV-Prevention and Unequal Gender Relations, which employed memory work, photo-voice, drama, drawings, and focus group discussions with third-year student teachers in a life orientation module. Focussing on the data generated through drama, I present an arts-based activity that was used to teach about HIV transmission to student teachers in a bid to equip them with alternative ways of teaching school-learners about HIV and AIDS. The findings highlight student teachers' lived experiences and how they have shaped their perceptions of HIV infections and living with AIDS. I argue from the findings, that arts-based pedagogies allow for enhanced understanding of complex phenomena due to their participatory and in-built intervention nature. Thus, I posit that pedagogies that employ participatory, arts-based, and visual methodologies should be extensively employed in teacher-education towards reducing new HIV infections among the youth.

Keywords: HIV and AIDS education, HIV transmission, arts-based pedagogies, drama

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Introduction

Sub-Saharan Africa remains the region most heavily affected by HIV. Thirty-eight years into the HIV and AIDS pandemic, the world is still striving towards zero new HIV infections and AIDS related deaths by 2030. According to the UNAIDS (2024b) report, more than half of all new HIV infections (55%) in 2022 occurred among people from key populations[1] and their sexual partners, representing an increase of 11% from 2010 when the estimated proportion was 44%. New HIV infections among the age group15–49 years declined by 35% between 2010 and 2022 globally, but there was only a decline of 11% among key populations. The key factors for this difference are discrimination, stigma, and criminalisation of LGBTIQA+ activities, which prevent access to sexual health services for these people. This in turn, contributes to the unequal rates of progress in HIV responses for the LGBTIQA+ population.

Further, the UNAIDS (2024b) report noted that annual numbers of new HIV infections among gay men and other men who have sex with men increased by 11%, while the increase was 3% among transgender women, from 2010 to 2022. UNAIDS (2024b) also pointed out that the relative risk of acquiring HIV in 2022 was 14 times higher for people injecting drugs, and 23 times higher for gay men and other men who have sex with men. The global risk of new HIV infections for sex workers and their customers was nine times higher, while it was 20 times higher for transgender women than in the wider population. Of the global total of new infections, up to 80% occurred among key populations and their sexual partners in 2022, compared with 72% in 2010, with the majority being amongst gay men and other men who have sex with men. This shows that key populations remain at much higher risk of acquiring HIV than the wider population, which is unacceptable almost 40 years into the HIV pandemic.

However, sub-Saharan Africa had an annual decline of 600 000 in new adult infections between 2010 and 2022. Also, in comparison to the overall adult population, new infections among sex workers and their clients dropped by 50% and 67% respectively, showing that intentional provision of sexual health services is crucial to curbing new infections (UNAIDS, 2024b). Despite this, the relative risk of acquiring HIV remains high for sex workers in the region given that they are still 11 times more likely to acquire HIV than the wider population. Notwithstanding this encouraging trend, there was no decline in new infections among gay men, other men who have sex with men, and those who inject drugs. Thus, the global HIV response must be aimed at increasing key populations' access to high quality testing, prevention, and treatment services. There should be an intentional reduction of barriers to access of sexual health services, and such services should be expanded to reduce unmet needs. The disproportionate burden of new infections borne by key populations and their sex partners points to unequal access to life-extending services and treatment (UNAIDS, 2024a).

UNAIDS (2024a) reported that new HIV infections among adolescents and young people (15–24 years) have decreased more rapidly among males than females. The steepest declines among adolescent boys and young men were in Kenya, Lesotho, Malawi, South Africa, Uganda, and the United Republic of Tanzania, where at least 70% fewer adolescent boys and young men acquired HIV in 2022, compared with 2010. However, the HIV incidence among adolescent girls and young women remains exceptionally high in parts of eastern and southern Africa and in specific areas in western and central Africa. This disturbing trend is due to the intersectional vulnerabilities of adolescent girls and young women in many heteropatriarchal communities, where gender-based violence is also rife.

[1] "Key populations were defined as per the Global AIDS Strategy 2021-2026 to include gay men and other men who have sex with men, sex workers, transgender people, and people who inject drugs" (UNAIDS, 2024b, p. 1).

These statistics show that there is still a lot of work to be done among young people and key populations to reduce HIV risk and incidence. Thus, this paper presents a pedagogical strategy that was used to engage student teachers in understanding HIV transmission and the importance of safer sex practices. It responds to the question: "How can arts-based pedagogies be employed to enhance student understand of HIV transmission?"

HIV and AIDS in Education

With HIV infecting young and old people alike, there was a need for education-focused solutions to reducing new infections among the youth. Several studies have been conducted on school-going youth in order to establish the relationship between education and sexual behaviour. Morrell's (2003) and Pattman's (2006) studies focused on the power dynamics within heterosexual relationships and how these enabled coercive and unsafe sexual practices among the youth. Further, Buthelezi (2004) and Simpson (2007) explored some of the cultural practices that perpetuate the taboo nature of sex talk within communities, and how such practices are implicated in the increasing numbers of new HIV infections.

Additionally, Piot and Bartos (2002) highlighted how HIV ravages the education sector in many developing communities. They discussed how HIV impacts the demand for education and negatively affects young girls who drop out of school to take care of sick relatives and other family responsibilities. HIV also depletes household resources and incomes through death and lack of employment, hence creating challenges for children's schooling. This group of young people end up not having access to school-based interventions such as CSE and thus become vulnerable to the virus.

To address the ravages of HIV, UNAIDS (2010) initiated youth-centred programmes as a way of providing sexual and reproductive health education. These programmes were rolled out in different countries to ensure universal sexuality education coverage and prevention of new infections. UNAIDS (2010) argued that success in preventing new HIV infections could be achieved through sexuality education and youth-focused HIV prevention efforts. It also argued that countries needed to reduce youth's HIV vulnerability by ensuring equitable access to education and employment and enabling legal environments.

Kirby's (2008) study highlighted the effectiveness of school-based sexuality education based on the reduction in youth-related HIV infections globally. According to UNAIDS (2019), global numbers of new HIV infections had dropped, indicating that the pandemic could be halted by 2030. To achieve this milestone, there is need for concerted efforts to sustain CSE and other youth-centred programmes that provide youth friendly reproductive health services and information. Kelly (2002) further highlighted the need for discussions that unpack harmful sexual practices and norms.

Mitchell et al.'s (2004) study in South Africa investigated the construction of young people as unskilled in making decisions regarding their sexuality, which makes them vulnerable to HIV. They argued that the politics of innocence embedded in youth and childhood discourses within South African communities denied young people the agency to seek protective measures against sexual violence, sexually transmitted infections, and HIV. In agreement with the above sentiments, Parikh (2005) reported that issues of morality played a huge role in community responses towards sexuality education in Uganda. Parents argued that such an education would lead young people to experimenting with sex and becoming promiscuous.

In a study conducted in Lesotho with women science teachers, Khau (2010) found that women teachers were uncomfortable with teaching sexuality education due to their positioning as mothers within communities. They argued that teaching about sexuality resulted in them being seen as leading children astray and corrupting their innocence, and some argued that they felt uncomfortable talking about sex across the age divide. Thus, teacher identities impacted on their confidence in teaching sexuality education (see also Baxen, 2010). However, despite these challenges, teachers were aware of the need for sexuality education and were willing to be equipped with strategies to overcome their discomforts. In Khau's (2010) study, it was found that teachers lacked the necessary training to address sexuality issues and other phenomena labelled as taboo.

To clarifying the challenge faced by teachers in Khau (2010), is Epstein et al.'s (2003) argument that school-based sexuality education was the only subject requiring parental consent because of its sensitivity and the fact that it was seen as corrupting young children. Believing that children should be sexually unknowing makes it difficult to teach them about their sexuality. According to Epstein et al. (2003) and Paechter (2004), such a belief constructs children as sexually innocent and not needing to know about sexuality.

In another study, Khau (2012) found that traditional practices and societal values impeded effective school-based sexuality education. Religious beliefs were the dominant driving factor in parents being opposed to comprehensive sexuality education, arguing that it would destroy the innocence of children and lead them astray. They advocated for abstinence-only education. In the same study, Khau also found that CSE was a direct contradiction to traditional Basotho practices in relation to sexuality and rites of passage. This created a rift between communities and schools in terms of implementing CSE in schools.

Several scholars have attested to the effectiveness of comprehensive sexuality education in HIV and AIDS prevention (Bruess & Greenberg, 2004; Coombe, 2003; Hargreaves et al, 2008; Kirby, 2008). It has also been argued by scholars that programmes to protect young people from HIV must use combination prevention approaches that are friendly to young people (Coombe, 2003; Kelly, 2002; Pattman, 2006). Such programmes for young people must promote comprehensive services that include knowledge about HIV, sexuality education, access to sexual and reproductive health services, and discussion on harmful sexual norms and practices.

Many young people in sub-Saharan African educational institutions have little or no knowledge of how to ensure their safety against HIV infection (UNAIDS, 2024a). Interestingly, when Pouris and Pouris (2011) investigated the nature and extent of HIV-related published research worldwide, they concluded that South Africa was a *scientific powerhouse*, basing their findings on the number of journal articles published by South Africans in the period 2005–2009. South Africa was ranked fifth in the world, with most of the research being in the social sciences. With such research output, one would have expected a decline in the HIV prevalence within South Africa, especially among young people.

However, the high HIV prevalence rates suggest that the research has had a very small impact. Thus, Louw et al. (2009, para. 8), appropriately argued for "new generation universities" which should be of service to the society in relation to the immediate needs of the communities, such that they can address the "challenges faced by their constituent communities." It is within this context that this paper aims to explore how arts-based pedagogies could be employed with student teachers to enhance their understanding of HIV transmission.

Research Methodology

This qualitative research study employed participatory visual and arts-based methodologies. Finley (2005, p. 686) asserted that arts-based research "provides a formula for a radical, ethical and revolutionary qualitative inquiry." For this study, drama was used to enable student teachers to engage, communicate, and express their feelings and experiences in the classroom (Finley, 2005). Fels (2004) noted that in performative inquiry, drama is used to understand critical societal issues. This paper draws from a larger study that received ethical clearance from my university's Human Research Ethics Committee to ensure that all research activities would follow ethical protocols. The third-year life orientation student teachers were informed of the study and the request for their participation and freedom to opt out. All student teachers agreed to take part in the study, and they all signed informed consent forms. The student teachers were also informed that the activities for the research would not form part of assessment activities for the module. The student teachers were then allocated numbers to be used in lieu of their names in presentation of the data and findings. For example, Student Teacher 1 in Group 1 was denoted as (ST1G1).

The study took place in the context of a life orientation lecture for third-year student teachers. All 35 registered students for the course participated in the study. The class was divided into two groups consisting of actors (Group 1) and the audience (Group 2). The students were given a prompt to create a scenario of their choice in which the risk and vulnerability to HIV infections was high. They acted out their storied drama to highlight their lived experiences of vulnerability and risk to HIV infections. The student teachers all agreed to be video recorded when performing their drama, and audio recorded during the discussions of the video. The student teachers were provided different colours of washable finger paint with which to cover their palms to signify different stages of HIV infection.

During a lecture discussion on HIV infections and living positively with HIV, the student teachers talked about their experiences of being taught about HIV transmission in schools, their reactions to the teachings, and their perceptions regarding HIV and AIDS. These discussions revealed several issues pinpointing to a lack of understanding of HIV transmission and protective measures. Thus, the drama was planned to engage the student teachers in trying out a different strategy of learning about this phenomenon to enhance their own understanding. The student teachers' performance was based on the prompt: "How can drama pedagogy be used to teach about HIV transmission in classrooms?"

They were provided with a storyboard to plan their performance and to decide on who would act in which part. The storyboard was an important tool in getting the student teachers to think through their content and scenes. Once the actor group had completed their planning session and rehearsed their performance, they were given time to perform for the audience group in class. The audience group was asked to note the different palm colours of each actor at the beginning and at the end of the drama. The discussions between actor group and audience group were audio recorded. The student teachers' insights and experiences were analysed thematically. The different paint colours used were labelled as follows:

Table 1
Key Depicting Meanings of Colours Used

Paint Colour	HIV Status
No paint	HIV negative
White	HIV positive taking ARVs
Red	HIV positive, knows status, no ARVs
Yellow	HIV positive, does not know status
Red with latex glove	HIV positive, no ARVs, using latex condoms
Red with paper glove	HIV positive, no ARVs, using animal membrane condoms
Black	Full-blown AIDS

Drama Pedagogy

Drama pedagogy is aimed at developing critical consciousness and societal change. It challenges societal injustices and contributes towards transformed societies (Davies, 2014). Dalrymple (1997, p. 84) argued that drama pedagogy is holistic, experiential, and participatory, thus providing "a broad framework in which to explore ideas from a range of different perspectives." Drama pedagogy's purpose is positive social change (Neelands, 2007), and Giambrone (2016, p. 18) pointed out that it uses "identity recognition and personal transformation as a means to social change." These arguments are in line with Boal's (1979) theory that dramatic performance can assist people in changing their reality and transforming marginalised lives.

Theatre-in-education as a branch of drama pedagogy uses drama and theatrical performances as pedagogical tools for interactive learning (Lu, 2002). The process of theatre-in-education begins with a social issue of concern, which gets used as an overarching theme for theatrical creations and performance (Tarlington & Michaels, 1995). Students collaborate to select an aspect of the theme to develop a theatrical performance that depicts their understandings and perceptions of the theme for an audience. Once the performance is complete, the actors and audience reflect on the scripted issues to "actively engage the audience in the learning process" (Jackson, 2001, p. 1).

In this research, one group of third-year student teachers created a theatrical production based on their perceptions and understandings of HIV transmission and protective factors against infection, which they performed for the audience group and the lecturer within the context of the life orientation lecture room.

Theoretical framework

Dewey's philosophy of experience was employed as the theoretical framing to provide this study with a sense of direction (Blumer, 1969). As Patton (1990, p. 67) put it, "how you study the world determines what you learn about the world." Thus, employing the philosophy of experience as a frame yielded an understanding of the lived experiences of the participants regarding HIV transmission and prevention.

Dewey's writings (1934, 1938/1963) on the nature and forms of human experience provided a theoretical foundation for this inquiry into student teachers' lived experiences of learning about HIV infections and transmission. Dewey's philosophy of experience has two principles—continuity and interaction—(Clandinin & Connelly, 1994; Richert, 2002), which guided my narrative interpretation of the experiences of the student teachers. The principle of continuity claims that every experience borrows from those that have gone before, and informs those experiences that will come after (Dewey, 1938/1963). This principle was helpful in reminding me that every individual experience is shaped by our previous experiences. Thus, in making sense of the student teachers' experiences of learning about HIV infections and transmission, I had to be aware of their past and the future experiences that could be interwoven into these particular experiences.

The premise of the principle of interaction is that every personal experience connects with the past as well as shaping the future. Each experience is a consequence of the interaction between a person and what constitutes their environment. A person's environment, according to Dewey (1938/1963), is made up by the interaction of personal needs, desires, purposes, and capabilities that create experiences. Thus, the personal experiences of student teachers unfold "in an environment; not merely in it but because of it, [and] through interaction with it" (Dewey, 1934, p. 13). This principle was helpful in analysing the environmental influences that shaped the student teachers' experiences of HIV and AIDS education.

Dewey's concepts of *educative* and *mis-educative* experience were used to explain and understand the experiences of student teachers and their positioning as agents of change in the teaching of HIV and AIDS education. Dewey argued that education is a "development within, by and for experience" (1938/1963, p. 28). For Dewey, education, experience, and life are part of the same cloth. However, he warned that not all experiences are equally or genuinely educative. Dewey purported that a genuinely educative experience should leave one open to stimuli and provide opportunities for development in new directions while also adding to the general quality of one's life. If, on the other hand, an experience hinders or distorts the development of further experiences, it is mis-educative (Dewey, 1938/1963). Understanding whether their experiences of learning about HIV infection and transmission have been educative or mis-educative helped the student teachers and I to reflect on how our past experiences have impacted on our conduct and understanding as teachers in the context of the HIV and AIDS education classroom and hence, how we can improve our understanding and facilitation of HIV and AIDS education in schools.

Findings

The student teachers worked in two groups. The acting group used the washable finger paint to denote the different HIV stages as explained in Table 1 above. Before putting on the paint, they used the provided storyboard to decide on the setting and actors for their dramatisation. They decided that their setting would be a university residence party in which returning students meet new students. Once this was decided, the students painted their palms in different colours. In the drama, they portrayed drunk students dancing and "hooking-up" with and without protection. The hooking-up was demonstrated by holding hands using the painted palms, or just shaking hands. This allowed the transfer of paint from one student to the other. This transfer was used to denote possible HIV transmission. The mixing of the different colours after holding hands highlighted the increase in viral load after HIV was transmitted from one infected person to another. The students who had red paint and wore a tissue-paper glove denoted someone using edible animal membrane condoms, while those wearing a latex glove denoted wearing a latex condom. The students who had no paint on their palms also joined in the hooking-up with those who had paint, thus enabling paint transfer onto their palms. This transfer of paint from a painted palm to an unpainted palm denoted transmission of HIV from an infected person to an uninfected person.

Dramatising the party scene was very enjoyable to the students and they used their lived experiences as university students to portray what usually happens at such parties. The hooking-up and exchanging of paints created a fun activity for the student teachers who were actors, and also for the audience. The audience group was able to observe the behaviours portrayed and analyse them in relation to HIV transmission, infection, and prevention. A recorded video of the drama was played for the whole class to discuss and analyse. The discussions ensuing from watching the actual drama and the recording produced two themes:

- Beliefs, myths, and misconceptions about HIV transmission.
- Rethinking the teaching on HIV and AIDS education.

These two themes reflect the student teachers' experiences of living in a country riddled with HIV, and learning about HIV transmission, infection, and prevention. Using verbatim excerpts from the student teachers, these two themes are discussed below.

Beliefs, Myths, and Misconceptions About HIV Transmission

The discussions of the drama and video recording yielded interesting conversations among the student teachers relating to knowledge, perceptions, and understandings of HIV transmission. Some of the myths and misconceptions they held about HIV were revealed as exemplified in the following snippets.

> *It was interesting to see that the tissue-paper glove allowed to the paints to mix. Which means it was not much of protection. I always thought all condoms provided protection against HIV. (ST8G1)*

> *It was like there was no protection at all. The paints on the palms got mixed like there was no barrier in between the palms . . . sjoe! (ST4G2)*

> *This is scary because I always believed that every condom provides protection against HIV infections . . . and I am sure I am not the only one. (ST5G1)*

At this point, I asked the student teachers why there was transfer of paint through the tissue-paper glove, such that we could get to an understanding of the effectiveness of different materials in prevention HIV transmission. Some argued that the tissue-paper was porous and thin, allowing matter to pass through. Our discussion went on to compare the tissue-paper glove to an animal membrane condom, which is mostly used for edible flavoured condoms. I discussed with the student teachers that condoms made of animal membrane were semi-permeable, thus allowing some solutes and solvents to pass through. This brought up a heated discussion on the usage of such condoms.

> *Mam, why then are people using such condoms, if they do not provide protection? (ST6G2)*

> *I think they are used for fun . . . see . . . when you are playing with your partner and eating the condoms, it creates fun foreplay . . . hhahaaaa! (ST4G1)*

> *Maybe they are used by people who know their status and are faithful to each other . . . you know . . . to spice things up! (ST11G2)*

Allowing the student teachers to discuss and respond to each other provided grounds to hear their level of understanding of how HIV transmission occurs. I then discussed with them that animal membrane condoms are not made to protect one against HIV transmission because the animal membrane cannot block the HI virus from passing through. I then emphasised the importance of

checking the condom packaging before buying or using, to ensure that they are getting protective condoms made of latex.

> *Yah, the paint from the other person remained only on the glove and did not get onto my palm . . . but I got traces of paint where the glove had rolled up. (ST1G1)*
>
> *Hahahahaa . . . so your palm was protected somehow, but the rest of your hand got new paint because your glove was not on properly? (ST3G2)*
>
> *The glove must have rolled up while hooking-up (shaking hands) with different people. I should have checked whether it was still on properly . . . hahahaa. (ST1G1)*
>
> *True that! Many people believe that as long as they have a condom on, they are protected. They do not check whether they have put it on properly, or whether during the act it has rolled up or slipped off. (ST10G2)*

This was another teachable moment where I discussed with the student teachers that latex condoms can provide protection against HIV infection during sexual intercourse, provided they are used properly. We then had a demonstration of putting a latex condom on a banana. I informed the student teachers to first check the expiry date on the package, and then check whether there were any holes or openings on the package. Once they had confirmed that all was in order, I asked them to open the condom package with their eyes closed. Many of them immediately put the condom pack between their teeth to tear it. Some struggled with opening the packet for a few minutes. The student teachers were then asked to check whether the condom was the right side up, pinch the air out of the condom tip, and place it on the banana. This yielded a hilarious engagement among the student teachers because they were struggling with doing this activity while their eyes were closed. Finally, I asked them to open their eyes and check whether their condoms were on properly.

> *Mine is torn because I used my long nails to tear the package. (ST3G1)*
>
> *Mine is up-side-down because I could not see what I was doing . . . hahaha . . . It is not even quarter-way on, as it could not unroll. (ST11G2)*
>
> *Mine is on properly, but there is air in the head because I could not pinch it out before rolling it on. (ST5G2)*
>
> *I am the winner . . . hahaha . . . mine is properly on and there is no air in it. (ST2G1)*

I then asked the student teachers why they thought I had asked them to the activity with eyes closed:

> *Mam, because sexual intercourse usually happens in the dark . . . dark room or at night. (ST12G1)*
>
> *Because when people want sex, their minds stop functioning and they cannot see properly . . . hahaha. (ST7G2)*
>
> *Mam, I think it is because in the heat of passion, people are in a hurry to get to the penetration and they cannot think rationally. (ST4G1)*

This discussion allowed us to get into the realities of sex as experienced by the student teachers. I therefore took this opportunity to engage them in discussing how to ensure that condom usage does not become an afterthought but an integral part of sexual intercourse. Although many of the students

had believed that just using a condom could provide protection against HIV transmission, they realised that there was more to it than they had imagined. I emphasised that for latex condoms to provide the necessary protection from HIV and other sexually transmitted infections, they had to be used properly every time. We then came up with the following checklist:

- Do not leave latex condoms in hot places like in a car cubbyhole, or back pocket of pants.
- Check expiry date on package.
- Check for cuts and holes on package.
- Push condom to one side within the package.
- Tear the package along the serrated edge with your fingers.
- Take the condom out of package and check that the rolling part is on the outside of the condom.
- Pinch the tip of the condom to remove residual air.
- While still pinching the tip of the condom, unroll it onto an erect penis.
- Ensure that the condom is fully unrolled, and the penis shaft is covered.

I also discussed with the student teachers the benefits of using foreplay as an opportunity to put condoms on properly. This did not sit well with some student teachers because some of the women believed that condom usage was the forte of men, while some of the men had a problem with their partners seeing their genitals.

> *But Mam, male condoms must be the responsibility of men. Why should women assist them in putting the condom on? (ST10G2)*

"Would you rather have women infected with HIV because they did not ensure the proper usage of condoms by their partners?" I asked. The whole class became quiet after this question. I could see that they were deliberating how to respond, or maybe reflecting on their personal experiences with condom usage. Eventually one of the male student teachers said:

> *Maybe in a stable relationship, I could allow my wife to put a condom on me . . . not a girlfriend . . . no ways . . . these girls talk about our sizes with their friends . . . hahahaa. (ST17G1)*

> *Mam, I think the including condoms in foreplay is a brilliant idea because safety does not become a burden, but part of the pleasure. Imagine you get two minutes of pleasure and a lifetime of misery because you did not use a condom properly? Haibo . . . ngeke. (ST11G2)*

At this stage, the discussion was becoming uncomfortable for some of the student teachers because of their religious and cultural beliefs. I decided to get into a discussion to inform students that due to their anatomy, women and girls are more vulnerable to infections than men and boys. Thus, I encouraged that women and girls ensure that their sexual partners are using protection properly. While this places an unnecessary burden on women and girls, I pointed out that it was a lesser evil than acquiring HIV.

Mam, what about including fellatio and cunnilingus in foreplay? I do not think people use protection for those. So, what is the use of using a condom after muffing someone whose status you do not know? (S16G1)

My thoughts exactly Mam! Anything can happen during the oral sex, but we do not talk much about protection in that stage. (ST8G1)

Some of us have always believed that oral sex was safer because that is what we were told by other young people. . . . Does it mean we have been risking our lives? (ST9G1)

I could see that the understanding of the student teachers regarding the transmission of HIV was changing as they discussed the drama, video, and the banana demonstration. I then told the student teachers that as long as there is transfer of protein-based body fluids between individuals, there is a chance of HIV transmission. While saliva is not protein-based and may not carry much of the HI virus, semen and vaginal fluids do carry enough of the HIV for transmission to occur, especially where there are open entries such as cuts and sores. Thus, I emphasised the importance of being protected using the right method in any type of sexual engagement, whether oral, vaginal, or anal. In discussing infection through anal intercourse, the discomfort levels also got high because of a difference in attitudes and values. However, I managed to inform the student teachers that anal intercourse runs the risk of rupturing the capillaries in the anal canal, thus creating a fertile ground for infection. Therefore, I also highlighted the importance of using water-based lubricants with condoms during sexual intercourse because oil-based lubricants affect the structural integrity of the latex causing it to break.

So, Mam, why did you say we should check for holes and openings on the package? (ST6G2)

I think it is because once the package is damaged, the integrity of the condom cannot be guaranteed . . . basic economics . . . hahaha. (ST12G2)

I also think that it is because some boys put holes on condoms to punish or take revenge against girls and women . . . honest . . . I saw a programme on TV. (ST7G2)

I discussed with the student teachers that latex, as a rubber, only retains its structural integrity under certain conditions. Thus, if a condom is left in excessive heat, used with an oil-based lubricant, or the package is damaged then the condom begins to disintegrate. This destabilises the protective structure of the latex such that it becomes permeable and matter can pass through. This brought us to our next theme where we related the drama experiences with teaching and learning about HIV transmission, infection, and prevention. This is discussed next.

Rethinking the teaching on HIV and AIDS education

I asked the class to talk about their experiences of the painted palms in the drama, and what these meant to them. The purpose of this discussion was to find out from the student teachers whether any changes had occurred in their understanding of HIV transmission, infection, and prevention.

Yah, Mam! When the person with yellow paint held hands with the person with red paint, both paints mixed, and the two palms were left with a different paint. To me, this means that they went to the party with different levels of infection and came home with something totally new and different. (ST10G2)

I had no paint on my hand, but I shook hands with the black paint palm and my palm became totally black. When I think of it, it made it easier for me to understand how easy it was for one to get HIV. (ST3G1)

My palm was painted white. When I shook hands with red paint, all the white was gone, and I had light shade of red. This made me realise that taking ARVs does not mean that one could not get re-infected. I realised that it was important to use ARVs as well as condoms for proper protection against HIV infection. (ST5G1)

Yah neh! My palm was painted red without any glove. My plan in the drama was to go and infect others. However, when I shook hands with the one painted yellow, my colour changed. When I shook hands with the black paint, my palm became black. For me, this means that in trying to infect others, one places themselves at risk of re-infection thus increasing their viral load. I think when one knows their status, it is better to stay with that and not add more. (ST10G1)

I was more interested in the person with red paint and latex glove. Where the glove was not covering, there was transfer of paint. This means that it is important to use the latex condoms properly every time. Otherwise, one might think they are safe, only to find themselves infected. (ST15G2)

The student teachers' discussions and reflections highlighted a change in their thinking and understanding of HIV transmission, infection, and prevention. They realised that they had been holding onto misconceptions and wrong beliefs about HIV infection and prevention. Painting their hands to demonstrate HIV transmission brought an invisible phenomenon to light. They could see the paints getting mixed, or unpainted hands getting painted, or painted hands with tissue-paper gloves getting mixed paints. This brought to light the ability of arts-based pedagogies to bring to life complex and abstract phenomena.

Discussion

The findings of the study show that the student teachers are uncomfortable to discuss issues pertaining to sex, despite them being expected to teach about this phenomenon in schools. It has been argued by scholars across the globe that teachers face challenges regarding the teaching of sexuality education and HIV and AIDS education due to the constructions of sexuality within their communities (Baxen, 2010; Epstein et al., 2003; Khau, 2012; Mitchell et al., 2004; Paechter, 2004). The student teachers' religious and cultural beliefs created barriers to their engaging fully with the classroom activity and discussions. Bhana et al. (2019) argued that religious and cultural beliefs in communities construct sexuality as a taboo subject thus making it difficult for teachers to teach any subject related to human sexuality. While the student teachers were comfortable with the use of paint and drama, they were uncomfortable with the activity involving a condom and a banana. The male student teachers argued that such discussions would lower their standing in the eyes of their female counterparts. This reflected their patriarchal socialisation that a man should be respected (Baxen, 2010; Khau, 2012).

The prompt for the drama performance was left open and general to enable the student teacher group of actors to decide on a theme and setting of their choice. They were provided with washable finger paint, paper gloves, and latex gloves for use in their performance. Using their lived experiences of university life and sexual encounters, they created a university party to highlight their experiences. This was in line with Dewey's (1938/1963) principle of continuity, which was helpful in reminding me that the student teachers' current experiences were shaped by their previous experiences. Thus, in making sense of the student teachers' experiences of learning about HIV infections and transmission,

I was able to relate to their past experiences, which influenced their decision during the drama performance, and their beliefs regarding HIV transmission, infection, and prevention.

The student teachers were socialised into heteropatriarchal communities that construct human sexuality as a shameful and taboo subject (Parikh, 2005). Although creating challenges for the effective teaching about sexuality and HIV infections, this socialisation is maintained because the student teachers have a vested interest in it. They stand to gain respect by upholding the respectful and good adulthood norms of their communities (Epstein et al., 2003; Francis & De Palma, 2015; Mitchell et al., 2004). However, Dewey (1938/1963) has highlighted the fact that an experience that hinders or distorts the development of further experiences is mis-educative. Thus, in my lecture room, I was met with several mis-educative experiences from the student teachers that required unravelling. I had to come up with further strategies to ensure that the resistant student teachers came to the fore with their beliefs so that we could transform their thinking and understanding.

In using drama performance, I was creating new experiences for the student teachers, from which they could build future experiences in relation to HIV transmission, infection, and prevention. I based myself on Dewey's principle of interaction, which stipulates that each experience is a consequence of the interaction between a person and what constitutes their environment. A person's environment, according to Dewey (1938/1963), is made up by the interaction of personal needs, desires, purposes, and capabilities that create experiences. Thus, the personal experiences of student teachers unfold "in an environment; not merely in it but because of it, [and] through interaction with it" (Dewey, 1934, p. 13). This principle was helpful in analysing the environmental influences that shaped the student teachers' experiences of HIV and AIDS education. It enabled an understanding of their socialisation in their home communities as well as their socialisation within the university community. Thus, taking all these into account, I was able to bring forth their past experiences, and reshape their current experiences with a hope of transforming their future experiences.

The engagement of student teachers with the drama performance and the video recording thereof created a rich platform for misconceptions and myths to come through, thus, allowing for a deconstruction of such. Through seeing the colour transfer and challenges with condom usage, the student teachers' understandings regarding HIV transmission, infection, and prevention were transformed. They could visualise the paint as representing the virus, thus enabling them to see the material reality of HIV transmission. Dewey argued that education, experience, and life are part of the same cloth, and that education is a "development within, by and for experience" (1938/1963, p. 28). In line with Dewey's assertion that a genuinely educative experience should leave one open to stimuli and provide opportunities for development in new directions while also adding to the general quality of one's life, I believe that our drama performance and engagement was an educative experience for the third-year student teachers.

Conclusion

In this article, I explored how arts-based pedagogies could be employed with third-year student teachers to enhance their understanding of HIV transmission, infection, and prevention. The purpose of using drama pedagogy was to enable the student teachers to unleash their agency in selecting a theme and context, deciding on how to perform, and bringing to the fore their lived experiences regarding sexual relationships, sexual interactions, and HIV prevention. Each group of actors chose, created, and performed their play on HIV transmission, infection, and prevention. Their performance showed their understandings of the content of HIV and AIDS education and their perceptions of how transmissions occur in their daily lives. Although the prompt for the drama performance was open, the student teachers chose a theme and context that was familiar to them. However, their cultural and

religious socialisations impeded their freedom to discuss issues of sexuality and HIV within the classroom.

Teachers socialised in communities that pathologise sex and sexuality feel vulnerable when it comes to teaching about these phenomena. This makes it a challenge for learners who are expected to learn from such teachers because they would not be able to get all the factual information to allow them to make informed choices regarding their sexual lives. They thus become vulnerable to sexually transmitted infections including HIV and AIDS, and unwanted pregnancies. This study has highlighted the importance of arts-based pedagogies to enhance engagement and understanding of complex phenomena by student teachers. It also highlighted the importance of teaching student teachers about different pedagogical strategies that they could adopt in their own classrooms in schools. Thus, I believe that there is room to employ more participatory and arts-based pedagogies to enhance teaching and learning for complex phenomena, especially in science subjects.

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Enabling STE(A)M in Sustainability Education Through Dialogic/Dialectic Reconciliation

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Abstract

In the context of a need for finding and enabling alternatives to unequal and extractivist perspectives on development, growth, and human well-being, this positioning paper explores possibilities for STEAM (science, technology, engineering, arts, and mathematics) education with an education for sustainable development focus that counters disciplinary alienations particularly between the arts and the STEM (science, technology, engineering and mathematics) disciplines. The paper argues that unnecessary alienations between cultural-emblematic and mathematical-logical epistemes, especially those linked to narrow interpretations and restricted developments in dialogism and dialectics, respectively, are influenced by restricted understandings of epistemological, ontological, and praxiological philosophical drivers in meaning making and responsive action. In response, the paper develops a series of philosophical principles that, it argues, could usefully underpin STEAM education practices. These are a) iterations of epistemological expansion and contraction (in response to monologic meaning making), b) an expansive and deepening ontology (in response to ontological collapse in describing the world), c) critical and judgmental rationality (finding a middle ground between radical relativism and dogma), and d) concrete utopianism (in response to idealism and additive holisticism). The emergence of the four philosophical principles is developed through illustrative examples of a broad range of arts (fine art, performance art, photography, film, poetry, prose, and music).

Keywords: STEAM education, education for sustainable development, dialectical critical realism, dialogism, transformative pedagogies

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> *The history of our species is the history of forgetting. Our deepest existential longing is the longing for remembering . . . cosmic belonging, and the work of creativity is the work of reminding us. We may give the tendrils of our creative longing different names—poetry or physics, music or mathematics, astronomy or art—but they all give us one thing: an antidote to forgetting, so that we may live, even for a little while, wonder-smitten by reality. (Popova, 2022b, para. 2)*

Introduction to Education for Sustainable Development in STEAM Education

Science, technology, engineering, and mathematics (STEM) are believed to collectively play an important role in economic growth, sustainable development, and the shift to a knowledge economy (Kahn, 2022). However, of these, economic growth has been pinpointed as problematic in international debate since as far back as the first Club of Rome report (Meadows et al., 1972). The growth critique has been raging since the 1970s, particularly with respect to unequal distribution of wealth and resources, but realisation of planetary boundaries as an additional and integrated concern has taken time to gain traction and broaden into more fields in international debate. And in 2020, for the first time in the 30-year history of its Human Development Report, the United Nations Development Programme (UNDP) argued that material resources can be made to matter more "when fairly distributed and within planetary boundaries because they expand people's opportunities, from one generation to the next" (Conceição, 2020, p. 6).

As an alternative to the prevailing hegemonic discourse of economic growth, Daly (1993) suggested the establishment of a steady state economy that "can be expressed in terms of a constant stock of physical capital, capable of being maintained by a low rate of material throughput that lies within the regenerative and assimilative capacities of the ecosystem" (Jackson, 2009, p. 77). Yet, despite Daly's (1990) and others' repetitive reminders of, and elaboration on, sustainable growth as an *impossibility theorem*, society remains in the grip of increased ecological and social vulnerability (Price & Lotz-Sisitka, 2015). This highlights a need to protect both people and planet in a way that can "integrate environmental protection and ecological integrity, economic viability, and social and human development" (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2016, p. 3).

Jackson (2009) provided useful insight into a way forward that does not trap us in a push-and-pull between planetary health and human well-being. He acknowledged the role of growth in addressing inequalities where material possessions ensure critical elements of well-being such as participation in society, education, health, resilience, and the development of human capability. But he challenged growth that is bundled in macro-economic policies that depend on, and perpetuate, unbridled consumerism in which we use the language of goods to communicate our social status, identities, social affiliations, feelings for each other, and more. Jackson's social-ecological thinking problematised a world that prioritises the protection of economies over human and planetary well-being.

Building on the coupling of equal distribution of resources with planetary and ecological sensibilities, in countries where poverty, social exclusion, inequality, and environmental risk and injustices abound, STEM needs to take a critical stand on development and growth that ensures that human development and well-being—as well as planetary well-being—are respected and protected. Jackson suggested the importance of

> *investments in public infrastructures, sustainable technologies and ecological maintenance and protection. [This] new macro-economics for sustainability must abandon the presumption of growth in material consumption as the basis for economic stability. It will have to be ecologically and socially literate, ending the folly of separating economy from society and environment. (2011, p. 10)*

In the 2022 Human Development Report, the UNDP argued that "our social, economic and political choices—about where innovation can be directed, to what priorities and to serve which people—determine how technology changes and how innovations advance human development (Conceição, 2022, p. 160). This new way of thinking about human well-being and planetary health calls for "talent, ingenuity, compassion and creativity"—qualities of STEM that enable humanity to confront "the challenges of the post 2000 'Age of Crisis'" (Kahn, 2021, p. 7). To extend the potential of these integrated sciences to rise to 21st century challenges, this paper considers the complementary role offered by art where "A" is added to STEM education to support the development of "agency, creativity, innovation, and problem-solving skills" in the practice of STEAM education (Yang et al., 2023, p. 2).

Simply adding the "A" to our acronym is not necessarily going to push thinking in the challenging ways that are needed for the dilemmas described above. Mejias et al. (2021, p. 210) lamented that "the pedagogy and moniker of STEAM have sometimes been deployed in ways that do not fully consider the epistemological potency or educational potential of deep integration of STEM and the arts." In other words, there is insufficient emphasis on strengthening knowledge in educational contexts. Those authors were concerned with offering "new ways of doing and knowing in the arts and STEM fields, often with emancipatory and critical pedagogical approaches to learning that can be at odds with an economistic focus" (Mejias et al., 2021, p. 210).

This paper focuses on transformative ways of doing and knowing in the context of social-ecological risk as discussed above. Such new ways can better serve historically marginalised and underserved populations, emphasising development practices that do not simply serve the inequality and extractivism of the current socio-ecological status quo. Such approaches to STEAM can "contribute to social change and promote a more sustainable and equitable world" (Yang et al., 2023, p. 3) particularly in the light of UNESCO's Sustainable Development Goals.

The next section discusses the trans- and interdisciplinary meaning-making potential of STEAM. Education for Sustainable Development (ESD) is strongly dependent on such meaning making (Schudel & Lotz-Sisitka, 2021) and, similar to STEAM education, is a driving force in guiding transformative educational responses to social-ecological risk (O'Donoghue, 2014; Schudel et al., 2021) in a "quest to achieve social-ecological justice, resilience and sustainability through educational interventions" (Price & Lotz-Sisitka, 2015, p. 2). Thus, this common interest in trans- and interdisciplinary meaning making, plus a common interest in social-ecological change are the drivers in the pairing of STEAM education with ESD in this paper.

The paper is particularly topical for the South African context (from which I write) given the Department of Basic Education's recent call to consider ESD a cross-cutting priority as part of its 2024 curriculum strengthening initiative and its commitment to integrating and "mainstreaming of ESD into policies and curriculum, and institutional activities" (2023, p. 164) in response to South Africa's commitment to developing a national strategic framework for ESD in the context of UNESCO's (2020) ESD for 2030 framework. It is also in support of the South African general curriculum aim of "demonstrating an understanding of the world as a set of related systems by recognizing that problem solving contexts do not exist in isolation" (Department of Basic Education, 2011, p. 5), which is aligned with the STEM/STEAM emphasis on integrated learning and on real-world problem-solving.

The paper argues that one of the challenges for exploring the practice of STEAM education is perceptions of the incommensurability of (traditional) dialectic reasoning and dialogic processes, with the former embracing a mathematical-logical episteme and the latter a cultural-emblematic episteme. It furthermore explains how narrow perceptions of science and arts create unhelpful antagonistic

ontological, epistemological, and praxiological tensions. The main aim of this position paper is to is to seek a conciliatory space for these historically divisive discourses particularly in the face of social-ecological challenges in ESD that require "considerable tolerance for ambiguity and uncertainty, autonomy for making judgments, and the confidence and insight to challenge conventional wisdom" (Stevenson, 1987, p. 77). The methodology employed is one of tracing the philosophical roots of arts and sciences using illustrative examples and vignettes posing problems at the nexus of these broad disciplinary groupings. The theoretical framing of Bhaskar's (1993) dialectical critical realism and Bakhtin's (1984) dialogism provide lenses for viewing the tensions and synergies between the disciplines. The paper concludes by describing four reconciliatory philosophical principles as potential philosophical guides for STEAM education with an ESD focus.

Beyond Historically Divisive Discourses

Histories of disciplinary development have often pitted the arts and the STEM disciplines against each other, thus posing a challenge for the deep integration of these disciplines as described above. Lähdesmäki and Fenyvesi (2017) explained how mathematics and the arts are represented in a dualistic way with argument over whether the universal laws of mathematics or culture-bound narratives and symbols best represent the world. They gave insight into this disciplinary divide by explaining how the fields of science and the arts, since the Renaissance, have experienced reduced interaction and dialogue due to a misguided perception of the sciences and arts as dependent solely on mathematical-logical and cultural-emblematic epistemes, respectively. Lack of dialogue between these two knowledge-building strategies has resulted in them being seen as "two incompatible modes of 'grasping' the world" (Lähdesmäki & Fenyvesi, 2017, p. 6). However, pointing to an interdisciplinary turn in understanding the world in context, Scharf (2021, para. 6) highlighted how, in the 21st century, we are "starting to see real erosion of those artificial [disciplinary] walls, so that it's less and less unusual to be an "interdisciplinary" researcher (see also Bhaskar, 2010 from an environmental and climate change perspective).

Similarly, dialectics and dialogism have distinct differences with the dialogic tradition focused on "voices, utterance, speech genres, polyphony" and the dialectic tradition focused on "contradiction, development, the distinction between understanding and reason" (Dafermos, 2018, p. 14). I suggest that the cultural-emblematic knowledge-building strategy (most often, and problematically, associated only with the arts) is commensurate with dialogism—and the mathematical-logical knowledge building strategy (most often, and problematically, associated only with the sciences) is commensurate with dialectical reasoning.

Despite significant resistance to the possibility for cooperation between dialogism and dialectics, groundwork for the reconciliatory space between these two meaning-making traditions has already been made by other authors (Dafermos, 2018; Daniels, 2012; Mah y Busch, 2014). This paper further explores this reconciliatory space through vignettes and illustrative examples demonstrating the complementarity of dialogism and dialectics. An additional contribution to new knowledge by this paper is to consider the role of dialectics and dialogism in a STE(A)M ESD context (with ESD being the focus of all the vignettes and illustrative examples).

The vignettes and illustrative examples also illustrate the importance of inter- and transdisciplinary opportunities through STEAM education, with transdisciplinarity ("a perspective that transcends the limitations of disciplinary boundaries") being different from interdisciplinarity ("a cumulative perspective from different disciplines") (Schudel & Lotz-Sisitka, 2021, p. 36). The paper explores STEAM's potential for contextual understandings and real-world problem solving with reference to social-ecological issues and risks in ESD as the trans- and interdisciplinary point of interest at the cusp of STEM and the arts.

Resolving Philosophical Problems

This paper achieves its reconciliatory aim by constructing a philosophical base on which to argue the falsity of the incommensurability of the arts and sciences as knowledge building strategies, and by demonstrating dialogism and dialectics as complementary and integrated forms of making meaning in the world. The sections below consider four philosophical problems that set different ways of engaging the world (dialectic and dialogic) at odds. Through critical and non-dualistic treatment of philosophical problems, the paper suggests that reconciliation between unnecessarily opposed epistemes enables possibilities for dialogue, transformation, and change in a world in social-ecological crisis. The posed problems and reconciliations are:

- Narrowing intentions and monologism in meaning making reconciled through epistemological expansion and contraction in meaning making.
- Ontological collapse and monovalence reconciled through an expansive and deepening ontology.
- Radical relativism reconciled through critical and judgmental rationality.
- Idealism and additive holism, reconciled through concrete utopianism.

Epistemological Expansion and Contraction in Meaning Making

In meaning-making processes, the double-edged sword of words is that they can tease out, clarify, and identify unknowns—but they can also tighten, contract, or restrict. As elaborated by Mah y Busch (2014), words can be useful in concisely describing and summarising a situation but over-dependence on the linear, bounding, and binding use of words can sometimes be detrimental to expansive opportunities in meaning-making processes.

In an argument for a more open-ended use of words, Bakhtin described what he saw as problematic monologic readings of Dostoevsky's novels where closed-off discourse using words that expect no answer (because of an assumption that there is only one logical answer) drove Bakhtin's call for alternative readings of these novels. That is, readings that acknowledge Dostoevsky's intention for promoting "dialogically oriented discourse" (Bakhtin, 1984, p. 63).[1]

Following this paper's interest in exploring the possibilities for STEAM education, I have drawn Bakhtin's ideas on the novel into a conversation regarding the arts in relation to the STEM disciplines. In this case, reflections on the arts are drawn from fine art, performance art, photography, film, poetry, prose, and music. This strategy embraces Bakhtin's view that "in dialogue a person participates wholly and throughout his whole life: with his eyes, lips, hands, soul, spirit, with his whole body" (1984, p. 293).

Like words, photographs and fine art in the sciences can capture moments in space and time (for example, an insect wing in mid-flap), detail form and function (for example a fuzzy bee pollinating a flower), detail complex ecological interactions as did Maria Sibylla Merian in her depictions of insect–plant relationships (Heard, 2016), or honour an object of beauty (for example, an intricate clock mechanism). Equally, the arts can document cases where science has been misused and abused. For example, Cornelia Hesse-Honegger's paintings of wildly mutated insects in the wake of the Chernobyl

[1] Important to understand about dialogics, is that the notion is not about speech per se, and that it also should not be conflated with dialogue (Mah y Busch, 2014).

nuclear disaster (Suchin, 2000), and photographs that reach us daily in the news depicting science in the service of war and war crimes and which can be used to rally necessary protest (Thompson, 2023).

But not all artists seek such definition or conciseness in their work. For example, in a series of interviews led by Paul Cronin with the filmmaker, Werner Herzog, Herzog dismissed a banal, superficial, or accountant's truth in favour of a "poetic, ecstatic truth," that is, a truth that is "mysterious and elusive, and can be reached only through fabrication and imagination and stylisation" (as cited in Cronin, 2002, p. 301). That is, not to deny histories in filmmaking, but to see the art form as opportunity for reflection on historicity rather than "a claim that one is experiencing something authentic, trans-historical or even 'essential'" (Prager, 2007, pg. 46)

This problem of the "surety" of truth and the associated danger of positions of closure limiting creative moments of possibility is one of the positions of tension between dialectics and dialogism, that is, a tension linking to the problem of monologism. However, a space for reconciliation between dialectics and dialogue was opened for me through Mah y Busch's metaphor of the pedagogic heartbeat in which he argued for both moments of contraction (not monologic but synthesising and clarifying) and expansion in meaning-making processes. He suggested that:

> *The primacy of words in critical dialectics threatens over-contraction. Arrhythmia. Such forms of awareness, though necessary, can get trapped in the extended tightening of language and its linear logic, which, like a sentence, valorizes the world of the subject's action. Words yearn to clarify. They need to grasp, always distinguishing and specifying. But what if something is beyond the reach of language? (Mah y Busch, 2014, p. 122)*

Before responding to Mah y Busch's question, I need to address Bakhtin's reservations about monologism in the work of Hegel. Bakhtin argued that a "unified, dialectically evolving spirit, understood in Hegelian terms, can give rise to nothing but a philosophical monologue" (1984, p. 26). However, the dialectical tradition is long and varied and Bhaskar developed a critical realist dialectic which he described as "the 'great loosener,' freeing up our concepts from fixated or excessively fixed meanings and usages" in a process that over-reaches but does not transcend analytical thought (2016, p. 124). By this, he implied concern regarding interpreting a situation based purely on tight, reproducible, analytics. He implied that such analytics should not be ignored but can be expanded. With this broader perspective of dialectics there appears to be room for a much more complementary role between moments of letting go/feeling the way (expansion) and others of refining, reworking, re-describing (contraction) in open-ended and exploratory iterations between dialogism and dialectics.

An example of a great loosener can be seen in the work of the conceptual artist Mark Wilby (2014), as described in Vignette 1. Wilby explained that he wanted to see if creating a story (through an elaborate performance piece and subsequent choreography of a reality encounter around the crisis of rhino poaching) could be more effective than the conventional anti-poaching campaigns in response to the crisis (personal communication, December 8, 2023). While such campaigns might be considered to be essential in the short term and a necessary response to a serious crisis, we would be well-advised to question the wisdom of "combatants rumbling into confrontation . . . not always with sufficient pause for the complexities involved, or the unintended consequences" (Wilby, 2014, para. 1) so that maladaptive resilience[2] (Lotz-Sisitka et al., 2015; Sriskandarajah et al., 2013) becomes our only recourse.

[2] For example, resilience that perpetuates or exacerbates an oppressive or exclusionary status quo.

Vignette 1
Story of the Cliptivists

On the 18th of October 2012 a small-town newspaper published an article titled: Take our toenails not our rhino (Grocott's Mail, 2012). They reported how Grahamstown artist and filmmaker Mark Wilby, responding to the devastating discovery of four poached rhino at a nearby private game reserve, had walked into the reception area of *Grocott's Mail* and clipped his toenails. He had then put the clippings into an envelope and posted it to the Chinese Embassy in Pretoria with "To whom it does concern" written neatly across the top. The article explained this seemingly bizarre action, describing the slaughter of almost 400 rhinos in that year, when rhino horn, according to scientists, has none of the miraculous properties its proponents claim. Instead, scientists argue that rhino horn is made up of inert and useless keratin – the same polypeptides making up the outer layer of human skin, hair, fingernails and toenails. The newspaper reported Mark lamenting the conflicting beliefs about the powers of rhino horn and his frustration with the sea of petitions and franchised charities, saying: "Given the urgency of the crisis, anti-poaching tactics are essential. But this addresses the symptom, not the cause." (text adapted from the Grocott's article).

After the toenail clipping campaign, Mark provocatively emulated a media reality show, and assembled a disparate group of people (a university computer engineering student, a community activist, a lecturer in media law, a retired teacher and practicing Buddhist, and a drama educator) under the name of 'The Cliptivists' to explore the complexity of rhino killings in South Africa. Through visits to game reserves, a talk with a local wildlife veterinarian, some fitness training (tongue-in-cheek preparation for anti-poaching patrols) and mediated deliberative sessions discussing different conservation initiatives and possible interventions; Mark facilitated a different kind of dialogue for The Cliptivists.

From a STEAM education perspective, the Cliptivist challenge could be emulated with research across disciplines: the sciences (ecology, pharmacology), technology (conservation technologies), mathematics (calculations of who and where the profit margins of rhino poaching lie), and arts (fine art, poetry, and prose exploring social-ecological relationships, for example, Owen, 2013).

An Expansive and Deepening Ontology

Both the arts and science are committed to describing events and experiences in the real world. That is, they have an ontology (an understanding of what is real) committed to aspects of the world that are actualised and empirically detectable. An example is the documentation role played by science and art described above (either through measurable scientific closed lab experiments, or more open-ended and contextualised fieldwork, or artists' realist representations of phenomena).

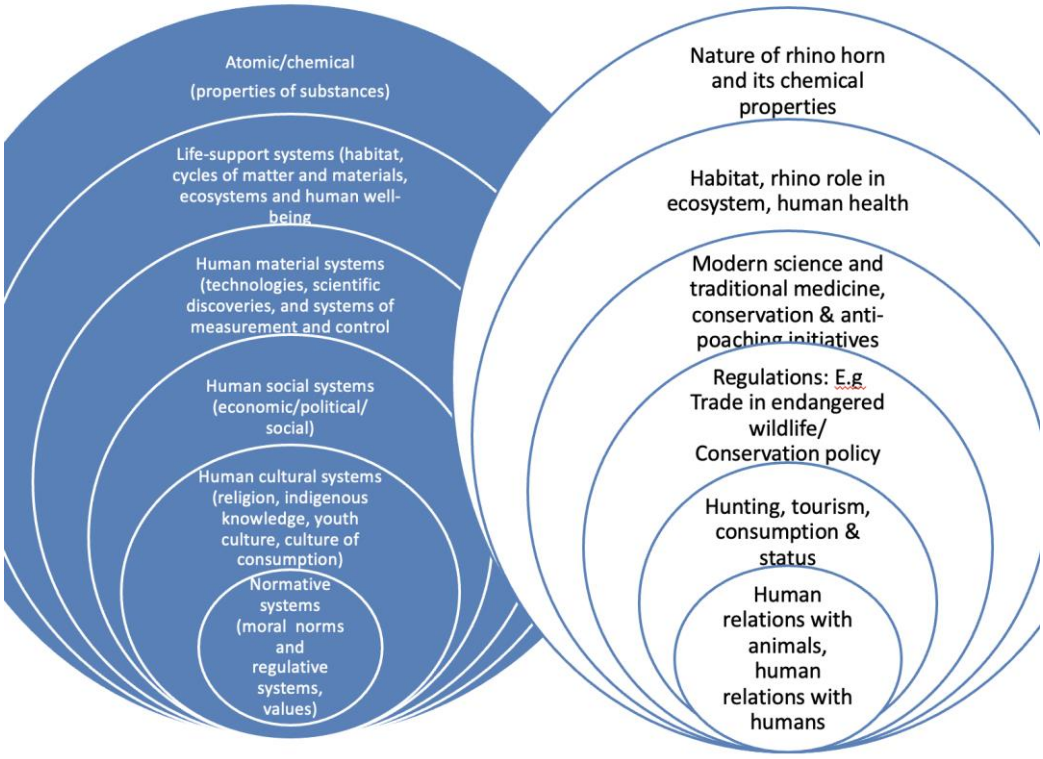
However, dialectical critical realism presents an expansive ontology that moves beyond the description of events through experience and insists that the sciences are necessarily both broader and deeper than this. Equally, the examples provided below will attempt to illustrate the complementary role played by the arts in revealing an expansive ontology including:

- Laminated ontological *breadth*

- Ontological *depth* and unactualised possibilities

The first—ontological breadth—is detectable via critical realism's concept of *laminated totality*. For an example of laminated totality in use, as an ESD practitioner, I was invited to work with the Cliptivists (Vignette 1 above) to help them to make sense of the complexities they were facing. In workshopping the rhino crisis in our local area, the contradictions and tensions between a) traditional and scientific claims on the properties of rhino horn, b) consumption and conservationist/ecologist arguments, c) human rights and animal rights values, d) cultural and scientific beliefs (see the right hand side of Figure 1) were mapped against laminations of reality adapted from application in other contexts (see the left hand side of Figure 1; Bhaskar & Danermark, 2006; Bhaskar et al., 2018; Parker, 2010). This workshop highlighted how anti-poaching strategies (military-style defence and moralising by one group towards others) were clearly insufficient in the face of the complexity or "conjunctive multiplicity" of the crisis (Bhaskar, 2010, p. 14).

Figure 1
Interpreting the Rhino Crisis Through the Lens of Laminated Totality



Another example of the power of the arts in alerting us to complex realities is the musician David Kramer's (2004) intensely moving song about the Karoo (Vignette 2), with its historical entanglements of belonging and loss. These lyrics from his song *Dans Mettie Dood* [Dance with the Dead] translate as

People come from overseas

And the farmers just build BnBs

They drive up and down with cameras and 4x4s

Everyone is searching for the old Karoo

If you want to see it, just look in my eyes

The world changes before you rub your eyes.

The unsustainability of the obvious commodity fetishism (see concerns raised by Jackson, 2011, above), landscape use change (from farming/food production to tourism), and land misuse (by 4x4 vehicles) show further conjunctive multiplicities that provide insight into the cycles of poverty evident in the Karoo today. Slabbert described Kramer's music as a form of eco-criticism, demonstrating how "nature and animals become commercial objects exploited for human entertainment" (2011, p. 118).

Vignette 2
Extract from *Dans Mettie Dood* by David Kramer (2004)

Mense kom van oorie see
En die Boere bou net b en b.
Hylle ry op en af met kameras en vier-by-vier.

Almal is op soek na die ou Karoo;
As jy daai wil sien, kyk net in my oë ...
Die wêreld verander voor jy jou oë uitvee

Laminated totality offers an ever-broadening scope for describing the world—requiring input from the natural sciences (biology, chemistry, geographical sciences, physics) and the social sciences which describe both social systems and their embeddedness in the natural world (agricultural sciences, anthropology, economics, human development geography, politics, etc).

The second important tool in an expansive ontology is Bhaskar's (1978) notion of stratified ontology, which affords ontological depth in real-world meaning making, and which acknowledges that reality is inclusive of both actual events and unactualised possibilities that could come to be, given the right circumstances and context. The role of natural and social sciences can be described at both a surface level (for example, description and classification of the natural world or description of policies or different farming methods) and at a deeper level explaining these underlying structures and mechanisms, as well as the contingencies that influence the actualisation (or not) of their real powers (Bhaskar, 1978; Danermark et al., 2002). For example, chemicals may have properties and tendencies, but only react under certain conditions; policies may present ideal situations and practices but are contingent on public support, resources, infrastructure and more; and farming methods may work in one social-ecological context, but not in others. Critical realists thus insist on contingent, non-linear, open-ended interpretations of the world and can identify "both necessity and possibility or potential in the world—what things must go together, and what could happen, given the nature of the objects" (Sayer, 2000, p. 11).

This understanding is significant for ESD because it opens new possibilities for change. Change is not only about what should not be done. Instead, it should include consideration of "real, but non-actualized, possibilities inherent in a situation, thus inspiring grounded hope to inform emancipatory praxis" (Bhaskar, 1998, p. 112). The role of the arts in STEAM for ESD in supporting disruptive thinking

for new possibility is significant here. For example, McGarry described his work with "uncanny artifacts" which he used to "to encourage generative, emergent, and empathetic learning encounters" (2022, p. 95). Illustratively, he presented us with an (uncanny) two-handled shovel to suggest the need for "solidarity and co-defining matters of concern" (2022, p. 97); and he presented an uncanny perspective on a bank note which instead of "a materialist tunnelvision that forgets the profound wealth of the social, the wealth of friendship" can be poetically re-imagined as holding "no material wealth, rather surety that we will catch you in sickness and health" (2022, p. 102).

Another arts-based stimulus for new possibility can be found both in dystopian novels (considering the world that could be, but which we do not want) or utopian novels (an idealistic or imagined place). An example of the former is reminiscent of the open-ended role of dialogism as introduced above. In a post-human world, Paolo Bacigalupi's biopunk science fiction novel, *The Windup Girl,* presents a futuristic earth of "posthuman beings and un-natural ecology" (Bacigalupi, 2009, as cited in Hageman, 2012, p. 293) where the boundaries between nature and technology (both plant and animal and including humans) are blurred. The main setting of the novel is a small country (a 23rd century Thailand) struggling in vain to remain independent and to isolate itself from world-wide environmental catastrophe; a world overrun by mega agri-corporations, and beset with biodiversity loss, fossil fuel collapse, and moral degeneration in relation to human and more-than-human rights and dignities. The parallel lives of the characters in the novel display

> *a rigorous focus on contradictions rather than portrayals of false consciousness, nostalgic naïveté, or willful hypocrisy. All of the characters struggling to match their perceptions to the blistering speed of economic and ecological shifts appear caught in a space between a disintegrating paradigm and a still amorphous paradigm yet to emerge in its place. (Hageman, 2012, p. 293)*

From a STE(A)M perspective, it is important to consider how fiction often takes poetic license regarding scientific possibility and impossibility (see Margot, 2005, on a little-known play by Jules Verne: *Journey Through the Impossible*) treading lines between science fantasy and science fiction. *The Windup Girl* has controversially been critiqued as another case in point (Schaller, 2015).
There are other meticulously researched fiction novels such as Richard Powers' *The Overstory* (2018), which envelops the reader in the extraordinary world of trees, ecology, and the many layers of activism, appreciations, and dependencies that humans have in relation to the forest giants of the plant world. The controversies in these fiction stories (and any challenges posed to their poetic license) can provide interesting scientific research possibilities in STEAM education contexts with an ESD focus.

These arts-based opportunities can be used in support of enriching ontologies and human engagement with these in dialogic and dialectical STEAM processes to live gladly, as Popova suggested:

> *To live wonder-smitten with reality is the gladdest way to live. But with our creaturely capacity for wonder comes a responsibility to it—the recognition that reality is not a singularity but a plane. Each time we presume to have seen the whole, the plane tilts ever so slightly to reveal new vistas of truth and new horizons of mystery, staggering us with the sudden sense that we had been looking at only a fragment, framed by our parochial point of view. (2022a, para. 1)*

Critical and Judgmental Rationality

The poem by Robinson Jeffers (Vignette 3) suggests the coexistence of myth, metaphor, and theory in the evolution of knowledge and the entanglement of science and art in describing the world. In Stanza 1, the scientific theory of the moon's once-connection to the Earth after a process of fission is

described and then reinforced with descriptors of the moon as a “cold white stone” and “haggard with loneliness.” The accepted theory of the gravitational pull of the moon creating the ocean tides on Earth is described in Stanza 1 as the moon “dragging the sea-tides after her.” This sense of nostalgia created by the idea of past connection makes the theory ever more compelling. But acknowledgement of the fallibility of science is introduced with the second stanza, which suggests that Jeffers was likely aware of alternative theories of the origin of the moon: as capture, as co-creation with Earth, or as the result of collision between Earth and a protoplanet.[3]

Vignette 3
Poem reproduced from Robinson Jeffers (1963, p. 11, poetic form maintained as much as possible))

The great Wound

At the near approach of a star-huge tides
Agitated the molten surface of the earth.
The tides grew higher as it passed. It tore from the earth
The top of one great wave: the moon was torn
Out of the Pacific basin: the cold white stone that lights us at night
Left that great wound in the earth, the Pacific Ocean
With all its islands and navies. I can stand on the cliff here
And hear the half-molten basalt and granite tearing apart and see that huge bird
Leaping up to her star. But the star passed,
The moon remained, circling her ancient home,
Dragging the sea-tides after her, haggard with loneliness.

The mathematicians and physics men
Have their mythology; they work alongside the truth,
Never touching it; their equations are false
But the things work. Or, when gross error appears,
They invent new ones; they drop the theory of waves
In universal ether and imagine curved space.
Nevertheless their equations bombed Hiroshima.
The terrible things worked.
The poet also
Has his mythology. He tells you the moon arose
Out of the Pacific basin. He tells you that Troy was burnt for a vagrant
Beautiful woman, whose face launched a thousand ships.
It is unlikely: it might be true: but church and state
Depend on more peculiarly impossible myths:
That all men are born free and equal: consider that!
And that a wandering Hebrew poet named Jesus
Is the God of the universe. Consider that!

[3] This last (and favoured today) theory was proposed in the 1970s (after Jefferson’s poem was written) but at the time of writing, competing theories would likely have been a topic of scientific debate.

Dialectics originate in the Socratic method of "hypothesis elimination that takes the form of a question–answer dialogue [which] brings out the contradictions in the interlocutor's arguments" (Dafermos, 2018, p. 5). One could easily describe the process scientists undertook to arrive at the acceptance of both wave and particle nature of light, and to settle on a favoured (collision) theory of the origin of the moon (Lotzof, n.d.) in terms of dialectics. Yet Jeffers' poem above suggests that the evolution of knowledge (which must contend with "terrible things"—Stanza 2—and "peculiarly impossible myths"—Stanza 3) is a complex process of "mythology" and products of invention and of the imagination that can be proved "false" and fraught with "gross error" (Stanza 2). Thus, knowledge building moves beyond the dialectics' "famous formula 'thesis–antithesis–synthesis' [which] represents a very schematic and over simplistic description of the dialectical understanding of development" (Dafermos, 2018, p. 6).

ESD is a notoriously contested knowledge space (Lotz-Sisitka et al., 2015; Schudel & Lotz-Sisitka, 2021) and, particularly when ethical deliberations around terrible things are engaged, it is hard to make peace with conflicting viewpoints. Relativism[4] is proffered by some critics as a problematic outcome of dialogic processes. But the concept of relativism needs careful analysis. Tensions within the concept parallel the tensions between expansion and contraction in intellectual processes introduced earlier in the paper. For example, "on the one hand, relativism appears to promise tolerance, flexibility, co-existence, an individual's right to self-fashioning; on the other, it holds forth the specter of a value-free universe with no shared or coordinating norms" (Emerson, 1999, p. 140).

The pathway for reconciliation is set for this paper by Dop (2000, pp. 14–15) who traced Bakhtinian dialogism to Plato's (earlier expression of) dialectic, which was constituted by a twofold process: "to examine closely, and enquire into fact (anacrisis); that which has been 'separated, compared, and compounded anew' (syncrisis)."

This suggests a process analogous to cycles of dialogic, dialectic, and (deepening) dialogue. It is also consistent with Daniels' (2012, p. 70) "vision of dialectical processes which embody internal and between person dialogues." Through this relational and reciprocal perspective on dialogism/dialectic, Dop indicated distrust of the characterisation of dialogism as "subjectivism and radical relativism— a world in which no truth is possible, because it contains only the discourses of various interlocutors, a world in which all opinions are equally valid" (Todorov, 1998 in Dop, 2000, p. 7).

The necessity of acknowledging relativism (not a radical relativism as suggested above but as a moment within a dialectic/dialogic interaction) is strengthened by critical realism's insistence on the existence of epistemological relativism (Bhaskar, 2016). This requires us to acknowledge that the distance between an object and knowledge of it will necessitate multiple interpretations and understandings, and to deny such relativism would be to create unhelpful blind spots in social spaces of working through social-ecological issues and risks in ESD contexts. However, this is not to deny the existence of the thing on which interpretations are based and the existence of powers and tendencies of that thing that transcend these interpretations.

This position was supported in the words of photographer Tim Flach, who explained in an interview for Photoshop.com:

> *I might have an image of a neck of a horse: at one level it is a horse, in another way people might see it more as a mountain, but having heard people discussing it, I see they can find*

[4] Relativism is the notion that knowledge, truth, and morality are defined by culture, society, or historical context, and are therefore not absolute.

> *other associations. Photographs have this potential for layering, many interpretations, ambiguity, which makes photography very special. But still it has this ultimate strength, in that something existed at some point in front of the lens; if that ingredient is maintained, respected, then you have the potential for people to find a lot of connections out of that original moment that you may never have anticipated, that you could never anticipate. (Flach, n.d., in Slye, 2013, para. 18)*

It is the commitment to the essential thingness of an object that means that critical realism does not expect all interpretations of a situation to be defensible as valid. Dialectical critical realism suggests that, while it is important to acknowledge the many voices and conflicting stances on an issue, knowledge is fallible and open to critique (Bhaskar, 2016). Similarly, Emerson (1999, p. 150) presented Bakhtin as "a tolerant man" up to a point. He described Bakhtin's resistance to a "value wilderness" and his belief that "evaluation is not an afterthought but a central component of the cognitive process. There could be no virtue in announcing, therefore, that all positions, in principle and as yet not examined in context, have equal rights to exist" (Emerson, 1999, p. 150).

An important aspect of the dialectic/dialogic partnership being proposed in this paper is that dialectics should not become dogmatically set on the necessity of finding one single truth. At the same time, dialogism should not become radically relativist in the sense of accepting that any position has validity and therefore anything goes. Possibility for such partnering was suggested by Bakhtin's analysis of Dostoevsky's authorial voice:

> *He keeps his feet firmly on the ground, he has faith, he knows how to let go of an authoritative voice and thus how to share gratitude and wonder, both with his fictional characters and with his readers. This is possible (Bakhtin would say) because those two ghostly, unpalatable extremes, relativism and dogmatism, are separated by a long inhabitable stretch of space, which is dialogue. (in Emerson, 1999, p. 157)*

Concrete Utopianism

An emergent problem with acknowledging the existence of epistemological relativism and Emerson's "long inhabitable stretch of dialogue" described above is that some may "use complexity as a scapegoat for inaction that ultimately protects the status quo" (Jickling et al., 2021, p. 272). Both arts and sciences though, need to be associated with transformation and newness to be useful in ESD practice. From a dialogic perspective, that means an ability to "frame dialogues with others as creating new knowledge, where question leads to answers leads to questions to generate newness" (Chappell, 2022, p. 496). Bhaskar et al. did not exclude scientists from these dialogic processes either, describing the genesis of new ideas by creative scientists acting in interdisciplinary contexts as "a bit like cognitive magpies, picking up interesting resources (in the form of analogies, metaphors, and models) wherever they can find them in order to construct an explanation that fits with the new kind of reality they have unearthed" (2018, p. 48).

A failure to see possibility for newness can paralyse our ability to act because "how can we act if we cannot choose between better or worse?" (Price, 2007, p. 107). Above, I have highlighted both Bhaskar's and Bakhtin's insistence on epistemological relativism and on the necessity for critiquing the validity of truth claims. Challenges for making truth claims are a rejection of empty moralising in which we seek to provide judgement from a moral high ground that fails to engage adequately in the world with the issues and concerns; and avoidance of a naive position that "assumes that whatever is agreed to be good will come into being" (Sayer, 2000, p. 178). This begs the next question, which is about *how* to make the (non-dogmatic) judgements necessary to move forward, to act.

Mah y Busch expressed doubt about the capacity for "whole sight and harmony" (2014, p. 125) to help us in making these judgements. Similarly, not all dialectics accept idealist notions of reconciliation. Contrary to Hegel's idealist response to contradiction as simply "failure of reason," dialectical understanding needs to include the epistemic, ethical, and ontological domains as possible explanations for contradiction and difference and acknowledge that any of these can constitute "the underlying generative mechanisms or structures that represent the grounds for ideas" (Norrie, 2010, p. 73) and which influence possibility for action. If attempts to gain insight into social-ecological complexities continue to trim and cauterise "onto-epistemological rootedness and entanglements" (McGarry, 2023, p. 18), it is unlikely that any productive way forward can emerge.

Examples of ontological realities that influence possibility for change are: When using arts-based pedagogies in an educational project exploring the social-ecological complexities of water access and health with youth from disparate communities in Cape Town, Anna James was led to reflect that "the possibility across space of performing environmental activism differs drastically" (2018, p. 215). This emerged from a discussion she had with youths about climate change activism at the time of the climate change protests. She compared one youth who suggested she (Anna) should not bring her bicycle (a typical alternative to driving as a climate change response) to his home community because it would get stolen, with another whose father encouraged her to ride to school in a safer community, and with yet another who expressed fear of moving between school and community in the wake of a violent rape and murder highly publicised in Cape Town at the time.

The issue of safety was also raised in an international study employing arts-based pedagogy (youths created photonarratives of days in their lives). This study compared transport possibilities and choices (along with other aspects of well-being) amongst youth in seven cities across the world. Stark contrasts were shown between youth from Christchurch, New Zealand who felt safe cycling and walking because of dedicated lanes and lighting, and youth from Makhanda, South Africa who chose not to walk because of fear of personal safety. Epistemologies influencing freedom of travel in cities included gender stereotyping restricting women and girls because of the opinion that "'women do not know how to drive' and 'do not drive safe'" (Nissen et al., 2020, p. 7).

These examples all illustrate that there are times in the dialogic/dialectic iterations when a sense of stuckness can emerge in a particular space, time, and context. James described the problem as "collapsing the need for active praxis into ossified ideologies fails to engage with the reality of the socio-material context and how it is dialectically linked to our consciousness (a sense of learning)" (James, 2018, p. 11).

However, significant changes emerging from dialogic/dialectic iterations in arts-based projects are not impossibilities. For example, Gavin Krastin's interdisciplinary project, *12 Labours,* at the 2022 South African National Arts Festival challenged understandings of heroism and masculinity through the performance/actions of "a group of queer artists-come-garden-gnomes, in collaboration with local artisans, civil servants, gardeners and contractors who collectively perform[ed] a series of actions centred around notions of repair, community building, gratitude and transgressive joy" (National Arts Festival, 2022, para. 1). Amongst the 12 labours were the creation of an indigenous rock garden at a derelict traffic circle in Makhanda, painting a bus stop gold (like a throne), fixing of potholes, growing sweet potatoes, and more.

In the field of ESD, Dylan McGarry (2023) integrated an alternative form of theatre that he called empatheatre into the discipline of marine science through an interactive performance called *Lalela uLwandle* [Listen to the Sea]. In this piece, the participants explore "themes of intergenerational environmental injustices, tangible and intangible ocean heritage, ecological grief, the role of marine

science in governance, and the myriad threats to ocean health" (McGarry, 2023, p. 20). This art-based intervention has been pivotal in involving and integrating the voices of marginalised groups into ongoing public conversations on ocean governance.

Just as this paper has needed to examine the concept of relativism, it must also present a careful analysis of holism. Mah y Busch (2014) critiqued a holisticism suggested in the epistemology of dialogism in which different knowledges simply coexist without consideration of their relationality (2014). While raising the issue of such unreflective additive holisticism, Mah y Busch (2014, p. 128) argued "the dialogic is inherently more relational and multidimensional than a dialectic, and therefore also seems more immediately whole and harmonious." But, to challenge this perspective on dialectic, once again, we need to return to Bhaskar's particular critical realist process of dialectic in which relationality and multi-dimensionality are central tenets.

The ontological multi-dimensionality and open-ended nature of dialectical critical realism have been presented above. That is, a dialectic in search of patterns rather than linear, ordered interpretations of the world, and which emphasise laminated systems with "relationships of dependency and interdependency, and of their characteristic patterns of interaction and intra-action" (Bhaskar, 2010, p. 14). That is, an "open and multiform dialectic" more able to reflect the world's "contextual disorder," its "material meshwork of causality, space and time in an open future" and its "messiness, its perturbation and change, and its unfinished character, not one that cleans everything up and provides it with a linear ordering" (Norrie, 2010, p. 65).

Based on the above, I suggest that a relational and integrative holism within an open-ended multiform laminated totality can give critical ontological grounding to make informed judgements on a way forward.

Further thinking around the question of integrative holism has to do with the questions around the possibility of universal or generalisable ways of describing the world and the danger of imposing idealised outsider directives for change on others. Mah y Busch (2014, p. 128) suggested that an integrative holistic standpoint "transcends the particular, the presumed location of difference." At the same time, dialogism is not fixed in an abstracted space as indicated by Dop's (2000, p. 11) interpretation of Bakhtin's work that "the proper understanding of an object, or a concept such as truth, lies in the necessary determinate relationship between the particular and the universal." By emphasising the relationship between the universal and the particular in an integrative holism, dialogism thus suggests strategies for avoiding the imposition of theories of change on others through idealised holisticism.

Discussed above, were dystopian and utopian novels in literature. Other genres that may be of use in STEAM education contexts with an ESD focus are those exploring ecotopias—often from a feminist perspective, and solarpunk which intertwines "issues of race, gender, sexuality, class, and colonialism with an ecological ethic" (Johnson, 2010, para. 1). Another consideration is Garforth's (2005, p. 418) description of certain (but not all) "green utopias" which present "vivid and experiential suggestions of what an inhabitable green future might be like," and which require that we "deconstruct the linear visions of future progress and abundance that continue to saturate public discourse and haunt the Utopian tradition, and to dislocate dreams of an organic interdependency with nature from escapist nostalgia and social conservatism."

The notion of concrete utopianism was developed in Bhaskar's dialectical critical realism. His suggestion of a dialectical relationship between the concrete singular (particular) and the concrete universal is consistent with the experiential suggestions of green utopias described above. The

emphasis on concreteness is what enables dialectical critical realism to move beyond idealism to the idea of a concrete utopianism. Bhaskar (2016, p. 125) explained that "Concrete Utopianism involves a differentiation within the domain of possibilities of those that are real form those that are not. 'Real' here means 'realisable' and designates which possibilities may be actualised given a particular constraint". Additionally, concrete utopianism is rooted in grounded possibility and dependent on the depth and breadth ontologies described above. Bhaskar (1993, p. 209) also explained that concrete utopianism plays a "role of creative fantasy . . . that yields at once hope and possibility" thus playing an important role in developing non-idealist new ways of doing and knowing in dialectical/dialogic relational processes.

Conclusion

The intention in this paper has been to further conversations about dialogue and cooperation across disciplines by drawing the arts into STEM education as a non-siloed and integrated approach to trans- and interdisciplinarity. Through reference to a broad range of arts-based practices responding to issues of relevance to ESD, the paper has explored the philosophical roots of this trans- and interdisciplinary space through reconciling dialogism and dialectics where the one neither subsumes nor sublates the other. The reconciliation is theoretically informed by Bhaskar's critical realist specification of dialectics (and distinguishable from other forms in historical developments of dialectics) and particular interpretations of Bakhtin's dialogism.

In summary, the paper has explored four points of tension between dialectics and dialogism and from this has developed four philosophical principles and synergies in which these ways of engaging the world can find common ground, and which enable them to partner each other productively without fundamental contradictions.

The paper has demonstrated the necessity of truth seeking in both Bhaskar's dialectical critical realism and Bakhtin's dialogism and shown the potential richness in cycles of expansion and contraction in meaning making in exploring complex phenomena (the first philosophical principle). In response to the problem of monologism (a critique of Hegelian dialectics), the paper has argued the impossibility of absolutism and surety of specific truth claims.

The second philosophical principle is one of expansive and deepening ontologies. Through critical realist descriptions of laminated reality (ontological breadth), and the importance of understanding a depth ontology for recognising unactualised possibilities, the paper has argued against ontological collapse. This has been backed by dialogism's potential for expansion of ideas, and the role that dialogism and the arts play in extending the perspectival palette and in enabling creative and grounded fantasy.

The third philosophical principle is one of critical judgmental rationality. In the paper, both dialogism and dialectics were shown to acknowledge (and indeed depend on) epistemological relativism for creative re-imagining and acknowledgement of multi-voiced engagement in phenomena. Both, also, cannot allow dogmatic interpretations and propositions in real-world engagements. At the same time, neither tradition supports a radical relativism in which anything goes, and both insist on the fallibility of knowledge and the need for criticality in exploring phenomena.

The fourth philosophical principle is one of concrete utopianism. Concrete utopianism recognises the fallibility of idealised and additive holisticism. Both dialogism and dialectics were shown to appreciate both the universal and the particular, the necessity to work in and out of context, and the necessity of

embracing epistemic, ethical, and ontological domains in facing contradiction and difference in real-world ESD contexts.

Through the reconciliatory work between dialectics and dialogism, the paper has demonstrated complementarity between mathematical-logic and cultural-emblematic epistemes, that is, their respective knowledge-building traditions. Ultimately, the paper has demonstrated that neither the sciences nor the arts need to be exclusively tied to either of these two epistemes, nor to either dialogic or dialogical meaning making. Instead, the paper has demonstrated the potential for complementary work to be done across the arts and STEM disciplines in ways that strengthen their capacity for responding to social-ecological complexities in STEAM education with an ESD focus. The paper suggests STEAM education pedagogies that:

- Require that scientific facts and concepts, case studies, and scientific research as well as literature, photographs, films, and drama be brought as resources to teaching and learning situations to engage learners in consideration of non-idealised concrete possibility and exploration of unrealised possibility in the world.
- Encourage scientific inquiry and discovery as well as descriptive and imaginative exploration in both known and new contexts through developing learners' own talents for using multiple scientific and artistic tools and expressive media.
- Integrate problem-solving and futures thinking tasks that require critical thinking and creativity and which naturally embrace and explicitly develop mathematical-logical as well as cultural-emblematic epistemes as integral to both sciences and arts, but not exclusively specific to either.
- Create assessment tasks that ensure a relational flow between moments of expansion and contraction in meaning-making contexts.

With these considerations of how to bring the sciences and arts into a dialectical/dialogic exchange, I suggest that complex social-ecological problems in STEAM education with a focus on ESD can achieve more reliability, criticality, depth, breadth, and opportunity for facilitating necessary change in the world. I further recommend empirical studies testing these pedagogical ideas in relation to capacity for supporting quality STEAM education in ESD contexts.

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Exploring Design Principles for STEAM Learning Activities Development by Science and Technology Teachers[1]

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Abstract

This study explored the design principles of science, technology, engineering, arts, and mathematics (STEAM) learning activities developed by science and technology teachers for classroom practice. Through a qualitative approach, interpretive paradigm, and design-based research, 12 Bachelor of Education honours degree students were conveniently sampled. Data were collected by means of reflections and development of learning materials through the analysis, design, development, implementation, and evaluation (ADDIE) model. The study followed the design-based research stages of needs analysis, development, testing, and reflection to produce design principles, and it was underpinned by the learning theory of constructionism. The findings showcase the design principles to include design thinking, finding solutions for learning problems, creativity, and innovation applied to instructional design. The study recommends the use of design thinking pedagogies in developing teacher knowledge on STEAM classroom practice.

Keywords: 21st century skills development, design thinking, STEAM material design and development

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Introduction and Background

Science, technology, engineering, and mathematics (STEM) education prepares learners for life by equipping them with the important 21st century skills. There are widespread beliefs that the fastest growing professions require STEM knowledge and skills (du Plessis, 2018). Nadelson and Seifert (2017) indicated that the 21st century is undergoing a synthesis age in which new professions are emerging. Accordingly, the teaching and learning of STEM in the classrooms must be relevant to the learners'

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everyday lives and their career aspirations. The achievement of STEM literacies such as creativity, innovation, critical thinking, and problem solving is an important goal in the 21st century. STEM education develops innovative talent in citizens to meet the economic development, environmental, and social well-being needs of the 21st century (Wang et al., 2018).

Nadelson and Seifert (2017) expanded the list of the 21st century skills to include identifying/recognising/classifying, design/experimentation, modelling/simulation, repurposing and restructuring, inventing and creating, theorising/critiquing and validation, and more importantly, innovation. The STEM subjects are critical for the development of these skills. However, the achievement of these STEM skills has been elusive. One of the strategies used to enhance the development of STEM skills in the classroom is embracing holistic and discipline-integrative approaches (Bartels et al., 2019). By implementing STEM education, there is a recognition that life problems and real-life situations are multidisciplinary (Bybee, 2013). There is a call to shift away from instructional strategies that do not bring out the relevance of teaching and learning through the implementation of STEM education. One way of making STEM education relevant is the integration of the arts—resulting in a shift to science, technology, engineering, arts, and mathematics (STEAM) education.

Quigley and Herro (2016) described STEAM education as a modified curriculum, and pointed out that there is a limited scope of studies on the actual implementation of STEAM in the classrooms. The learning of STEAM is lauded for its potential to enhance development of the 21st-century skills of creativity and innovation. In their review of literature, Perignat and Katz-Buonincontro (2019) concluded that there are various interpretations of the arts, and that there are no specific outcomes for the related skills of creativity, problem solving, and arts education. It can be argued that integrating the arts into STEM education requires teachers to display creativity and innovative skills, and to engage in critical thinking and problem solving as they design and develop learning materials. For teachers to teach these skills, they have to be competent in those skills. If the teachers do not possess knowledge of the aforementioned 21st-century skills, it may be difficult for them to teach these in their classrooms. In support of that argument, Jho and Song (2016) observed in their study of a successful case of STEAM implementation in two Korean schools, that the teachers applied open-mindedness and innovativeness. However, Anisimova et al. (2020) have argued that traditional ways of preparing teachers may not help them to teach STEAM effectively in the classroom, and thus underscored the importance employing innovative strategies. This paper problematises science and technology teachers using creativity, innovation, and problem-solving skills to facilitate STEAM learning activities for learners. Accordingly, the study explored the design and development of STEAM learning activities by science and technology teachers enrolled in a Bachelor of Education (BEd) honours degree programme at a South African university. The study contributes insights on how science and technology teachers use innovativeness, creativity, and problem-solving skills to develop STEAM learning activities. Therefore, the research question guiding this study is: “How do science and technology teachers use design principles for STEAM learning activities for classroom practice?”

Related Literature on Designing STEAM Learning Activities

Most school curricula use a multidisciplinary approach for the teaching of STEAM subjects, in which the constituent subjects are taught separately. Therefore, the curriculum innovation of STEAM is not packaged as a stand-alone subject in many school curricula but is taught through integration approaches in subjects such as science and technology, science, mathematics, and engineering. The result is that teachers must go out of their way to plan for the integration of arts into the subjects they teach. Hawari and Noor (2020) confirmed that one of the challenges in the implementation of STEAM education pertains to curriculum demands. As McDonald et al. (2020) pointed out, the implementation

of STEAM education is impeded by the use of traditional teaching strategies, and the placement of the STEAM constituent subjects in hierarchies that lead to the neglect of some.

Another challenge faced by teachers is that STEAM learning activities are not evident and readily available in the curriculum materials and textbooks. Keane and Keane (2016) asserted that teachers must engage in design thinking to come up with the relevant learning materials to ensure that STEAM is taught in schools. And Henriksen (2017) said teachers need to be creative in order to come up with STEAM learning activities. In support of Keane and Keane (2016), Henriksen (2017) also suggested that teachers employ creativity skills and engage in design thinking to develop STEAM learning materials. However, Anisimova et al. (2020) argued that the teachers must first be trained in design and research competencies for them to be able to develop materials and implement STEAM curriculum innovation. That argument makes sense because it would be unfair to ask teachers to implement something for which they are not competent.

Engaging learners in STEAM also involves exposing learners to design thinking (Ozkan & Umdu Topsakal, 2021). Design thinking in STEAM teaching enables learners to be innovative and creative as shown by Ozkan and Umdu Topsakal (2021) who used STEAM learning activities in which learners were engaged in design thinking to develop creative thinking skills. What can be deduced from the findings by Henriksen (2017) and Ozkan and Umdu Topsakal (2021) is that in the implementation of STEAM, design thinking is crucial for the development of creativity skills for learners. And teachers must be competent in design thinking and creativity because these skills are needed in the development of STEAM learning materials.

STEAM education can be combined with other instructional strategies to enhance learning outcomes. Baidal-Bustamante et al. (2023) investigated a STEAM and problem-based approach to teach the science topic of Pascal's principle using an experimental research design, and they observed that learners in the experimental group were more motivated to complete the tasks and performed better than the learners in the control group. Similarly, Hawari and Noor (2020) used problem-based learning emphasised an artistic way of completing a STEAM project, and found that the learners developed skills of collaboration, communication, and problem solving. In a study by Temiz and Çevik (2023) in which five STEAM projects were given to 5–6-year-old learners, it was observed they came up with designs and created their own products. Those project activities required enough time for engagement and materials necessary for creating product.

Theoretical Framework

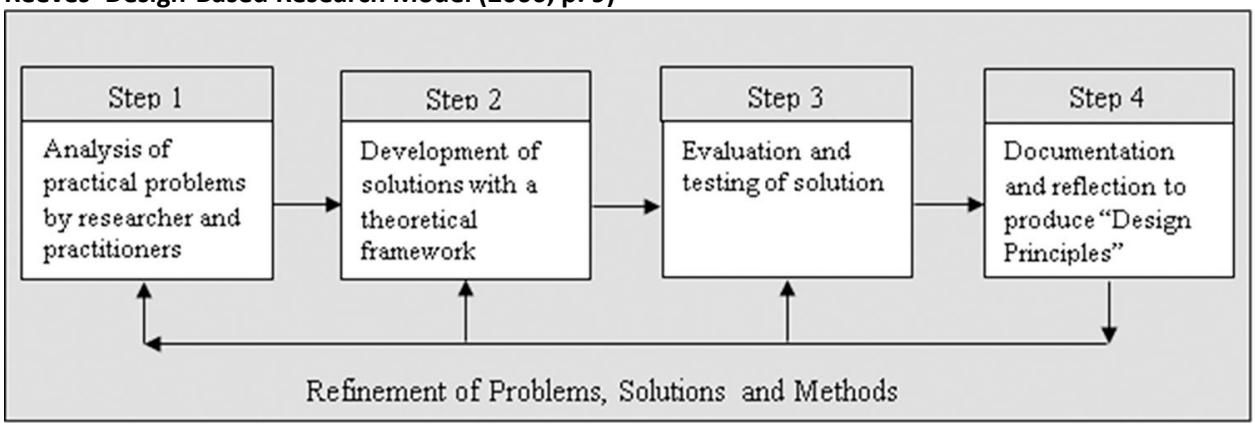
This study is underpinned by the learning theory of constructionism, in which the focus is on the meanings generated by the students who participated in the study—rather than focusing on their shortcomings. Kynigos (2015) asserted that constructionism is also considered a theory of design. Ackermann (2001) explained Papert's constructionism by comparing it with Piaget's constructivism, saying the latter provides insights on what humans can do at different stages of development, and the former puts the humans at the centre of learning by allowing them to make things while they are learning. Parpet's constructionism theory is used in this study, based on its tenets of learner-centredness, allowing the learner to make things, enabling self-directed learning, and learning to learn (Ackermann, 2001). Constructionism was used as a lens to make meaning of the design principles used by BEd honours students to develop STEAM learning activities for science and technology classrooms. Constructionism puts emphasis on learning by doing and, in this case, the participating students were given an opportunity to engage in STEAM activities design, and the development of materials through the ADDIE (analysis, design, development, implementation, and evaluation) model of instructional design. The ADDIE model has been lauded for providing structure and guiding instructional design (Budoya et al., 2019; Hess & Greer, 2016). The ADDIE model of instructional design was useful in this

study because, according to researchers such as Keane and Keane (2016) and Henriksen (2017), teachers are able to implement STEAM education in the classrooms if they can design the learning materials.

Research Methods and Data Analysis

The study used a qualitative approach and interpretive paradigm based on Reeves' (2000) design-based research model (Figure 1).

Figure 1
Reeves' Design-Based Research Model (2000, p. 9)



The model was used to explore the perspectives of 12 BEd honours students at a South African university on teaching STEAM in school science and technology classrooms. The students were all science and technology teachers with teaching experience ranging from 1–5 years. These students were purposely and conveniently selected for being teachers of science or technology participating in the BEd honours degree programme. Their names were anonymised as BHS1–BHS12 (BEd honours degree Student 1 to BEd honours Student 12. They consisted of seven men and five women; four taught in primary schools and eight taught in secondary schools. The primary school teachers taught both natural sciences and technology. Of the secondary school teachers, four taught life sciences and four taught physical sciences.

Data Collection Procedures

The qualitative data were collected by means of a STEAM design task consisting of open-ended design prompts and reflections. The design process was guided by the ADDIE process for curriculum design. The first phase of the research, the needs analysis (Reeves, 2000), was based on a review of the BEd honours science and technology subject specialisation course, resulting in the addition of curriculum innovation topics that included STEAM education. In order to assess the needs of the participants, the researcher applied an intervention that entailed four 2-hour sessions to discuss the STEM and STEAM frameworks implemented in school science and technology classrooms. The intervention was in the form of lectures and group discussions. During the discussions, the students reflected on their experiences of facilitating STEAM activities. From the discussions, the researcher noted that not all students were familiar with STEAM integration in the classrooms. This is evidenced by what four of the students said below. BHS10 with 5 years of teaching experience claimed he was only aware of STEM and not STEAM. He said:

> *I did not know what STEAM education was, because I only had an idea of STEM education before—not knowing [that] the integration of art is involved as much as science, technology, and mathematics are integrated.*

That sentiment was shared by BHS11 who said:

> *Above all else, for me, the ability to incorporate the arts into STEM fields is also a big revelation to me about STEAM.*

After the intervention based on STEAM activity integration in the classrooms, BHS7 admitted to learning something new. He said:

> *Prior to the STEAM/STEM activities, my understanding of STEAM education was limited. I primarily associated it with the integration of science, technology, engineering, arts, and mathematics, but I had not explored its practical applications in teaching and learning.*

This unfamiliarity with STEAM was echoed by BHS11 who said:

> *My grasp of STEAM education was minimal. I understood that it was an educational method that merged science, technology, engineering, the arts, and mathematics, but I didn't completely understand how or why these disciplines were linked. I always viewed the arts as different from and inferior to the STEM sciences. Art is creative and not logical, we learned art in school as a subject that had nothing to do with science and inferior to science.*

These students' reflections (collected during the interventions, and which indicated limited experiences and familiarity with STEAM activities) were used to develop learning experiences that were used in the second stage of design-based research (Figure 1). The stage entailed the development of solutions, undergirded by conceptual framework based on constructionism through the ADDIE model of curriculum design and STEAM education. This was followed by an evaluation and testing stage (Figure 1) where the students were given the task of designing learning materials that could be used in their science and technology classrooms. The STEAM activity design task given to the students is displayed in Figure 2.

Figure 2

Design-Based Task to Develop STEAM Teaching and Learning Materials Using the ADDIE Model

Activity: Design-based task to develop STEAM teaching and learning materials using the ADDIE model.
As a science or technology teacher, in this activity, you must use the ADDIE (analysis, design, develop, implement, and evaluate) curriculum design and development model to design and develop steam materials and a lesson plan for your classroom. The table below displays what you must do under each stage of the ADDIE model and your efforts under each criterion will be evaluated based on your creativity, innovativeness, and problem-solving skills.

Stage of curriculum design & development	Tasks to be completed	Rubric to evaluate teacher activities **Teacher creativity: Yes/no** **Teacher innovativeness: Yes/no** **Teacher problem-solving skills: Yes/no**
Analysis	The needs analysis entails identifying a learning problem in your science or technology classroom that can be solved through STEAM education.	Learning problem STEAM solution
Design	Design the learning activity by indicating the STEAM education approach to be used. Include the purpose/outcome of the STEAM learning activity, grade, topic, and instructional strategy(ies).	STEAM education approach STEAM education learning purpose/outcome STEAM topic and instructional strategies
Development	Develop the lesson objectives, content, learning activities, learning materials, the arts component to be integrated, and how.	Lesson objectives Learning activities Learning materials Arts integration
Implementation	Display/exemplification of the teacher and learner activities.	Teacher activities Learner activities
Evaluation	Describe and provide assessment tools that will be given to learners.	Description of the assessment tool The assessment tool

Reflect on how you have been creative and innovative in designing and developing the STEAM learning activity for your learners.
Reflect on your understanding of STEAM education prior to participating in this study.
Reflect on how your participation in this study has changed your understanding of STEAM education if at all. Give reasons.

In the fourth stage of the design-based research (Figure 1), the researcher analysed and reflected on the reflections of the students and the STEAM materials they developed. A mix of directed and inductive content analysis was used to generate categories that were further collapsed into themes. Table 1 is an extract of a code book showing examples of how the data were coded and analysed.

Table1
Code Book Extract Showing Examples of the Data Analysis

Code	Description of code	Example of data	Emerging category
Needs analysis	-Needs analysis for STEAM integration -Challenges encountered when teaching STEAM disciplines	-In all my experience of teaching life sciences in rural areas, learners are deprived the practical part of life sciences. (BHS1)	STEAM activities used to engage learners in hands-on activities
Design of STEAM activities	-Selected topics to be taught -Identification of the arts activities to be used	-I designed activities that are fun and engaging as learners get to explore STEAM materials in completing all the activities. (BHS1)	STEAM activities are engaging and enjoyed by learners
Development of STEAM activities	-Arts-based activities conducted and materials developed by the learners in the classrooms -Arts-based materials used for teaching	Learners will draw a colourful chart of the human respiratory system. Learners will compose and sing the song in front of their peers. (BHS5)	Use of visual arts and music
Implementation of STEAM activities	-Proposed instructional strategies to implement STEAM in the classroom	Learners work in groups to conduct hands-on activities using materials that include balloons, a darkened room, fluorescent lamps, a sink, and running water including computer simulations. (BHS6)	Use of group work and hands-on activities
Evaluation of the STEAM activities through reflection	-BHS reflections of the STEAM material development -Development of learner assessments of the STEAM activities	-Designing STEAM activities helped me to access different ways in which art can be integrated with life sciences. (BHS1)	Teachers become innovative and creative

Further, a summary of the participant students' profiles and their STEAM activities designs is displayed in Table 2.

Table 2
Summary of Participants' Profiles and STEAM Activity Designs

Student	Teaching experience	Analysis/problem	Design arts	Development/lesson topic	Implementation	Evaluation
BHS1 (female)	1 year	Lack of practical work	Visual arts: posters	Phototropism (secondary science)	Experiments and drawing	Poster presentation
BHS2 (female)	1 year	Lack of practical work	Dance	States of matter (primary science)	Experiments and dance	Group work and oral questioning
BHS3 (female)	1 year	Misconceptions	Visual arts: models & crafts	Earth's rotation (primary science)	Demonstrations and project-based learning	Models
BHS4 (male)	2 years	Misconceptions	Visual arts: drawing	Structure of matter (secondary science)	Virtual reality practical work	Quizzes
BHS5 (male)	1 year	Misconceptions	Song Visual arts: posters, and models	Respiratory system (secondary science)	Demonstrations and project-based learning	Poster presentation and models
BHS6 (male)	1 year	Misconceptions	Visual arts: drawings and videos	Electricity (secondary science)	Demonstrations, hands-on & virtual reality experiments	Drawings and quizzes
BHS7 (male)	1 year	Misconceptions	Visual arts: augmented reality	Earth and beyond (primary science)	Augmented reality field trips	Oral questioning
BHS8 (male)	1 year	Misconceptions	Visual arts: models and virtual reality	Electrical circuits (primary technology)	Project-based learning and virtual reality experiments	Projects
BHS9 (male)	1 year	Misconceptions	Visual arts: videos and models	Newton's laws (secondary science)	Demonstrations and virtual reality experiments	Quizzes and models
BHS10 (male)	5 years	Misconceptions	Visual arts: drawing	Drawing (secondary technology)	Project-based learning	Projects
BHS11 (female)	1 year	Misconceptions	Visual arts: drawing and models	DNA (secondary science)	Model building and drawing	Models
BHS12 (female)	3 years	Misconceptions	Visual arts: models	Respiratory system (secondary science)	Project-based learning	Models

Findings of the Study

The inductive content analysis following the directed content analysis of the data yielded four themes, which were used to present the findings of the study. The four themes are, (1) perceptions of learning problems solved by STEAM integration, (2) science and technology teachers' perceptions of the arts in STEAM, (3) science and technology teachers' perceptions of STEAM integration strategies, and (4) perceptions of benefits and challenges of STEAM integration in the classrooms.

Perceptions of Learning Problems Solved by STEAM Integration

The science and technology teachers identified two learning problems that could be solved by engaging learners in STEAM activities. These learning problems are discussed below.

Lack of Learner Exposure to Linking Theory Into Practical Work Activities

One of the learning problems identified by the science and technology teachers was that learners are mostly taught in class without engaging in practical work activities. BHS1 shared her experiences, saying:

> *In all my experience of teaching life sciences in rural areas, learners are deprived the practical part of life sciences.*

This was supported by BHS2 who said:

> *The learning problem is that they [learners] grasp the theoretical understanding of matter, but fail to grasp it in a practical, real-life way.*

In the teaching of the technology subject, BHS10 indicated that learners lacked the practical skills of drawing, saying:

> *Learners are having a drawing problem in the subject of technology.*

Therefore, one of the learning problems stemming from the science and technology teachers' experiences was that learners fail to apply the theoretical concepts taught in practical work activities.

Poor Conceptual Understanding Displayed by Learners in the Science and Technology Classrooms

The science and technology teachers identified poor conceptual understanding by the learners as one of the learning problems they experienced in their classrooms. Science and technology teacher, BHS3 indicated that through her experience when teaching the topic of Earth and Beyond, she noticed that learners held some misconceptions. She said:

> *There is a common misconception about the motion of the sun, as some learners wrongly believe that the sun orbits the Earth because of the apparent daily motion of the sun across the sky. Therefore, it is difficult for them to comprehend that Earth's rotation is a cause of this seeming motion. In addition, there is a misunderstanding about day and night. Some learners find it difficult to connect the concept of the Earth's rotation with the occurrence of day and night. As a result, they are unaware that one of Earth's sides is in daylight and the other side has darkness at any given moment.*

To show that learners in the science and technology classrooms held misconceptions, BHS4 said:

> *What I have observed, is that Grade 10 learners cannot correctly visualise the basic structure of an atom. This has led to a poor conceptualisation of the subatomic particles—protons, neutrons, and electrons. Even though most learners can differentiate between the charges of these particles they, however, struggle with explaining the location of the electron orbitals, and where the protons and neutrons are located.*

The existence of this misconception was supported by BHS6 who explained that the STEAM activities he designed help learners improve their understanding of the atomic structure. He indicated that the activities were for:

> *Helping learners to understand the movement of sub-atomic particles when teaching the topic of static electricity.*

In support of the perception that learners held misconceptions in the science and technology classrooms, BHS5 indicated how the misconceptions are evidenced when teaching the topic of Gaseous Exchange. He said:

> *Learners understand the concept of breathing in and out. But the problem is that: (1) they don't understand that as you inhale, the volume of your lungs increases; (2) mastering the concepts such as inspiration and expiration.*

The existence of misconceptions in the topic of Gaseous Exchange was supported by BHS12 who pointed out:

> *They also cannot differentiate the role of different organs involved in gaseous exchange.*

From the participating science and technology teachers' experiences, two learning problems that could be solved by means of STEAM integration strategies were identified, and these were: learners failing to see the link between the theoretical concepts with the associated practical skills, and the lack of conceptual understanding in the different topics.

Science and Technology Teachers' Perceptions of the Arts in STEAM

The participating science and technology teachers perceived the arts in STEAM to be the (1) integration of visual arts in the classrooms, and the (2) integration of dance and music.

Integrating Visual Arts in Science and Technology Classrooms

The science and technology teachers suggested that the visual arts could be integrated in these three ways: (1) use of visual arts drawn and painted on charts, posters, and learners' books, (2) use of visual arts in the form of models and craft, and (3) use of digital technology-enabled visual arts.

> *Use of Visuals Drawn on Charts, Posters, and Learners' Books.*

The science and technology teachers perceived the arts in STEAM as the integration of visual arts as follows. BHS1 suggested the engaging of learners in practical work while learning the topic of phototropism that included the development of visual arts materials. She said:

> *I designed activities that are fun and engaging as learners get to explore STEAM materials in completing all the activities. An experiment which will be done by learners in groups for them to practically see how phototropism occurs and how plants respond to light. This will enhance collaboration, communication, critical thinking, and problem-solving skills. Lastly, learners will be required to make a poster, collage, paintings, infographic, or draw a sketch to show their understanding of the concept.*

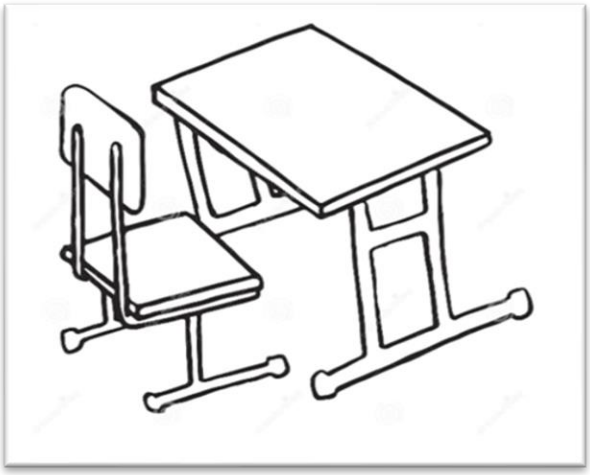
The use of visual arts was supported by BHS5 who had learners draw charts showing the respiratory system. He said:

> *Learners will draw a colourful chart of the human respiratory system.*

In further support of the use of visual arts, BHS6 suggested the drawing of charts and showing of videos demonstrating the movement of electrons in the teaching of static electricity.

In the teaching of technology subjects, learners use drawing to design objects that can be used in real-life situations, and they are required to be creative. In the example given by BHS10, learners can be tasked to design their own versions of desks and chairs that are stable enough to be used in the classrooms. The teacher would give the learners an example of a drawing of a desk and chair in Figure 3 to get them started in creating something different.

Figure 3
Drawing of a Desk and Chair Design Provided by BHS10



Use of Visual Arts in the Form of Models and Crafts.

Under the topic of the Earth's rotation around the sun, BHS3 suggested that learners build models of the earth in relation to the sun. She said:

> *The learners will design and create artistic representations of their own Earth and sun. DIY craft that will develop their understanding.*

Similarly, BH5 suggested the building of human respiratory models when teaching the respiratory system. He said:

> *Learners will create a model of the human respiratory system.*

He provided a picture of the model he created (Figure 4).

Figure 4
Model of the Respiratory System Created by BHS5

BHS12 also suggested the building of models when teaching the respiratory system. She said:

> *As I will be incorporating science, technology, and art in teaching and learning of gaseous exchange, learners will watch different videos based on exchange of gaseous in humans . . . . Learners will also be instructed to design a model of human breathing system. In this case, by designing the model they will be able to understand different organs involved.*

Similarly, BHS8 suggested that learners could build models of electrical gadgets in technology classrooms when they are learning about electrical circuits. He suggested:

> *Implement project-based learning activities in which learners are challenged to design, develop, and present their own electrical circuit projects. This method fosters creativity and problem-solving abilities. For example, learners could be assigned the task of creating a basic electronic gadget, such as a flashlight, and building the circuit needed to make it operate.*

BHS11 suggested the use of both drawing and model building when teaching about DNA. She said:

> *Learners had to design and create a 3-D model of the DNA double helix. The learners first had to draw their designs, then they had to build the model using assorted candy. They were free to use any theme and kind of candy, provided the model was accurate and reflective of the DNA double helix.*

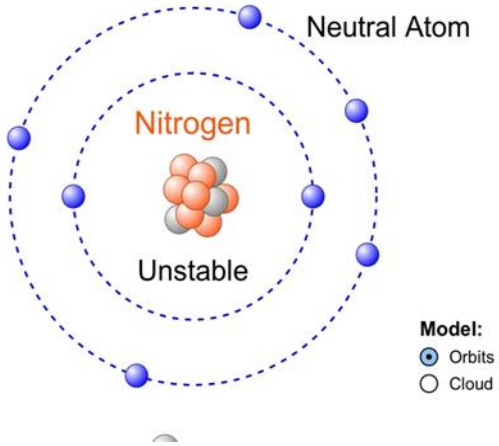
Drawing, making posters, and building models were some of the suggested arts integration methods.

The Use of Digital Technology-Enabled Visual Arts.

Some of the participating science and technology teachers perceived the integration of the arts in the classrooms to involve the use of digital technologies to demonstrate or draw the visuals. BHS4 suggested the use of interactive virtual laboratories for the learners to draw structures of the different atoms when teaching the structure of matter. He said:

Learners will draw their own unique atoms using the PhET simulations. The learner may draw a stable or unstable atom with any colour and reflect on the outcome. Learners can draw and visualise different drawings of atoms [see, for example, Figure 5].

Figure 5
A PhET Application Simulation of an Atom Drawing Provided by BHS4

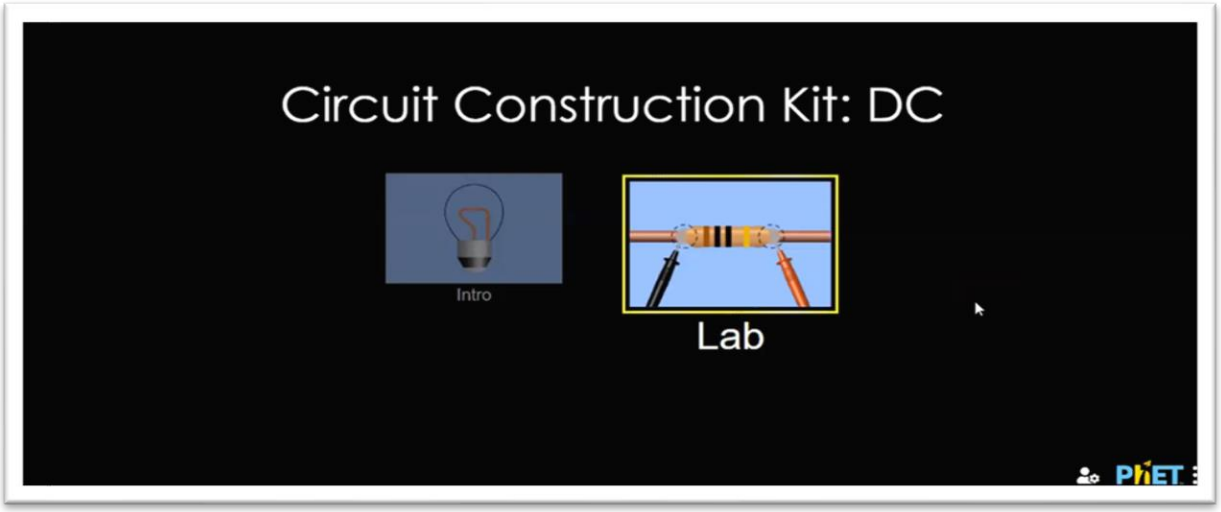


In addition to electrical gadget model building, BHS8 suggested that models could be built using interactive simulations. He said:

Create engaging interactive simulations that let learners investigate electrical circuits in a secure online setting. Learners should be able to interact with various circuit components, such as resistors, switches, and wires, to see how they affect the flow of electricity, through the inclusion of visual and hands-on features in these simulations.

Figure 6 shows the example provided by BHS8 of digital tools used to build circuit diagrams by learners.

Figure 6
PhET Circuit Construction Kit Provided by BHS8



The suggested digital technology-enabled visual arts included the use of videos to demonstrate some concepts in the teaching of science and technology. BHS3 included the use of videos that would provide explanations and demonstrations of the earth's rotation around the sun. She said:

> *The teacher will incorporate a video in the lesson that will provide learners with an explanation of the Earth's rotation and its effect on us (day and night).*

Similarly, BHS6 indicated that the use of charts could be combined with video simulations to demonstrate the movement of electrons. He suggested:

> *Use of visuals such as drawings on the charts brought by the teacher and the use of videos that demonstrate the movement of electrons.*

With digital technologies, the arts integration was done through the use of simulations to draw the structure of matter and build models of electrical circuits. Video simulations were also used to demonstrate the scientific phenomena.

Integrating Dance and Music in Science and Technology Classrooms

Dance and music were also identified as one of the ways to integrate the arts in science and technology classrooms. BHS2, teaching natural sciences and technology in primary school, suggested the use of dance by groups of learners to demonstrate the movement of particles in the different states of matter—solids, liquids, and gases. She said:

> *When exploring states of matter—solids, liquids, and gases—using their [learners] bodies to make real-life models of states of matter gave them the opportunity to be creative in a group format and come up with their own unique movements and models. During this lesson, learners got to have fun with movement and dance while constructing links between theory and real-life examples of states of matter.*

In the teaching of life sciences in secondary school, BHS5 suggested that music could be used in the teaching of gaseous exchange. He said:

> *Learners will work in groups or individually to compose a song based on the different organs of the respiratory system.*

However, examples of such songs were not given.

Science and Technology Teachers' Perceptions of STEAM Integration Strategies

The participating science and technology teachers identified the following teaching strategies that they would use in the implementation of STEAM in the classrooms.

Experiments Conducted by Learners in Groups

Experiments were some of the hands-on activities recommended by the science and technology teachers to use for STEAM integration. BHS1 included an experiment conducted by learners to observe the process of phototropism. She said:

> *An experiment, which will be done by learners in groups for them to practically see how phototropism occurs and how plants respond to light.*

Similarly, BHS2 used experiments for learners to learn about the states of matter. She said she would:

> *Guide students in conducting experiments to observe the changes in states of matter as materials are heated or cooled with a video and practical experiment in class. Instruct students to record their observations and discuss the changes they observe.*

The experiments were also suggested by BHS6 to teach the topic of electricity. He said:

> *Learners work in groups to conduct hands-on activities using materials that include balloons, a darkened room, fluorescent lamps, a sink and running water including computer simulations to demonstrate the phenomenon of static electricity and the movement of electrons.*

Project-Based Learning

Some of the participating science and technology suggested that the STEAM activities could be implemented by engaging the learners in project-based learning. BH8 suggested that learners could be engaged in a project to build an electrical gadget. He said:

> *Implement project-based learning activities in which learners are challenged to design, develop, and present their own electrical circuit projects. This method fosters creativity and problem-solving abilities. For example, learners could be assigned the task of creating a basic electronic gadget, such as a flashlight, and building the circuit needed to make it operate.*

Similarly, BHS9 suggested the use of project-based learning because it enables interdisciplinary learning. He said:

> *The activity will make use of project-based learning that is driven by interdisciplinary learning approach in which the disciplines of science, arts, and technology are incorporated in the session.*

Teacher and Video Demonstrations

Although the participating science and technology teachers perceived STEAM activities to be learner-centred, based on hands-on activities such as experiments and project-based learning, they felt that demonstrations by the teacher or videos were important to guide the learners. This strategy was suggested by BHS3:

> *Learners will watch as the teacher demonstrates the Earth rotation's rotation with the occurrence of day and night using globe and flashlight as well as the YouTube videos.*

The use of teacher demonstrations and videos was supported by BHS4 who said:

> *PhET simulations are used in the teacher-led demonstration to guide learners. The teacher will first demonstrate using the simplest atoms, for example, hydrogen.*

BHS6 also felt that visual media such as charts and videos could be used for demonstrations, saying:

> *[The] use of visuals such as drawings on the charts brought by the teacher, and the use of videos that demonstrate the movement of electrons.*

BHS8 indicated that demonstrations are important when the teachers are introducing new concepts through direct instruction. He said:

> *Introduction to electrical circuits. Direct instruction involves an organised and teacher-centred approach to teaching the fundamental principles of electrical circuits to learners. It usually includes clear explanation, demonstration, step-by-step guidance, and practice and feedback.*

The suggested instructional strategies to implement STEAM included experiments, group work, projects, teacher demonstrations, and videos.

Perceptions of Benefits and Challenges of STEAM Integration in the Classrooms

Through the open-ended reflections, the participating science and technology teachers, expressed their perceptions of the benefits and challenges of implementing STEAM activities in the classrooms.

Perceived Benefits of STEAM Activities

Three perceived benefits of implementing STEAM activities in the classrooms were identified by the participants.

STEAM Activities Are Fun and Engaging for the Learners.

One of the perceived benefits of STEAM activities identified was that they are fun and are enjoyed by the learners. BHS11 explained how she developed STEAM activities in which learners used candy to model the DNA helix, saying:

> *I chose DNA as my topic; this is a complex subject and incorporating the art element helped in making it less challenging and more fun.*

At the end of the activity, the learners could eat the candy they used to build the model of the DNA. BHS11 further said:

> *Another creative twist in the assignment, the model as it is made of candy is edible, learners could then savour their hard work after it was graded! These were the creative tools I used to incorporate STEAM in the activity.*

BHS2 also thought that using dance as a form of art to use in STEAM activities made the activities fun and enjoyable.

STEAM Activities May Address Learning Problems.

With the guidance of the ADDIE model for curriculum design, all the participating teachers had to identify a learning problem to be solved by means of STEAM activities. BHS4, who used the PhET application for learners to draw the structure of atoms, explained how the STEAM activities were used for solving learning problems. He said:

> *Having noticed and analysed the difficulty with visualisation of atoms among physical sciences learners, the infusion of computer simulation as a way to design atom structures takes advantage of technological inclination of the learners as well as the need to visualise PhET simulations.*

BHS8 who taught technology affirmed the notion that learners struggle with conceptual understanding. He said:

> *Grade 7 learners encounter challenges when it comes to grasping the foundational concepts of electrical circuits, which are integral components of their education in the fields of science and technology.*

After using STEAM activities in which learners used virtual reality simulations to draw visual representation of the flow of electrons in circuits and build models of circuits, the learners were expected to improve their understanding. BH8 further said:

> *By the end of this lesson, the Grade 7 learners will grasp the fundamentals of electrical circuits, including components and how they can build a simple circuit.*

The participants were thus able to identify learning problems that could be solved by engaging learners in STEAM activities.

Teachers Become Innovative, Creative, and Problem-Solvers.

Second, the participating science and technology teachers thought that the STEAM activities enabled both the learners and the teachers to develop skills such as problem solving and creativity. In showing that the teachers also needed to apply skills such as creativity and problem solving BHS7, showed how he had to think out of the box when designing the STEAM activities by incorporating digital technologies. He said:

> *I applied innovative, problem-solving, and creativity skills through the development of the "STEAM solution" to address the learning problem. We incorporated an interactive Orrery model, an augmented reality (AR) moon and Earth app, and a lunar phase art installation to enhance student engagement and comprehension. These solutions required creative design, technological integration, and a problem-solving approach to improve students' understanding of celestial motion.*

BH8 agreed with BHS7 that, as teachers, they had to demonstrate creativity and innovation in developing the STEAM activities. He said:

> *In designing the STEAM/STEM activity, I had to think beyond traditional teaching methods and find creative ways to engage learners. This involved brainstorming ideas, considering various approaches, and identifying the most effective way to integrate STEAM elements into the lesson.*

The science and technology teachers also thought the STEAM activities developed the learners' creativity. BHS10 who had five years of teaching experience said:

> *It has opened my eyes to see that already all these years I was not only teaching learners about technology. However, they have been creative in using art in all the processes.*

The design and development of the STEAM activities required the participants to be creative and innovative.

Perceived Challenges of STEAM Activities

The study participants identified three challenges they experienced when developing STEAM lessons, and these are described below.

STEAM Activities Difficult to Align With Assessment Demands.

The participants perceived the development of assessments aligned with the STEAM objectives to be a complex task. BHS7 said:

> *Ensuring that the assessment aligned with the STEAM objectives and accurately evaluated students' creativity and problem-solving skills was a complex task.*

Analysing what BHS10 said about his experience of developing an assessment for STEAM assessment task, it seemed it was difficult for him. BHS10 said:

> *I had to eventually try to develop an assessment task that accommodates STEAM in it.*

This was in addition to learning how to develop STEAM activities. BHS11 indicated how difficult it was for her to assess creativity because, to her, being creative was subjective. She said:

> *Another challenge I faced was how to go about developing an assessment tool for the task learners had to do in response to the identified learning problem. The rubric had to factor in creativity, and this was difficult as creativity is subjective and illogical. What is creative to one person, may not necessarily be the case for the other.*

Developing tasks that assessed STEAM objectives such as creativity, problem solving, and innovation was considered challenging.

Some of the STEAM Activities Are Material Resource Intensive.

The participating BEd honour students indicated that the implementation of STEAM in the classrooms involves the use of adequate learning resources. Some of these resources were not easy to secure. BHS1 said the following about resources:

> *We are only focusing on the theory part due to the lack of resources. Covering all the aspects, the theory, practical, and art in one lesson must be made possible.*

BHS6 shared his experiences with lack of resources in the rural areas, saying:

> *I am still new in the teaching field. However, I have had some experience teaching in the rural area. Because of lack of resources, I still use the old teaching method which is a chalk board for maths. However, for life sciences I have an advantage of a projector, which makes it easy for my learners to view this practically.*

BHS7 also indicated how it was difficult to secure the technologies used to teach the topic earth and beyond:

> *Resource limitations: Sourcing materials and technology for the interactive Orrery model and AR app was challenging. These challenges highlighted the need for effective planning and collaboration to successfully implement STEAM education.*

The findings in this section indicate that STEAM activities are made possible when the required resources are available—and sometimes, this is not the case in some schools.

Teachers' Limited Knowledge of STEAM.

The development of STEAM activities was not without knowledge challenges considering that before this learning experience, the participants had lacked familiarity with the curriculum innovation. BH7 mentioned two challenges that he encountered pertaining to the teacher knowledge required when designing STEAM activities. He mentioned technological knowledge and knowledge to integrate the STEAM disciplines is critical, saying:

> *Technological proficiency: Developing the AR moon and Earth app required learning new software and tools. Integration Barriers: Ensuring seamless integration of science, technology, engineering, arts, and mathematics elements in the project was complex but essential.*

In agreement with BHS7, participant BHS8 also mentioned how the ability to integrate the different disciplines in the STEAM activities could be a challenge:

> *One of the primary challenges was finding the right balance between the various components of STEAM, ensuring that each element was meaningfully integrated.*

The other challenge indicated by the participants in terms of teacher knowledge pertained to curriculum design method used in this study for the STEAM activities. BHS6 said the following about the ADDIE method:

> *For me it was a little bit challenging to understand how ADDIE works and how to incorporate it into a lesson plan. I had to watch YouTube videos to get better understanding.*

Technological knowledge, STEAM design knowledge, and knowledge to integrate the STEAM disciplines were identified as limited by the participants.

Discussion

This study focused on the how participating science and technology teachers used design principles to develop STEAM learning activities for classroom practice. Using Papert's constructionism as a lens, the study made the assumption that, in order for the participating teachers to be able to implement STEAM in the science and technology classrooms, they needed to engage in the design of curriculum materials (Henriksen, 2017; Keane & Keane, 2016). The need for the teachers to engage in design and developing of curriculum materials led to the deliberate decision to prescribe the ADDIE model of instructional design to guide participants as they engaged in STEAM design activities (Budoya et al., 2019; Hess & Greer, 2016). Anisimova et al. (2020) argued for the training of the STEAM teachers in design.

Four major themes led to four major findings of this study. First, by engaging in design, the teachers were involved in problem solving and thereby identified some learning problems that could be solved by engaging learners in STEAM activities. The analysis stage of the ADDIE model results in the identification of the problems to be solved by the design and development of the curriculum materials (Budoya et al., 2019; Hess & Greer, 2016). These learning problems included the alienation of theory from practical work experienced by learners, and misconceptions displayed by learners about different

topics. In order for the participating teachers to solve the identified problems, they designed solutions based on STEAM activities.

Second, the participating teachers had to be creative and innovative to design and integrate the arts component of STEAM for science and technology classroom practice. Forms of visual arts, dance, and music were designed and incorporated in their STEAM lesson plans. Perignat and Katz-Buonincontro (2019) confirmed that there are various interpretations of the arts, and that outcomes for integration also vary. The visual arts were integrated as (1) drawings and paintings on charts, posters, and learners' books, (2) models and craft created by learners, and (3) digital technology-enabled visual arts. The digital technologies included virtual reality, augmented reality, and videos.

The third finding revealed the instructional strategies perceived by the participating science and technology to be suitable for the implementation of STEAM. The instructional strategies included experiments conducted by learners in groups, project-based learning, and demonstrations led by the teacher or viewed from videos. Hawari and Noor (2020) and Temiz and Çevik (2023) also used project-based learning in their studies of the implementation of STEAM in the classrooms. STEAM activities enable learners to create artistic products, and allows them to engage in design thinking and problem- and project-based learning as strategies (Ozkan & Umdu Topsakal, 2021).

The fourth finding revealed the participants' perceptions of the benefits and challenges of engaging learners in STEAM activities. The participants identified three benefits, which were that (1) STEAM activities were fun and engaging for learners, (2) STEAM activities addressed learning problems and (3) STEAM activities pushed teachers to be creative and innovative in curriculum development. STEAM education is lauded for its potential to develop innovation and creative skills in learners. Similarly, teachers have been observed to apply open-mindedness and innovation when implementing STEAM in the classrooms (Jho & Song, 2016). The observation that STEAM activities are fun and engaging may explain why, in the study by Baidal-Bustamante et al. (2023), learners in the experimental group completed the activities faster than the learners in the control group.

The participants also identified three challenges, which were that (1) STEAM activities were difficult to align with assessment demands, (2) STEAM activities are material resource intensive, and (3) teachers displayed limited knowledge when implementing STEAM in the classrooms. Hawari and Noor (2020) affirmed that STEAM activities exert curriculum demands that teachers need to overcome. In addition, learners need materials to create the STEAM products they design, and these materials may not be available in some schools (Temiz & Çevik, 2023).

Conclusion

In conclusion, the theory of constructionism enabled the BEd honour's degree students to learn by designing and developing STEAM curriculum materials (Ackermann, 2001; Kynigos, 2015). The ADDIE model of instructional design guided the students to develop STEAM activities and instructional strategies that helped them find solutions for learning problems identified in the science and technology classrooms. As the students engaged in design thinking, they were able to apply innovation and creativity skills. Visual arts in the forms of drawing, painting, virtual reality and augmented reality, and the building of models were used in the STEAM activities. Music and dance were also employed to create ways of expressing scientific phenomena. STEAM activities allowed both the teachers and the learners to engage in design thinking. Accordingly, the study makes a recommendation to include design thinking in the professional development of STEAM teachers.

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Turning the Art of Karanga Beer Brewing Into a Science: An Example of Humanising Biology Teaching and Learning

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Abstract

South African National Senior Certificate examination reports consistently reflect poor performance in STEM (science, technology, engineering, and mathematics) subjects when compared to other subjects. This has resulted in a decline in the uptake of STEM subjects because many students perceive them as being difficult to learn. This phenomenon is not unique to South Africa, as many other African and developed countries are facing similar difficulties in terms of student participation in STEM subjects. Reasons for the low uptake of STEM subjects include perceived difficulty, perceived lack of ability, classroom experience of STEM subjects, and lack of enjoyment. Thus, STEM educators across the globe are confronted with the challenge of making the subjects attractive, accessible to, and relevant for students. Humanising the teaching of STEM subjects by building on Indigenous knowledges has been suggested as a way that secondary education could deal with these challenges, and turn them into STEM capabilities. The incorporation of Indigenous and other local knowledges into STEM subjects could promote authentic learning experiences, relevance, and inclusivity if teachers were prepared for this, and appropriate resources made available. In Africa, many children enrol in school while they are concurrently engaged in subsistence economic activities rooted in Indigenous practices. Leveraging the insights gained from these activities could humanise and enhance the relevance of school STEM curricula. Karanga beer brewing is one such activity that we participated in as children and, in this paper, we report our exploration of the science related to Karanga beer brewing and how it can be a way of humanising and promoting the relevance of school science and other STEM subjects.

Keywords: Karanga beer brewing, Indigenous knowledges, STEM, humanise, biology

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Introduction and Background

We (the authors) were born and bred in rural communities of Masvingo, Zimbabwe, where Karanga[1] is spoken. Throughout our schooling, we experienced science content that was not contextualised, and thus appeared irrelevant for our everyday rural life. For instance, when Eunice was in secondary school, a full day's trip was paid for, and a bus hired for, her class to go and learn about commercial beer brewing as a way of consolidating knowledge on the practical importance of microorganisms. Ironically, just outside the school grounds, traditional beer brewing was common practice, and a visit to the village would have provided Eunice's class with a more relevant experience of the practical importance of microorganisms. We are also both high school teachers by training, now scholars in science education, and Eunice is a practising science teacher educator. We both work at a South African university. Below, we present how traditional beer (*doro* in Karanga) is brewed by the Karanga people. We use Karanga beer brewing as an example to illustrate the possibilities of how educators can tap into relevant Indigenous knowledges to teach biology. We seek to answer the question: "What knowledge intersections between the Karanga beer brewing process and concepts in school biology content can be drawn upon to humanise science teaching?"

South African National Senior Certificate examination reports consistently reflect poor performance in STEM (science, technology, engineering, and mathematics) subjects when compared to other subjects. This consistent poor performance has seen a decline in the uptake of STEM subjects because many students (and people in general) perceive the subjects as being difficult to learn. This phenomenon is not unique to South Africa, and many African countries (Tikly et al., 2018), and many developed countries face similar difficulties in terms of student participation in STEM subjects (Aikenhead, 2021; Bennett et al., 2014; Morales-Doyle, 2017). A systematic literature review by Tripney et al. (2010) showed that some of the reasons behind a low uptake of STEM subjects include perceived difficulty, perceived lack of ability, classroom experience of STEM subjects, and lack of enjoyment. In Africa, and especially in South Africa, the problem is further complicated by teachers' inadequate content and pedagogic knowledge (Bold et al., 2017; Ramnarain & Fortus, 2013; Tikly et al., 2018), which leads to disengaged and unenthusiastic learners. As a result, STEM educators across the globe continue to be confronted with the challenges of making the subjects attractive, accessible to, and relevant for students (George, 2013; Mensah & Jackson, 2018; Zidny et al., 2022). Building on indigenous knowledges has been suggested as one way that secondary education can deal with these challenges and turn them into STEM capabilities (Avery, 2013; Morris et al., 2021; Tikly et al., 2018). The incorporation of Indigenous and other local knowledges into STEM subjects has been seen to promote authentic learning experiences, relevance, and inclusivity and can humanise the teaching and learning of these subjects. However, for STEM education to build on Indigenous knowledges, teachers need to be prepared for this, and appropriate resources made available. According to Kinyanjui and Khoudari (2013), the infusion of Indigenous knowledge systems into formal schooling has the potential to lay the groundwork for lifelong STEM education. Bringing Indigenous knowledge into the classroom can facilitate the exploration and expansion of STEM concepts derived from students' community experiences. In Africa, a significant portion of children enrol in schools while they are concurrently engaged in subsistence economic activities rooted in Indigenous practices (Khupe, 2014; Khupe et al., 2024; Nyamupangedengu & Nyamupangedengu, 2023; Tikly et al., 2018). Leveraging the insights gained from these subsistence activities has potential to humanise and, in turn, enhance the relevance

[1] Karanga language (known as ChiKaranga) is one of many that have officially been misrepresented as dialects of Shona (a term that was used in colonial Zimbabwe to refer to all languages spoken by Indigenous people who lived in the central and eastern parts of Zimbabwe. Some of the languages collectively known as ChiShona are ChiZezuru, ChiNdau, ChiManyika, ChiToko, and ChiBocha.

of school STEM curricula. Karanga beer brewing is one such activity that we participated in as children. In this paper, we report on our exploration of the science related to Karanga beer brewing, and how this science can be tapped into as a way of humanising and promoting the relevance of school science.

Literature Review

In formerly colonised contexts, although school science is often presented as abstract and context- and culture-free, it is often actually packaged and taught within a Western perspective. And the language of teaching is often not the home language of most learners (Probyn, 2018). This contributes to the well-documented challenges of low uptake, low interest, and poor academic outcomes in STEM subjects (George, 2013; Mensah & Jackson, 2018; Zidny et al., 2022). As argued by Aikenhead (1996), Cameron (2007), Malcolm and Samuel (2008), and Mensah and Jackson (2018), the content and method of teaching are often alienating for non-Western students. Almost three decades ago, Aikenhead (1996) expressed the science learning experience for many non-Western students as a form of cultural border crossing which could be smooth, managed, hazardous, or even impossible, depending on the level of difference that students perceived between their own culture and the culture of science learning. Our own experiences of learning science as Indigenous Karanga students growing up in rural communities have not been different from what the research suggests.

Cognisant of the above challenges, STEM education researchers across the globe have, over the past few decades, come up with suggestions (especially relating to science subjects) of making the subjects attractive, accessible to, and relevant for students (see Avery, 2013; George, 2013; Mensah & Jackson, 2018; Zidny et al., 2022). Suggestions for improved STEM outcomes from the literature include integrating Indigenous knowledge with STEM subject content—what Avery (2013) termed rural science learning—and using culturally relevant pedagogy (e.g. Aikenhead and Elliott, 2010; Khupe, 2014, 2020; Msimanga & Lelliott, 2013; Mosimege, 2020; Sexton, 2024). These suggestions are meant to address issues of social justice and to make STEM subjects more culturally relevant and relatable for students (Morales-Doyle, 2017). The inclusion of Indigenous knowledges in teaching and learning is consistent with situated learning and culturally relevant pedagogy (Khupe, 2020; Sexton, 2024). Despite these recommendations, a survey of the literature shows few practical examples that illustrate the Indigenous knowledges that teachers in Southern Africa can draw upon. As indicated earlier, for teachers to build on Indigenous and local knowledges, there is need for the documentation of more such contextually relevant examples. Our exploration of the science in Karanga beer brewing—a situated practice in our childhood context, seeks to contribute to that literature by providing examples of how Indigenous knowledges can be tapped into as a way of promoting the relevance of, and also humanising, school science.

Conceptual Framework

We draw on aspects of the framework of community-centred research (Khupe 2020; Khupe et al., 2024) as well as notions of learner-centredness as put forward by Malcolm and Samuel (2008) and Malcolm and Keane (2001). Both ideas assume the situated nature of knowledge, knowing, and learning. The socio-cultural attributes of a community (e.g. language and ways of knowledge sharing) are foundational to learning and should be equally foundational in teaching and learning (Vygotsky, 1978; Wertsch, 1985).

Community-Centredness

The elements of community-centredness as put forward by Khupe et al. (2024) include extending knowledge boundaries, relevance to community, and decoloniality. Extending knowledge boundaries is about intentionally valuing and including knowledges that communities hold, in formal education. Bringing in the knowledge that students gain experientially from subsistence activities is one way of

extending knowledge boundaries. Such knowledge is currently not common in many prescribed textbooks in Southern Africa, despite persistent calls to decolonise curricula and persistent suggestions for the inclusion of Indigenous knowledges. Knowledges in Indigenous communities are not developed for their own sake, but are relevant for the survival of those communities. If such relevant knowledge is infused in STEM curricula, the more useful those subjects are likely to be perceived. This approach humanises and develops in students an appreciation of local knowledges, contributing to decoloniality.

Learner-Centred Education

According to Malcolm and Samuel (2008), learner-centredness is about acknowledging and connecting learner knowledge and ways of doing and being to the curriculum. We take two elements of learner-centredness from Malcolm and Keane's assertion (2001). The first element is caring for students. This entails the educators believing in their learners' desires and abilities to learn. The second element is learner-centred pedagogy. This is when educators use teaching approaches that take into consideration students' existing knowledge and build on the diversity of experiences within their class. When, during teaching, the teacher draws from learners' experiences, it reflects both levels of learner-centredness identified above. In the Southern African context, this would mean linking STEM (in our case, biology) teaching and learning to relevant Indigenous knowledges. In this paper, we view the basing of teaching of biology concepts on processes found in students' contexts and experiences (such as Karanga beer brewing) as also exemplifying the forms of learner-centredness identified above. In addition, the inclusion of learners' languages, beliefs, interests, and learning strategies in biology teaching and learning aligns with social justice pedagogy (Morales-Doyle, 2017), which is likely to humanise and enhance interest and academic outcomes in the subject. For Malcolm and Samuel (2008), learner-centredness additionally provides opportunities for power-sharing—where the learners contribute to choices of what is worth learning and how. It is our view that such power sharing places the responsibility for learning on the learner and can contribute to more meaningful learning.

Methodology

In this qualitative study we reflected on our childhoods, focusing on Karanga beer brewing, a subsistence economic activity that we participated in and learnt about from our older relatives and the Karanga community at large. We zoomed into the knowledge intersections between Karanga beer brewing process and concepts in school biology content that we know and teach. We drew from elements of participatory research (Jagosh et al., 2012; Vaughn & Jacquez, 2020). We prioritised the knowledge generation in partnership with an Elder who is a custodian of knowledge on Karanga beer brewing. As indicated by Vaughn and Jacquez (2020), we engaged the Elder not as a "subject" but as one with lived expertise in the art of Karanga beer brewing.

Data Generation

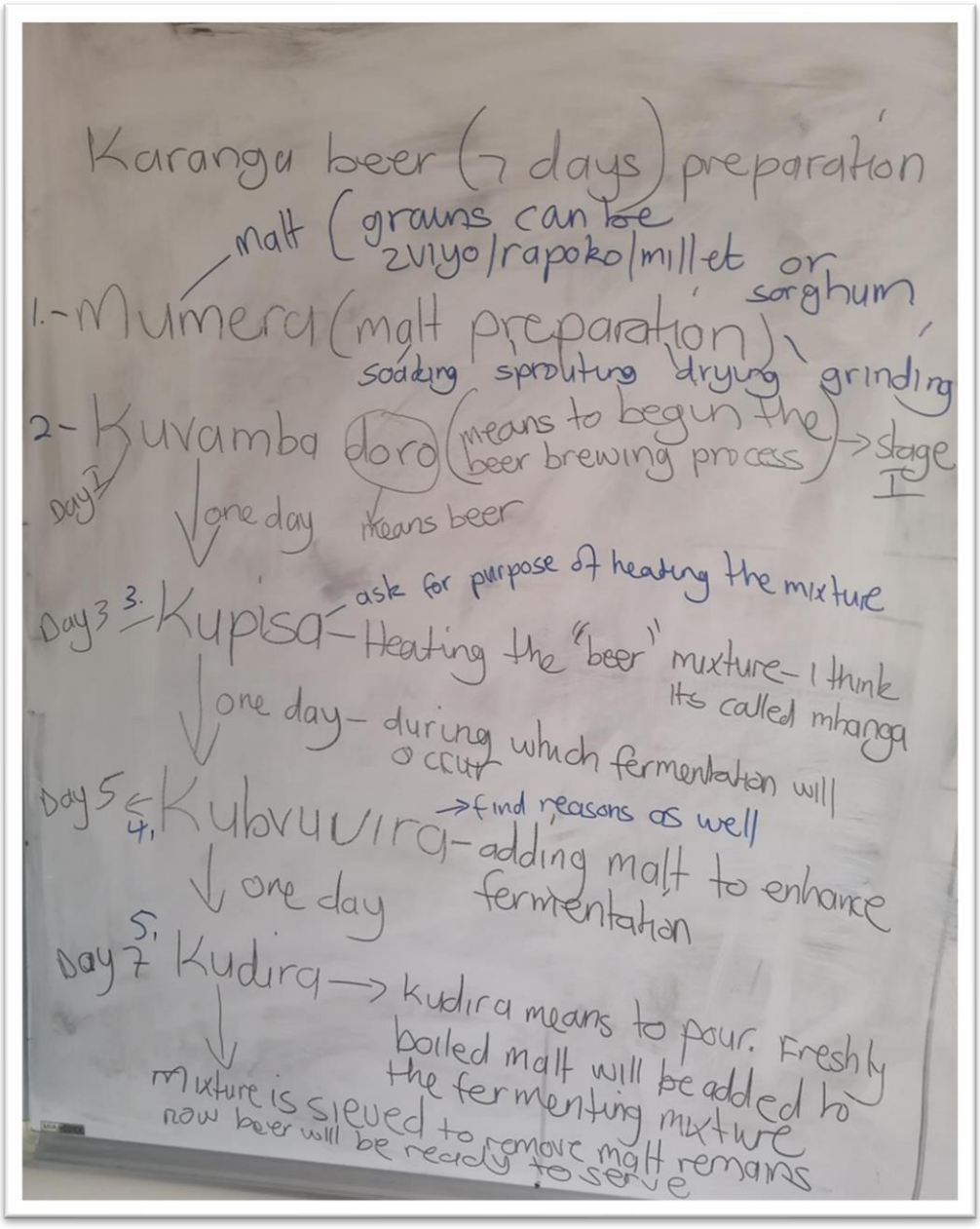
The data generation and analysis developed hermeneutically (Samaras, 2010). The data were generated in stages as follows: 1) researchers brainstorming beer brewing stages from memory, capturing what we could remember, 2) consulting with an Elder, 3) documenting the process, 4) member checking with the Elder, and 5) relating the shared knowledge to biology content.

Brainstorming From Memory

We started off by brainstorming what we could remember about Indigenous Karanga beer brewing from our childhoods. Karanga beer is colloquially known as "seven days," denoting the timeframe for the brewing process. The question that kick-started our brainstorming was: "What do we remember about Karanga beer brewing?" We used the seven days as prompts to jog our memories, therefore, the questions were: "What happens on Day 1, Day 2, Day 3, up to Day 7?" Responding to these

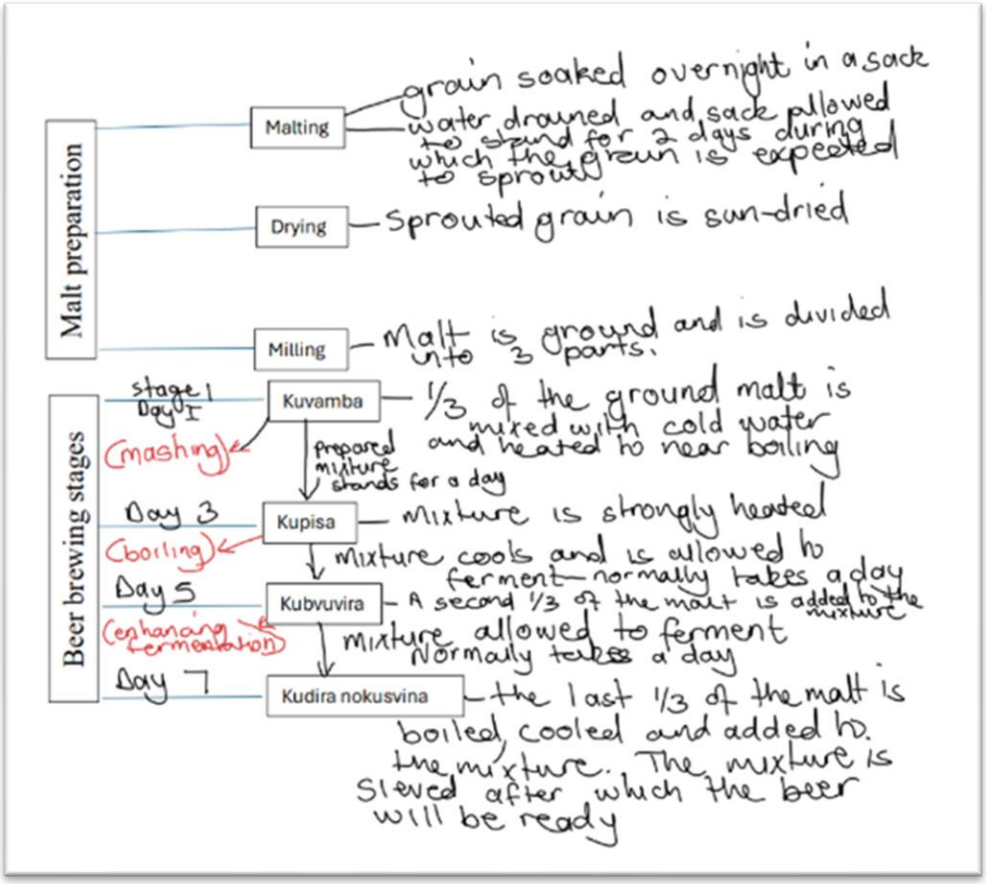
questions enlightened us on other aspects that we needed to document. For example, as soon as we started describing what happens on Day 1, Constance immediately added, “How about the grains that are used for beer brewing? We need to describe them.” Then another aspect came to mind: “Malt preparation. We also need to describe how malt is prepared.” We decided to capture what we could remember on a white board in Eunice’s office. The white board became a living space where, for a whole week, more beer brewing steps and aspects were being added (see Figure 1 below).

Figure 1
Brainstorming Karanga Beer Brewing Stages



During the follow-up meeting, which was a week later, we consolidated our ideas. We were able to produce a rough outline of the beer brewing process as well as links with biology concepts (see Figure 2). Our outline had the major stages of the malt preparation and beer brewing process, but we realised there were gaps in the details of the different stages.

Figure 2
Outline of Major Stages of Karanga Beer Brewing



Consulting an Elder

We sought the help of a family Elder and knowledge holder and expert in the Karanga beer brewing trade (Eunice's Mother, *Mbuya*[2] Dhodho). The choice of the Elder was purposive and consistent with Indigenous knowledge practice, where teaching is facilitated through familial and inter-generational relations, rather than mostly by outsiders (as in Western education). This is also consistent with the socio-cultural concept of *more-knowledgeable other* as proposed by Vygotsky (1978). Eunice shared with Mbuya Dhodho our desire to use the process of Karanga beer brewing as a resource for biology teaching and requested that she help us by sharing her knowledge of the process from preparing malt to the finished product. Although traditional research approaches require participant anonymity to rightly protect them from harm, in this study, for purposes of sharing ownership and power, and informed by McMahon and McKnight (2021), we asked Mbuya Dhodho if she wanted us to use her real name. She gladly agreed. From this point, the sharing was within her power, and she shared different aspects over a period of three days. The knowledge was not necessarily shared in chronological order of the beer brewing process, but as it came to the Elder's memory, and in terms of what she felt was important to highlight. Eunice took notes to fill gaps from our brainstormed outline (Figure 2). After each knowledge sharing session, Eunice narrated what she had captured to Mbuya Dhodho to get guidance on accuracy. Eunice used her knowledge of biology content to relate the beer brewing process to biology concepts. She read about the related biology concepts to deepen her

[2] *Mbuya* is a Karanga title for Grandmother.

knowledge and understanding of the biological processes involved in Karanga beer brewing. The knowledge shared by Mbuya Dhodho, together with the knowledge from further reading, gave us deeper insights into the knowledge intersections between the Karanga beer brewing process and concepts in school biology content.

Eunice also took pictures of the rapoko grain (see Figures 3a and 3b) and containers used in the beer brewing process. A limitation to this study was that we could not have a live observation of the beer brewing process. This is because in Karanga tradition, beer is not just brewed without a specific purpose. Beer is only brewed for ceremonial purposes, for example, wedding celebrations and ancestral worship events. Karanga beer may also be brewed by individuals when they need community help for collective work such as weeding the fields, harvesting crops, or thrashing grain—what we call *humwe* in Karanga. In addition, as indicated earlier, Karanga beer brewing is a subsistence economic activity in which the beer can also be brewed for sale. It would therefore have been inappropriate to ask Mbuya Dhodho to brew beer just for the purposes of this study.

Data Analysis

We read through our notes and annotations three times to ensure clear understanding of the process, and to identify possible gaps. As indicated earlier, the knowledge was not shared in chronological order so the readings enabled us to re-organise our notes. We categorised the knowledge that was shared as follows: grain types, preparing malt, role of containers used in beer brewing, and the beer brewing process. Below we present the results, using those categories as sub-headings. We deliberately first present the process of Karanga beer brewing separate from the related biological processes so the reader has opportunity to engage with the Indigenous Karanga knowledge without interference of thinking about school science.

Results

Grain Types

The beer is brewed using various grains such as *zviyo* or *rukweza* (rapoko or finger millet), *mhunga* (bulrush or pearl millet) and *mapfunde* (sorghum) or even maize. In the description that follows, we present how beer is brewed using rapoko, which the Elder mainly uses. Figures 3a and 3b show rapoko grains.

Figure 3a
Harvested Rukweza (Rapoko/Finger Millet) Head

Figure 3b
Rukweza (Rapoko/Finger Millet) Grain in a Winnowing Basket (Musero)

Malt (*Mumera*)[3] Preparation

There are several steps to preparing the malt.

Malting

The rapoko grain is soaked overnight in a large earthenware pot or in a sack. On the next day, the grain is cleaned thoroughly. If it has been soaked in a pot, it must be transferred into a sack and placed in a dark place for two days. Keeping the soaked grain in sacks ensures adequate warmth, moisture, and aeration. Where optimum conditions are not achieved, the germinating grain can rot because of the growth of fungi or moulds promoted by poor aeration. After Day 1, the sack is opened to check if the grain is sprouting and to loosen any grains that may be crumbed together. The second day allows for full sprouting of the grain.

Drying the Malt (Mumera)

The sprouted grain is sun-dried by sparsely spreading it on a flat rock outcrop or on sacks. The grain must be completely dry, and the sprouts shrivelled.

Milling

Firstly, the shrivelled sprouts must be separated from the grain. This is achieved by rubbing the grain between the hands to break off the sprouts and then to winnow (*kupepeta*) to separate the grain and the sprouts using a winnowing basket. The malt is ground coarsely on a traditional grinding stone (*guyo*, see Figure 4).

Figure 4
Grinding Malt on a Grinding Stone

[3] *Mumera* comes from the word *kumera* meaning to germinate

Although modern grinding mills are available, grinding by hand is preferable to achieve the required consistency of the malt. The ground malt is then divided into three parts for use at different stages of brewing.

Containers Used in Beer Brewing Process

Traditionally, clay pots and calabashes are used throughout the beer brewing process. Different containers are used for different functions such as heating, storage, and serving. Figures 5a and 5b show the different containers, and Table 1 shows their functions in the beer brewing process.

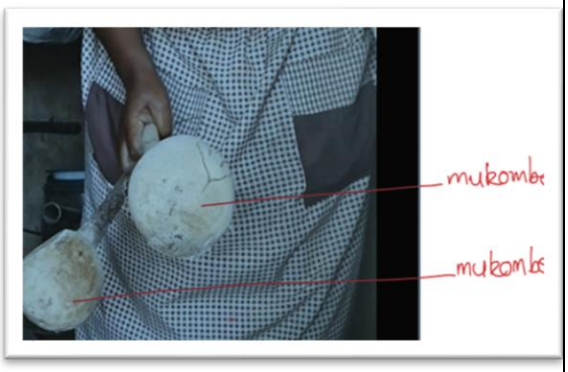
Figure 5a **Containers used in Brewing and Storage of Karanga Beer**	**Figure 5b** **Containers Used in Serving Karanga Beer**
	

Table 1
Containers for Karanga Beer Brewing

Name	Description	Function
Rukambe	Large clay pot	Used for heating at different stages: kuvamba, kupisa, and kubika masvusvu
Gate	Large clay pot	Used for storage of mhanga
Nyengero	Medium size clay pot	Used for storage of beer
Pfuko	Small clay pot	Used for storage and serving the beer
Dende	Calabash	Used for storage and serving beer
Mukombe	Gourd	Serving vessel

The containers are cleaned with clean water before and after use. No detergents are used. This is done to preserve the yeast spores on the surfaces or crevices of the pots to act as inoculant when next the beer is brewed.

Beer Brewing Stages

Mashing (Kuvamba)

The first portion of the malt is mixed with water in a large earthenware (clay) pot (*rukambe*) and heated while continually stirring until just before it boils. The heated mixture is left to cool, and then transferred to a different clay pot (*gate*) and left in a place especially prepared for beer preparation (*bikiro*). The mixture (now called *mhanga*) is left to stand until it ferments. To determine if the fermentation has reached the right level, the brewer looks for signs such as the extent of formation of

bubbles and foam, and the colour and taste of the mhanga. The fermentation process can take up to two days, depending on the weather conditions. Fermentation is faster in warm weather.

Boiling (Kupisa)

When the mhanga has adequately fermented, it is transferred back to the rukambe and heated (*kupisa*) until it turns dark brown. It is then left to stand and to cool down completely, after which it is transferred to the gate for fresh fermentation to occur. When the mhanga shows signs of fermenting it is time for the next stage.

Enhancing Fermentation (Kubvuvira)

The second batch of malt is added to the fermenting mhanga and stirred thoroughly. The new mhanga is left to stand until it has fully fermented, and foam has developed, and a certain flavour achieved. Then it is time for the next stage.

Kudira

The last batch of malt is mixed with water and brought to boiling point. The boiled mixture is called *masvusvu*. Masvusvu is very sweet. The pouring consistency of masvusvu depends on the thickness of the mhanga. If mhanga is thick, masvusvu should be thinner. If the mhanga is seen to be thin, masvusvu is made to be thicker. The masvusvu is left to cool to a lukewarm temperature then added to the mhanga in the gate. The mixture is stirred to allow for thorough mixing. This new mhanga-masvusvu mixture is called *madigwa*. Madigwa is freshly brewed beer, sweetish but not yet mature.

Sieving (*Kusvina*)

Throughout the beer brewing process, parts of the malt remain in suspension in the mhanga and madigwa, which necessitates filtration. A large strainer, traditionally made of weaved inner side of bark of young trees or bushes is used to separate the suspension mix (*masese*) from the beer. Nowadays metal sieves are more commonly used. The filtered madigwa is then distributed into smaller clay pots (*nyengero* and *pfuko*) or calabashes (*matende*). The madigwa is allowed to stand for further fermentation to occur and for the beer to mature. The beer maturity is determined by the same indicators of bubbles, foam, colour, and taste, after which the beer will be ready to be served.

Knowledge Intersections Between the Karanga Beer Brewing Process and Concepts in School Biology Content

In this section, we describe the science we identified in the Karanga beer brewing process, thus showing intersections between Indigenous Karanga knowledge of beer brewing and biology content. We make suggestions on how these intersections can be drawn on in biology teaching and learning.

Soaking the dry grain allows it to absorb water and increase in size. This process is called imbibition. Absorbed water activates hormones and the enzymes (amylases and proteinases) in the dormant endosperm of the grain. The teacher can draw on this aspect to show the important role of water in stimulating metabolic activities and why drying food is a common method of preserving food in rural areas where refrigerators cannot be used due to lack of electricity.

Activated amylase converts starch to glucose, and proteinases activate proteins to peptides. This process of conversion of starch to glucose and proteins to peptides is called hydrolysis. The presence of glucose enables respiration to occur which releases energy for germination of the grain. In addition to water and glucose, warmth and oxygen are necessary conditions for successful germination to occur. Keeping the soaked grain in sacks ensures adequate warmth, moisture, and aeration. Where

optimum conditions are not achieved, the germinating grain can rot because of the growth of fungi or moulds promoted by poor aeration. The teacher can draw on this knowledge when teaching about germination. Referring to this aspect in malt preparation can help learners to appreciate the importance of water, warmth, and air—specifically, oxygen.

When the grains have sprouted, it is now referred to as malt. Malted grain contains sugars and peptides and oils. Drying the malt stops the germination process thereby conserving the sugars in the seed. The malt is crushed to break open the seeds and expose the sugars. Yeast exists in abundance on surfaces of seeds and of pots used for making beer. That is the reason why all the pots that are used for beer-making are cleaned with clean plain water only, with no detergents. This is done to preserve the yeast spores on the surfaces and crevices of the pots to act as an inoculant when next the beer is brewed. This aspect can help learners to appreciate the effect of detergents on micro-organisms.

Yeast uses the sugars in the crushed grain for its own respiration. Mixing the malt with water and heating it but not bringing it to boil drives out any dissolved oxygen thereby creating anaerobic conditions. This forces the yeast to respire anaerobically. Heating the mixture provides the right temperature for the yeast. The first step in the respiration process is glycolysis, which does not require oxygen. Glycolysis splits glucose into two 3-carbon compounds called pyruvate. In the presence of oxygen, pyruvate is completely broken down into carbon dioxide and water with energy being released. However, in the absence of oxygen, yeast has enzymes that decarboxylate pyruvate, releasing carbon dioxide and forming a 2-carbon compound called acetaldehyde. Nicotinamide adenine dinucleotide (NAD) + hydrogen (H) NADH produced during glycolysis transfers hydrogen atoms to acetaldehyde, reducing it to form ethyl alcohol. The above explanation can be drawn upon when teaching the topic of respiration.

Heating the fermented malt during the kupisa stage sterilises the mixture, and evaporates the alcohol and excess water. Therefore, this kupisa process concentrates the sugars and other intermediate products. The batch is allowed to cool so that it doesn't kill the yeast in the crevices of the gate when it is returned to this pot. After the batch has completely cooled, it is poured back into the gate and allowed to stand until there is evidence of renewed fermentation. Allowing it to stand allows spontaneous natural fermentation. During this period, yeast will be multiplying in the fermentation pot. Adding a second batch of crushed grain at kubvuvira stage, provides the yeast with more sugars, which allows more fermentation and production of more alcohol. The last stage, which is kudira, requires masvusvu. Preparation of masvusvu releases sugars into the water to form a sweet suspension. Allowing masvusvu temperature to cool to just above lukewarm and then mixing with mhanga allows faster fermentation of the sugars in the masvusvu suspension. Sieving (kusvina) is a filtration process that separates the beer from the suspended seed coat remains (masese). Yeast fermentation involves chemical reactions. The various stages of Karanga beer brewing provide create conditions that are known to increase the rate of reactions, which include a higher concentration of reactants, a moderate temperature, and the physical state of the reactants. The effect of these factors can be explained in terms of the collision theory, which states that reactions occur only when reactants collide. Therefore, the higher concentration of reactants that is achieved at kupisa, kubvuvira, and kudira increases the possibilities of reactants colliding and hence, the rate of fermentation reactions. A warm temperature at kudira increases the kinetic energy of the reactant molecules thereby also increasing the possibilities of them colliding and a reaction taking place. Too high a temperature can however, denature enzymes hence the masvusvu mixture should only be added to mhanga when it has become lukewarm and not when still hot. Grinding the malt grains breaks the grains into smaller pieces thereby opening the grain and exposing the sugars inside. Mixing the ground malt with water and heating the mixture during masvusvu preparation dissolves and concentrates the sugars. Teachers can therefore, draw on this knowledge when teaching about factors that affect the rate of a chemical reactions.

Discussion

The Karanga beer brewing process presented above, and the description of the science related to the process, point to the presence of intersections between Karanga beer brewing and biology education. Our synthesis of the scientific knowledge related to Karanga traditional beer brewing opened our eyes to the numerous possibilities of how this seemingly simple process can be used as a foundation for the teaching of biology concepts. Examples of topics and concepts that can be taught drawing from Karanga beer brewing include seed dormancy, germination, respiration, microbiology, and hydrolysis. In our childhood context, most children had some knowledge of the Karanga beer brewing process, which would have made the process a useful biology teaching resource. Educators could have built on our prior knowledge (Ausubel, 1968) when teaching the listed topics by drawing on this Indigenous knowledge resource. To better facilitate the learning of biology concepts related to Indigenous processes like Karanga beer brewing, and considering that learners in different contexts have different knowledges and lived experiences, educators can draw on their own learners' local knowledges, languages, and lived experiences. This is consistent with learner-centredness as advocated by Malcolm and Keane (2001) and Malcolm and Samuel (2008). In addition, the observation made by many science education researchers (e.g. Aikenhead, 1996; Malcolm and Samuel, 2008; Morales-Doyle, 2017) that the teaching of science is often divorced from context is likely to be resolved through connecting learners to their knowledge and lived experience. Learning that is based on knowledge resources within the local context can create opportunities for learners to construct knowledge from what they already know, making biology more relatable and easier to understand. Such learner-centred teaching is likely to humanise the teaching of these biology concepts, as well as making them less abstract, more relevant, and more interesting. Furthermore, drawing from learners' experiences provides opportunities for power sharing (Malcolm & Samuel, 2008). This power sharing in the science classroom creates space for community-centredness, whereby learners' thinking in science is shaped by their experiences and cultures, rather than only through a Western perspective (Khupe et al., 2024). Science teaching that promotes community-centredness is humanising and is likely to lead to the greater valuing and appreciation of local and Indigenous knowledges and languages.

A commonly cited challenge for learner and community-centred approaches to science teaching is that the approaches are time consuming, considering educators must often rush to complete the syllabus. However, we contend that the benefits of increased learner understanding resulting from learner and community-centred teaching approaches outweigh the challenges. Our experiences as science teacher educators show that many current textbooks do not have examples that are contextualised to the experiences of learners. This dearth of Indigenous science examples and resources has perpetuated a reliance on decontextualised examples, a practice that continues to alienate Indigenous learners from STEM subjects' content. Looking at the biology topics and concepts that manifest at different stages of Indigenous Karanga beer brewing, we identified many examples that could be incorporated in textbooks and fill this gap. The prevalent practice of teaching and learning school science is through the use of published material, which as indicated earlier, does not have Indigenous examples. In this study, the knowledge on Indigenous Karanga brewing was shared by an Elder. Drawing on the knowledge of Elders as resource persons in the teaching of some biology topics or concepts can diversify teaching and learning resources and humanise and promote the valuing and appreciation of STEM-related Indigenous knowledge as well as community and learner-centred pedagogy (Malcolm & Keane, 2001). Most Indigenous knowledge is transmitted orally, which can be a challenge in contexts where such Elders are not easily accessible. It is time that, as educators and scholars, we undertake to acknowledge, document, and use the knowledge within our cultural spaces so that it becomes accessible and more usable for a wider audience.

Conclusion

Our study has illustrated that Karanga beer brewing is a rich resource for biology teaching. However, the value of that resource can only be realised through deliberate exploration. The Elders, who are the traditional knowledge holders, are themselves a resource for science content that if captured and documented can be used to humanise both the content and the teaching of STEM subjects, which is very often ignored. Our study, therefore, points to the need for deliberate efforts to gather and document Indigenous knowledge resources through formal, humanised research processes for this knowledge to be valued for its own sake and for use through formal teaching and learning. Science knowledge is meant to benefit learners and communities and therefore, should be taught with reference to its relevance.

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Book Review

Against Racial Capitalism: Selected Writings, Neville Alexander

Edited by Salim Vally and Enver Motala

Pluto Press, 2023

299 pp.

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This carefully curated collection of Neville Alexander's writing is the latest contribution by Salim Vally and Enver Motala[4] to the ongoing collective efforts to honour who Alexander was, acknowledge and interrogate the vital intellectual contributions he made (particularly in reference to contemporary struggles), and recognise the indelible mark he left—not just in South Africa but globally. The focus of the book then is apt, given that this was a subject to which Neville Alexander (1979, 2008) made immense contributions. In South Africa, the problematic of racial capitalism arose during the 1970s in debates in the anti-apartheid struggle as part of attempts to characterise the relationship between apartheid and capitalism and, in doing so, illuminate how to strategically engage in revolutionary struggle (Kelley, 2023).

One of the features of racial capitalism is its entanglements with both activism and the academy in key struggles across global contexts that range from apartheid South Africa in the 1970s and 1980s, to the anti-racism struggles in the United States. It is a term not only found in South Africa and the United States, but also in Namibia and Kenya in the early 1970s (Levenson & Paret, 2023), and is linked to the anti-colonial struggles that recognised the racialised nature of violent extraction and profitability that transcended geographical boundaries.

For Alexander, his contribution to racial capitalism was not an exercise in situated scholarship alone. It was first and foremost a strategic attempt to deal with the national question as articulated by the apartheid government, as well as a critique of the response of the dominant liberation movement at the time (Alexander, 1979). In ways that were subsequently mimicked in other parts of the world, Alexander's ideas around racial capitalism were not to simply describe apartheid, but to strategically inform the ways opponents to it could engage in the struggle against it. He was a key theorist who firmly believed that successful resistance to apartheid required a strategy that addressed not just

[4] See also, Motala and Vally (2017) for an exposition of Alexander's view on the national question as well as critiques against it.

structural inequalities as a result of capitalism, not just racism, but the intersection of the two in the particular context of apartheid South Africa.

It is important to note that Alexander's writings encompass a wide range of topics. The choices made by the editors for inclusion in their book span chronological time, and depth, and range across foci but represent only a selection of Alexander's impressive body of written work. We can appreciate that the editorial choices illuminate racial capitalism's defining feature of social and economic domination based on social theories of ostensibly intractable difference. Vally and Motala include Alexander's writings on the national question, on education, on language, culture, and identity, on racism, and, as mentioned, range from 1964 to 2013.

The book opens with a short foreword by John Samuels and Karen Press and presents to readers a timeline of South African and associated history from 1910, against which key events in Neville Alexander's life are mapped. We learn details of Alexander's life, education, and political activism situated within specific times and places as a way of reminding us to not detach who Alexander was from what and why he theorised. The book is sectioned into four parts, each comprising of an introduction written by the editors followed by a selection, in part or whole, of Alexander's writing.

Part I, entitled "Prison Writings: 'The University of Robben Island,' 1964–1974," includes excerpts from Alexander's time on Robben Island as a political prisoner and excerpts from his seminal text on the national question. Alexander documented and theorised various aspects of his experience on the island as a political prisoner, which included the brutality of prison life, practices of teaching and learning, and "work." The editors alert us to other writings done on the island such as "A note on beauty" that elucidates questions of dignity, ideology, racism, and prejudice. It was on Robben Island, through ongoing discussions with Nelson Mandela and others, that Alexander grappled with questions of what constitutes a nation, and the ways of building one antithetical to apartheid.

Part II ("Reaping the Whirlwind: The 1970s and the 1980s") is a collection of writing that situates the development and use of the concept of racial capitalism by Alexander within the debates and events that include the Soweto Uprising of 1976, the merger of the Black Consciousness organisations, and the development of the National Forum in opposition to the dominant liberation movement. The resultant orientation of a socialist alternative, based on a united front of forces against apartheid, was adopted in 1983 and identified racial capitalism as the central problematic in South Africa. This is dealt with in hindsight in the final article.

One of the dialectics that characterises racial capitalism is one of centre and periphery. With the undoing of the shackles of apartheid and the struggle and contestation of imagining and preparing for a new democracy, Part III ("The Transition to Democracy: 1990–1994") demonstrates how Alexander grappled with South Africa's deep existential notions of racial difference, and what it means politically to re-enter a world structured along neoliberal lines that threaten the very notions of democracy. World events and neo-colonial global arrangements are brought into conversation with the role of Africa in bringing about a more just global order, and concomitant issues of language and education offer practical alternatives premised on democratic ideals.

The final section of the book ("Post-1994 Essays, Talks, and Op-Eds") brings us full circle with a critical examination in a post-apartheid South Africa of how to build a "non-racial democratic republic" (Vally & Motala, 2023, p. 208). Racial capitalism in post-apartheid South Africa is dominated by legacies of dispossession and exploitation. The conception of racial capitalism as a "travelling theory" (Levenson & Paret, 2023, p. 336) that cannot be contained by temporal or geographical boundaries, but is shaped by its significance in struggle and resistance, is clear in the writing chosen for this section. The call for

the reconstitution of values, ideas, and practices in line with a democratic ethos alongside an ongoing analysis of post-apartheid political, economic, and social realities, are part of what Vally and Motala (2023, p. 209) say makes Alexander one of the "most committed and knowledgeable intellectuals."

As noted in the foreword, this edited selection of Neville Alexander's writing was done by two of his long-standing friends. Salim Vally and Enver Motala have, individually and collectively, struggled and continue to work tirelessly in workers' education, community struggles, political, worker and student organisations, and globally in anti-colonial struggles of various kinds. This contribution not only introduces Neville Alexander to another generation of activists and engaged intellectuals but also serves as an expression of radical love (Darder, 2002, p. 34), which encourages us to build critical communities, insist and engage in dialogical spaces, and develop critical reflective practices oriented towards human dignity and a more just world.

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Conference Report

Education(al) Foundations, Education(al) Futures

10th SAERA Conference
East London, South Africa
30 October–3 November 2023

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The 10th SAERA (South African Education Research Association) conference, hosted by Rhodes University from 30 October to 3 November 2023, was held at the Premier Hotel Regent in East London. The theme of the conference, *Education(al) Foundations, Education(al) Futures*, which was open to multiple interpretations, focused on engaging in the movement between what we do in education (at a foundational level) and our vision (for the future). The conference was well attended by over 300 delegates from across the spectrum of higher education institutions in South Africa and from a few international universities as well, notably from Sweden. A noteworthy feature of the conference was that it offered a rich, diverse programme that included plenary presentations by renowned educational researchers, workshops, parallel sessions, book launches, poster presentations, and ample opportunities for networking during the conference.

The pre-conference programme, which was held at the Blue Lagoon Hotel, East London on 30 October 2023, afforded delegates opportunities to participate in workshops focusing on support to doctoral students, and the challenges of assessment in higher education institutions. The keynote presented by Mthobisi Ndaba entitled "The Public Good of a Doctoral Qualification," served as an excellent precursor to these workshops as well as to the main conference, which commenced on 31 October.

In her opening address, the President of SAERA, Maureen Robinson, highlighted the importance of creating an archive of SAERA's history since its inception in 2013 so that a record could be kept of critical events and significant achievements over the 10-year period. She also explained the significance of consolidating the trajectory established by SAERA, and the importance of strengthening the quality and contribution of current research activities. Her address was followed with messages of welcome and support by Eureta Rosenberg, the local chair of the organising committee and executive dean of the Faculty of Education at Rhodes University.

The conference plenaries on 31 October included a panel chaired and moderated by Anil Kanjee, which presented an insightful review of a major research project entitled, "From Diagnosis to Understanding: A National View on Teacher Pedagogy." This presentation provided insights into the project (supported by the National Education Collaboration Trust, Department of Basic Education, and involving nine other higher education institutions) on how teachers transact pedagogy in South African classrooms. The

panellists, Godwin Khosa, Cina Mosito, and Tinti Enoch Rabotapi imparted significant insights into the policy implications and macro cross-provincial findings emerging from the study.

The third plenary presentation on 31 October was by Salim Vally who introduced, *Against Racial Capitalism: Selected Writings, Neville Alexander*, edited by him and Enver Motala (2023). In the collation of this book, a tribute to Neville Alexander and his work, the editors reviewed volumes of his writing to elicit key issues that captured the essence of racial capitalism, especially in view of its continued perpetuation in the current world in which we find ourselves.

Day 2's plenary presentation was Saleem Badat's Mandela Lecture. The SAERA Mandela Lecture invites the presenter to reflect on the work of Nelson Mandela—his resilience, his presence, and what his inspiration signifies for education in South Africa and beyond its borders. In his lecture, aptly entitled "Commodification, Corporatization, Complicity and Crisis: The University in Contemporary South Africa," Badat decried the ways in which South African universities, like those globally, have embraced neoliberal policies with a focus on economic growth as opposed to advancing the freedom of people and liberating students' minds. In his interrogation of the ways in which South African universities have become complicit in promoting a market-driven economy, he proposed a different future characterised by a sense of agency on the part of individuals and social groups dedicated to a new struggle following a different logic than the neoliberal one. In reflecting on what this means for the South African higher education scenario within our own contexts and experiences, he identified challenges, such as the erosion of cooperative governance structures due to corporatisation, political problems and protests, underfunding, persistent inequities, and organisational weakness as some key areas of concern that required immediate attention. In presenting his vision aligned to Mandela's legacy, Badat advocated for universities to embrace values and approaches based on quality, academic freedom, community engagement, social justice, and equity as they focus on working towards a more transformative and inclusive higher education system.

During the book launch that evening, delegates were invited to engage with the authors of the books. The books launched during the conference were: *Against Racial Capitalism: Selected Writings, Neville Alexander* edited by Salim Vally and Enver Motala (2023), *Transitioning Vocational Education and Training in Africa: A Social Skills Ecosystem Perspective* (part of the VET Africa collection by Simon McGrath et al., 2023), *Sankofa: Appreciating the Past in Planning the Future of Early Childhood Education and Development in Africa* edited by Alan Pence and colleagues (2023), and *Transforming Postgraduate Education in Africa* edited by Michael Samuel and Hyleen Mariaye (2023). These books were well received by a very appreciative and engaged audience.

The plenary sessions on Day 3 of the conference opened with Hasina Ebrahim's keynote, "Education Foundations: Troubling Early Childhood Foundations for Better Futures." This was followed by a panel dialogue entitled "Educational Foundations: Moderated Panel Response and Thoughts on the Conference Theme From Diverse Research Perspectives," presented by Nhlanhla Mpofu, Mlamuli Hlatswayo, and Michael Samuel.

The keynote presented by Lesley le Grange on Day 4 provided food for thought as he critically engaged with performativity from multiple vantage points in his paper, "Educational Futures: The Many Sides of Performativity." The day's second plenary was a panel session entitled "Educational Futures: Moderated Panel Response to This Aspect of the Conference Theme From Diverse Research Perspectives," in which Presha Ramsarup, Injairu Kulundu-Bolus, Nuraan Davids, and Mpho-Entle Modise shared insights into their engagement with the theme from various perspectives by focusing on how the theme of the conference spoke to their individual concerns, experiences, and visions for the future.

On the final day of the conference, there were opportunities for the SAERA SIGS (special interest groups) to share insights into their experiences and future research initiatives, and for the delegates to engage with them on a personal level to discuss future endeavours and the way forward in their particular focus areas.

The parallel sessions and workshops presented by academics across the spectrum of universities in South Africa and internationally over the 4-day programme, focused on an interrogation of issues, challenges, and perspectives across all phases of education ranging from primary and secondary education, to higher education, and the TVET sector. Many of the presentations imparted novel insights into how academics across the institutions have grappled with the nexus between theory and practice, and the creative projects that they have embarked on for the upliftment, development, and enrichment of their students and staff. A variety of presentations also used theory as a lens through which to examine education(al) foundations and education(al) futures so that the delegates could engage with issues affecting education from multiple perspectives and through multiple lenses. This led to enhanced understandings of what could be done differently to address some of the challenges confronting education at both national and global levels.

In the conference closure on the final day, the panellists stressed the importance of being aware of the power of neoliberal approaches to capture our minds, and the implications thereof for the future of academic freedom at higher education institutions. There was a sense among the delegates that as much as the conference had created opportunities to share frustrations in higher education, there were also golden opportunities to share positive experiences, to dream about future research initiatives, and to be inspired by the work of colleagues—some of whom work under trying circumstances. There was also a focus on the importance of contributing to the public good, working towards action, and confronting tensions rather than shying away from them. In the way forward, the panellists emphasised the importance of focusing on how research could be used to achieve common goals, and a closer examination of what knowledge universities require in the era in which we find ourselves.

There was consensus amongst the delegates that the conference had served to shed light on important issues affecting education at large, and contributed positively to their ongoing personal, professional, and academic development within the contexts of the higher education institutions in which they find themselves. The sense of sharing common issues, challenges, and concerns in a collaborative, collegial, and supportive space—especially for novice and emerging academics—signifies hope for the next generation of academics.

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