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South African Life Sciences teachers' pedagogical beliefs and their influence on information communication and technology integration

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Evidence suggests that learners actively construct knowledge and improve digital literacy when Information Communication and Technologies (ICTs) are used effectively. However, ICTs have not been exploited adequately in a science classroom. Early research argues that teachers' pedagogical beliefs are potential barriers to delaying effective ICT integration in teaching and learning. In South Africa, research is silent regarding investigating Life Sciences teachers' pedagogical beliefs translating into ICT integration. Hence, this study intended to close the knowledge gap and add to the body of knowledge. This study adopted a qualitative design to investigate three South African Life Sciences teachers pedagogical beliefs in Gauteng province. Qualitative data were collected from three Life Sciences teachers through lesson observations and semi-structured interviews. Teachers were observed teaching grade 11 Life Sciences classes. The video recordings were analyzed using the Teaching Dimension Observation Protocol (TDOP) to confirm findings from the questionnaire and establish how teachers integrate technology into teaching. Lastly, interviews were conducted to triangulate findings from lesson observations and questionnaires. The teachers integrated technology in ways that supported traditional beliefs. The results indicate the complexity of the relationship between pedagogical beliefs and ICT integration in practice. Teachers reflected on challenges in ICT integration that possibly impacted on their practices of ICT integration. They referred to a lack of learner access to smart devices and issues surrounding WiFi connectivity. In addition, teachers suggested that they needed training on innovative practices in ICT integration.

KEYWORDS

ICT integration, pedagogical beliefs, Life Sciences, teachers integrated technology, innovative practices

Introduction

Across the world, there is pressure on the education system to integrate Information Communication and Technologies (ICTs) in teaching and learning to prepare learners to be productive citizens of the 4th Industrial Revolution (Teo et al., 2021). In Science education, teachers are encouraged to move from traditional to innovative pedagogies. ICTs in education

help create a 21st-century learning environment for digital natives that promotes the construction of knowledge (Cope and Kalantzis, 2014).

Much evidence suggests that when educational technology tools are used appropriately and effectively in science classrooms, learners actively engage in their knowledge construction and improve their thinking and problem-solving skills (Trowbridge et al., 2008). Despite this evidence, ICTs have not been exploited adequately in science classrooms (Gray et al., 2010). In response, much research has been centered on studying potential barriers influencing ICT integration into teaching and learning (Farjon et al., 2019; Magen-Nagar and Firstater, 2019). Variables associated with access to ICT resources (first-order barriers) (Ertmer, 1999), such as the provision of computers and smart devices, have been widely investigated worldwide and in South Africa (Draper, 2010). Researchers have documented teachers' pedagogical beliefs as second-order barriers that greatly influence ICT integration in teaching and learning (Ertmer, 1999; Taimalu and Luik, 2019; Nelson and Hawk, 2020). Recent studies indicated that 1st order barriers are being addressed due to investments that have been made in ICT resources for the school sector. However, ICTs are still not fully utilized as cognitive tools (Taimalu and Luik, 2019; Juggernath and Govendor, 2020; Mlambo et al., 2020). Hence, there is a need to focus more acutely on pedagogical beliefs as second-order barriers to ICT integration.

Teacher pedagogical beliefs are a crucial construct in influencing ICT integration, and it is recommended that research focus on this construct to understand classroom use of technology (Ertmer, 2005; Liu et al., 2017; Tondeur et al., 2017). Research also confirms a strong link between teacher pedagogical beliefs and classroom practice (Ertmer, 2005; Ertmer and Koehler, 2015; Tondeur et al., 2017). Pedagogical beliefs influence lesson planning, the decision to integrate technology or not, the choice of activities, and strategies for managing classroom behavior (Kagan, 2010). It has been recommended that further studies be conducted to focus on teacher pedagogical beliefs in specific academic content areas since beliefs are context-bound and influence the uptake and rejection of technology (Pajares, 1992; Ertmer, 2005). There has been a dearth of research on the relationship between teachers' pedagogical beliefs and ICT integration in teaching and learning of Science. Studies conducted in other disciplines do suggest that teachers' pedagogical beliefs is a factor in the way that teachers' integrate ICT in their teaching (Bozkurt, 2016). This lack of empirical studies in Science education leaves the field open to speculation on this relationship. There is therefore a need for an empirical study that will yield credible evidence. Against this background, this study investigated the relationship between Life Sciences teachers' pedagogical beliefs and ICT integration into the science classroom.

In South Africa, the White Paper on e-Learning set a target that, by 2013, all primary and high school learners should not only be computer literate, but that ICT be integrated into the curriculum. The document uses phrases like "learning about ICT," "learning with ICT," and "learning through the use of ICT" (Department of Education, 2004). Despite this policy imperative, there is limited evidence of effective ICT integration in teaching and learning (Goosen and Van der Merwe, 2015; Padayachee, 2017; Ojo and Adu, 2018; Munje and Jita, 2020; Bamath, 2021) as anticipated by the Department of Education (DoE). Researchers argued that there are various reasons for teachers not integrating technology in teaching (Munje and Jita, 2020), and some indicated that the reasons are not known (Ramorola, 2013). Many researchers concurred that when all external factors are eliminated, teacher pedagogical beliefs remain the main barrier hindering effective technology integration (Ertmer, 2005). In South Africa, despite the curriculum focus for ICT integration, there is a lack of research on interaction between teacher beliefs and practices. In particular, there is dearth of studies on Life Sciences teachers' pedagogical beliefs." This study, therefore, aimed to investigate the influence of Grade 11 Life Sciences teachers' pedagogical beliefs on ICT integration into teaching practice. As such, the research was guided by the following research questions:

> How do Life Sciences teachers integrate ICT into their teaching practices?
>
> How do Life Sciences teachers' pedagogical beliefs influence their ICT integration in teaching practice?

Theoretical framework and literature review

The theoretical underpinning of this research are the assumptions made about beliefs and the difference between beliefs and knowledge. Savasci-Acikalin (2009) engages with the debate on the difference between knowledge and beliefs. In her article she alludes to Richardson (1996) who speaks about the notion of "truth condition" that differentiates knowledge from beliefs. Knowledge must satisfy the "truth condition" or have some evidence but beliefs do not require a "truth condition." According to Calderhead (1996), beliefs generally refer to "suppositions, commitments, and ideologies while knowledge refers to factual propositions and the understandings that inform skillful action" (p. 715). According to Pajares (1992), beliefs cannot be directly observed or measured but must be inferred from what people say, intend, and do. This research took the position that beliefs cannot be quantified but inferences can be made on beliefs based on lessons taught by teachers and what teachers said when interviewed.

Pedagogical beliefs

In an educational context, Kagan defined teacher beliefs as "tacit, often unconsciously held assumptions about students, classroom, and the academic material to be taught" (2010, p. 65). Teacher beliefs are teachers' convictions or opinions and subjective theories about how students learn, what a teacher should or should not do, and which instructional strategies work effectively (Jaaskela et al., 2017). Earlier research suggested that future research should distinguish between teachers' general belief systems and educational beliefs.

This research focused on teacher educational beliefs, also referred to as pedagogical beliefs (Tondeur et al., 2008; Ertmer et al., 2012; Mlambo et al., 2020). Teacher pedagogical beliefs are understandings, premises, or prepositions about education based on one's experiences (Pajares, 1992). Pedagogical beliefs consist of an eclectic mix of the rule of thumb, generalizations, opinions, values, and expectations that underlie teaching, planning, decision making, and behavior in the classroom (Lowyck, 1994; Kagan, 2010). In addition, those are beliefs about the nature of teaching and how teaching should be carried out

(Chai, 2010). While many factors influence teachers' practices, researchers admittedly believe that pedagogical beliefs highly affect teachers' practices (Teo et al., 2008; Kagan, 2010; Jaaskela et al., 2017; Tondeur et al., 2017). Teachers' pedagogical beliefs are commonly classified as traditional or constructivist teacher beliefs (Chai, 2010; Deng et al., 2014).

Traditional teacher beliefs align with the psychological behaviorism paradigm (Pritchard, 2013; Agakar, 2019). Based on the notion of conditioning, behaviorists believe that a learner's behavior is a response to their experience. Therefore, according to this belief classroom interaction should focus mainly on behavior modification where learners passively respond to external environmental stimuli–classroom instruction, where the teacher transmits information to the learners. This was considered the most effective mode of education in the 20th century (Pritchard, 2013).

Constructivist teacher beliefs align with constructivist theories of learning (Agakar, 2019). The principles of constructivism can be traced back to the work of John Dewey and Montessori's progressive education, Piaget's cognitive constructivism (1977, 1990), Vygotsky's social constructivism (1978), Von Glaserfeld's radical constructivism (1917–2010), Bruner's (1996) discovery learning, Bandura's social learning theories (1925–2021), and the Socratic teaching approach (5th century), among others. Constructivism is an approach to learning that promulgates that people actively construct or make their knowledge and that the learner's experiences determine reality (Elliott et al., 2000). In addition, they also claim that meaning is influenced by the interaction of prior knowledge and new events (Von Glaserfeld, 1974; Cardellini, 2008). Constructivism is revealed as an epistemological view of knowledge acquisition that emphasizes construction rather than knowledge transmission and recording of information conveyed by others (Applefield et al., 2001). That is, "learning takes place when new information is built into and added onto an individual's current structure of knowledge, understanding, and skills; we learn best when we actively construct our understanding" (Pritchard, 2013, p. 18). Thus, a constructivist teacher asserts that learning is an active process of constructing knowledge through interaction with the physical and human nature of the world. The learner's role in a constructivist learning environment is to build and transform knowledge, while the teacher assumes a facilitator or mentorship role (Emiere, 2021).

The relationship between pedagogical beliefs and ICT integration

Research on educational innovations claims that technology integration into teaching and learning can only be fully understood when teachers' pedagogical beliefs are considered (Ertmer, 2005; Sang et al., 2010), suggesting a relationship between the two. Research indicates teachers' pedagogical beliefs highly influence classroom practice (Pajares, 1992; Kagan, 2010). Evidence reveals that pedagogical beliefs influence decisions regarding integrating technology, choice of technological activities, and software to be used by the teacher in the classroom (Deng et al., 2014; Tondeur et al., 2017). In addition, teachers select specific instructional strategies, technological devices, and applications that align with their existing pedagogical beliefs (Hermans et al., 2008; Prestridge, 2012). Pedagogical beliefs also inform lesson planning, activities, and how the teacher disciplines learners in the classroom (Prestridge, 2012; Alt, 2018). A study by Mansour (2013) found out that science teachers who hold traditional beliefs do most of the talking in class, their ideas dominate, and a textbook is the primary source of knowledge. Evidence suggests that teachers who hold constructivist beliefs tend to use them in more student-centered ways, allowing students to select and direct their own uses of available technology tools (e.g., Judson, 2006).

On the contrary, some studies suggest no alignment between teachers' beliefs and classroom technology practice (Ertmer et al., 2001; Tondeur et al., 2008). Ertmer et al. (2001) reported that despite the fact that most of the teachers described themselves as having constructivist philosophies, they implemented technology in ways that might best be described as representing a mixed approach. Teachers' explanations for these inconsistencies often included references to contextual constraints, such as curricular requirements or social pressure exerted by parents, peers, or administrators. Other findings also indicate a low positive relationship where science teachers' ICT practices in the classroom were inconsistent with their pedagogical beliefs (Mansour, 2013). Literature review findings using a meta-aggregative approach to synthesize qualitative evidence over time claimed that a bilateral relationship does exist (Tondeur et al., 2017). The review pointed to studies where teachers' experiences with technology were enablers for supporting pedagogical belief change.

Conversely, inconsistencies between teachers' pedagogical beliefs and technology practices have been recorded (Pajares, 1992; Mansour, 2013), making understanding the relationship even more complex. Some evidence implies that teachers' beliefs and practices are unidimensional, that is, student-centered or teacher-centered, instead of multi-dimensional (Tondeur et al., 2017). Some also suggest that teachers hold varying degrees of pedagogical beliefs (Ertmer et al., 2017), possess both, or alternate between student-centered and teacher-centered beliefs (Liu et al., 2017), bringing variations into practice. It is, therefore, evident that teaching practices that manifest in the classroom are the outcome of the complex interaction between the various forms of beliefs and contexts (Chai and Draxler, 2014; Deng et al., 2014; Ham and Dekkers, 2019). Cultural, social, and organizational contexts in which teachers work influence teachers' use of technology (Liu et al., 2017). This research attempted to unpack the complexity of the relationship between Life Sciences pedagogical beliefs and their integration of ICT in teaching in many countries.

In the case of South Africa, the investigation of how these constructs relate to each other is in the preliminary stage. As a developing country, schools in South Africa experience first-order barriers to ICT integration such as availability of resources most of the time. However, with the increasing rollout of ICTs at schools, second-order barriers such as teachers' pedagogical beliefs invite investigation. Preliminary findings from a qualitative study of Cape Town secondary school teachers by Sherman and Howard (2012) suggest that a variety of socio-cultural factors impact on teachers' beliefs and pedagogical practices pertaining to technology use. At the time of that study, ICT integration was not wide spread and no conclusive finding could be made on the relationship between pedagogical beliefs and practices. A later study by Van Der Ross and Tsibolane (2017) found that in schools with well-endowed ICT resources where teachers believe that ICT is beneficial, their ICT integration behavior was inconsistent with these beliefs. In addition, few, if any studies explored this relationship

in relation to science teachers, which a topic of interest in the present study.

Method

Research design

A qualitative research design investigated how three Life Sciences teachers' pedagogical beliefs influence ICT integration into teaching and learning. Qualitative research is best suited to address a research problem in which specific variables are relatively unknown and that which need further exploration (Creswell, 2012).

Sampling

Three Life Sciences teachers from three different schools were purposively selected based on their availability, and them teaching at schools that are technologically well-resourced school. The teachers were also conveniently sampled geographically because of their proximity to the researcher's location for easy access. Pseudonyms were used to protect the teachers' privacy and confidentiality.

The profiles of the teachers are presented in Table 1.

Research context

All three schools are public schools. They are situated in Erkurhuleni South District, Gauteng Province in South African. All South African public schools are divided into five quintile rankings based on the school community's socio-economic status for funding purposes. Quintiles 1–3 schools are in previously disadvantaged communities and hence called "no-fee paying" schools. Quintiles 4 and 5 are fee-paying schools. The schools selected for this study selected were quintile 3. All classrooms at these schools have smartboards installed with internet connectivity. Each teacher has a laptop connected to the school Wi-Fi. Teachers receive training on integrating ICT in teaching and learning, and both teachers and learners have access to the Gauteng provincial department's e-learning portal, where they can access teaching and learning resources. The average class size is 30 learners.

Data collection and analysis

Data were collected through lesson observations and interviews. Each teacher was observed teaching two grade 11 Life Sciences lessons. Six lessons were observed in total. The lessons lasted for an average of 35 min. The topics included population ecology and human impact on the environment. The lessons were video-recorded, and the recordings were then analyzed using the Teaching Dimension Observation Protocol (TDOP) (Hora and Ferrare, 2014). The TDOP is a customizable observation protocol that can be used to produce robust and nuanced depictions of the dynamics that unfold among teachers, students, and technologies in the classroom. This instrument addresses the following 7 dimensions:

1. Instructional practices dimension: This dimension focuses on teaching methods and activities, which can be either teacher-or student-focused, regarding the teacher as the main actor.
2. Student-teacher dialog dimension: Describes the nature of student-teacher interactions, which can either be teacher-or student-led in terms of the primary speaker.
3. Instructional technology dimension: Teachers' use of technology and other artifacts for teaching.
4. Potential student cognitive engagement dimension: Students' potential cognitive engagement.
5. Pedagogical strategies dimension: The teachers' teaching style.
6. Student engagement dimension: Students' time on task.
7. 21st-century skills: Students' critical thinking, creativity, communication and collaboration

The TDOP online version that was used for this analysis allowed the researcher to click on a code when it is observed during a two-minute interval with reference to the codebook compiled based on the TDOP reference manual (Hora and Ferrare, 2014) while transcribing notes to add detail to the codes observed. At times more than one code was recorded within the same interval. The codes could be from the same TDOP dimension or different dimensions confirming the holistic nature of the protocol. Where a behavior started in one interval and ended in the next interval, it was coded in both intervals. Total codes per participant were analyzed descriptively and then compared among the participants. A second researcher also analyzed the same lessons using TDOP and inter-rater reliability was automatically calculated on TDOP website.

Semi-structured interviews followed to confirm findings from the first two data sources. The interview schedule consisted of a set of open-ended questions which allowed for probing (McMillan and Schumacher, 2010). The interviews probed the participant teachers on their teaching beliefs, teaching strategy, assessment strategy, and their use of ICT in teaching science. Interviews were recorded, transcribed, and analyzed through a thematic coding approach (Miles and Huberman, 1994). This technique was suitable for this study because "theming data is more applicable to interviews and it allows data collected to be categorized through commonalities" (Saldana, 2009, p. 142). For example, the theme on "ICT in Life Sciences teaching and learning" was informed by codes such as "I use a smartboard when teaching," "I prepare powerpoint presentations," and "I

TABLE 1 Profile of participant Life Sciences teachers.

	Mr. Bheki	Mr. Kuna	Mr. Gcina
Qualification	Bachelor of Education (Life Sciences)	Bachelor of Education (Life Sciences & Life Orientation)	Bachelor of Education (Life Sciences & Life Orientation)
Teaching Experience	5 years	8 years	6–10 years

administer a test online." The analysis was done per teacher, and the findings were compared based on emerging themes. Interviews were also used to validate findings from the TPBS and lesson observations to provide richly descriptive results (Creswell, 2009).

Findings

Life Sciences teachers integration of ICT into their teaching practices

The teachers were observed teaching topics of strand three: Environmental Studies of the CAPS curriculum. The video lessons were analyzed using the TDOP online version, which captures both teachers' pedagogical beliefs and the use of ICTs during teaching. To account for every minute during a teaching class, the TDOP presented time series for individual codes, and frequency of individual codes. An analysis of a lesson is now presented for a lesson taught by each teacher.

Mr. Bheki's lesson

Mr. Bheki's lesson was observed in a classroom which looked like an old laboratory. The laboratory fittings were no longer working and there were movable desks and chairs. One smartboard was installed with connectivity in this classroom. The teacher had a laptop and a USB. All learners' desks were arranged in rows such that learners sat facing the front. The class had 30 learners comprising both girls and boys. Mr. Bheki's lesson focussed on Population Ecology.

Figure 1 shows the frequency of codes related to each of the dimensions.

This data describes the prevalence of certain instructional practices across the seven TDOP dimensions. The data indicates that Mr. Bheki spent 67% of the period lecturing (L), 58% of the time lecturing with visuals (LVIS). This data also shows that 92% of the period was spent interacting with the smartboard (CB) and a power-point presentation (PP). During the same lesson, learners had only 8% time for asking questions (SQ), answering comprehension questions (ICQ) and creating (CR). These results highlight the prevalence of instructional technology used in a lecture method of instruction that is teacher-centered.

Mr. Kuna's lesson

Mr. Kuna's class had 25 learners made up of both girls and boys. Learners' desks were arranged in rows facing the front where a smartboard was installed. Although the learners sat facing the front, they were unevenly distributed in the classroom. Some were in pairs while others sat individually. Those who were in pairs were observed sharing handouts or textbooks. Mr. Kuna had a copy of handouts given to learners and a USB which he inserted on the smartboard to access a powerpoint presentation. His lessons focused on Loss of Biodiversity, Food Security and Water availability.

Data presented in Figure 2 shows the prevalence of different codes throughout the duration of the lesson which was automatically calculated by TDOP built-in function each time a code is observed. Learner engagement was maintained at a very high level (VHI) throughout the duration of the lesson. VHI activities were observed in each interval during the lesson followed by strategies bringing real-life experiences in the classroom, and lecturing (CNL and L) which were observed for 94% of the period. On the other hand, behaviors such as creativity (CR) and administrative tasks (AT) featured for only 6% of the duration of the lesson. TDOP built-in

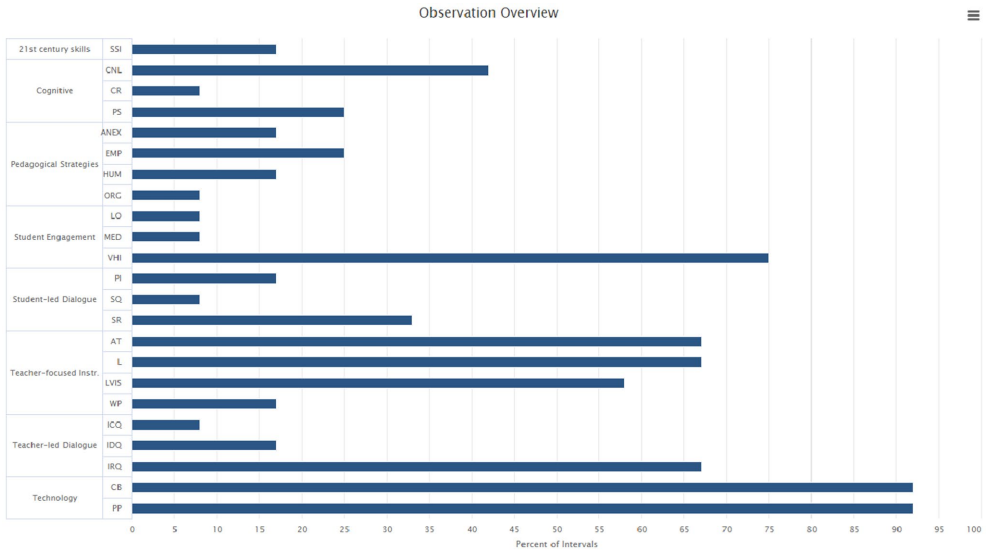

FIGURE 1
Frequency of codes for Mr. Bheki's lesson.

analysis function automatically excluded problem solving (PS), 21st century skills dimension and peer interaction (PI) because they were not observed during the lesson observations. The data therefore suggest that Mr. Kuna's class was mainly dominated by teacher-centered activities.

Mr. Gcina's lesson

Mr. Gcina's classroom had a smartboard and a whiteboard. Mr. Gcina had a laptop and a USB which he used to transfer a powerpoint presentation and some videos onto the smartboard. His classes had 27 learners of both boys and girls. The desks were arranged in such a way that all learners face the front. Some desks allowed learners to be in pairs while some only allowed for individual sitting arrangement. The teacher's desk was placed in the mid-front of the class facing learners. Mr. Gcina's lessons focused on Loss of Biodiversity, Food security and Water availability.

The data in Figure 3 presents how often a code was observed during the entire duration of the lesson. The percentages of how many times a code appeared suggest Mr. Gcina's instructional strategies observed as he was teaching. The code with the highest frequency of 100% is lecturing (L). Lecturing with visuals (LVIS) 67%, and students answering question from the teacher (SR) 89%. Some of the codes

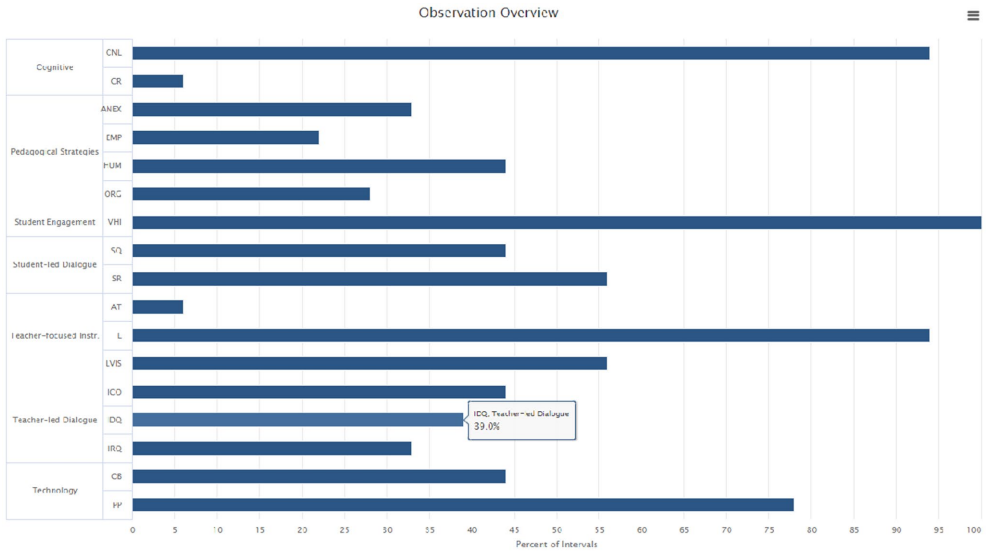

FIGURE 2
Frequency of codes for Mr. Kuna's lesson.

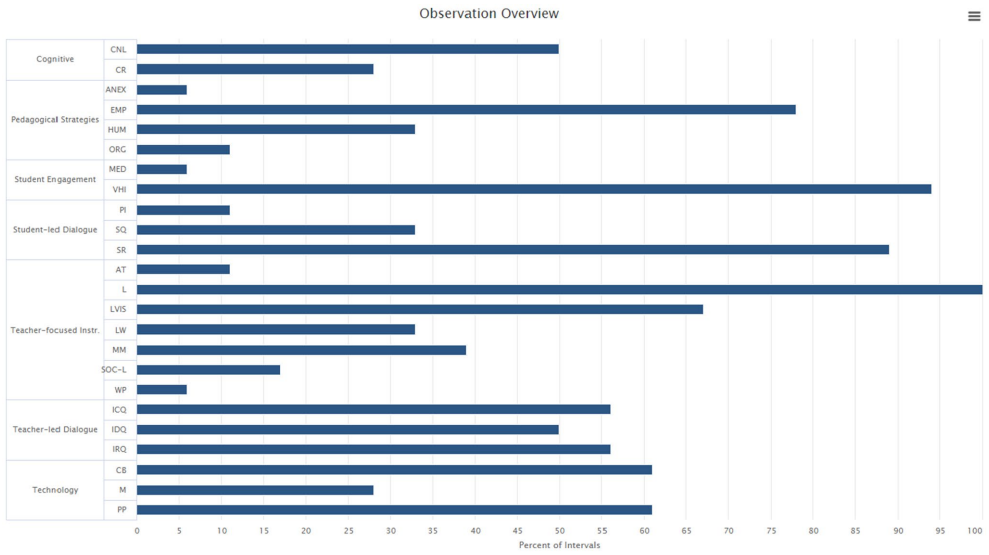

FIGURE 3
Frequency of codes for Mr. Geina's lesson.

were never observed hence were automatically excluded from the analysis by the TDOP analysis function. These include 21st century skills dimension, problem solving (PS), the use of simulations (S) and the student-focused instruction dimension. The above-mentioned evidence suggest that Mr. Gcina's lesson is aligned to teacher-centered instruction.

The relationship between Life Sciences teachers' pedagogical beliefs and ICT integration into their teaching practice

Semi-structured interviews were used to establish the relationship between teachers' pedagogical beliefs and their practice of ICT integration observed in the lessons.

The findings from interviews are reported based on the five themes that emerged: lesson planning and presentation; teaching and learning resources; assessment in Life Sciences; challenges faced in integrating ICTs in teaching Life Sciences; ICTs in teaching and learning Life Sciences; and teacher development.

Theme 1: Lesson planning and presentation.

Interview questions under this theme gathered data on what teachers considered during the preparation phase of teaching and what they did during the actual teaching period. When teachers were asked, "How do you decide instructional goals and objectives of the class?" the teachers responded similarly by referring to the CAPS curriculum document and the need for them to achieve curriculum objectives. Here are some excerpts of their responses.

> We need to comply with what is on the CAPS document as our guide, but as we go into those classes, they differ in the different situations. But in whatever that they come across, we must not forget the intention, which is to achieve those objectives. We need to get those from the CAPS document (Mr. Kuna).
>
> Yes, of course, the questions that we ask or activities those questions should be in relation to the curriculum, not something that is out of what we are been doing. So even those activities will be addressing the topic that we'll be doing in class yes. (Mr. Bheki).
>
> Ma'am this is how I decide; remember as educators we are being guided by the ATP [Annual Teaching Plan]. So, whatever that I do follows ATP, however, I'm trying to use different methods that are in line with ATP (Mr. Gcina).

The evidence presented indicated that teachers followed the syllabus or curriculum in whatever they did. This appeared to impinge upon their use of learner-centered approaches such as group work. They were afraid they would not be able to cover the syllabus since group work or projects consume time. All of these utterances suggest that teachers possess traditional pedagogical beliefs.

Theme 2: Assessment in Life Sciences class.

Questions in this section gathered data on assessment strategies used by teachers. Questions also sought to determine how they measured understanding after teaching a concept. The teachers primarily set tests that learners wrote. The responses to the tests indicated to teachers the extent to which learners grasped concepts. This is reflected in the following responses.

> Yes, so that you can check the learners' level of understanding when you test them, and what's nice now is their use of topic test after drilling a particular topic, you give them an informal test in relation to that topic so that they get used to being assessed continuously. By the time you give them the formal assessment they know how they are going to be marked because at times when they answer they do not look at the mark allocation so that they know how much they need to put into answering that question (Mr. Kuna).
>
> By assessment. Every time after we finish a topic, we have a topic test. The topic tests we are writing some out of 30 some out of 20 out of 40. They are to check whether the learner is able to understand what we were doing (Mr. Gcina).

The teachers regard tests are being important preparation for high-stakes examination. This suggested that they lean toward a traditionalist belief in science teaching.

Theme 3: Teaching and learning resources.

Teachers were also asked about the resources they use with learners. The teachers flagged the textbook as a primary resource. At the same time the teachers use WhatsApp groups to send resources such as videos. This is evident from their responses below.

> Particularly with grade 11 we are using a textbook, at times I ensure that I make copies from a different book then I give learners. They have their prescribed textbook that they are using which is Understanding Life Sciences (textbook). Some of the resources that they use I send to the WhatsApp group. So now and then, when I download something maybe from YouTube, I send it to the WhatsApp group (Mr. Bheki).
>
> We use textbooks, and PowerPoint presentations that come from the district which we share with them in the form of soft copies in our WhatsApp groups where we give them different question papers and previous question papers (Mr. Gcina).

Although they sometimes used videos and printouts from the internet, their reliance on the prescribed textbook was a behavior that is typical of traditional teachers.

Theme 4: Challenges in ICT integration into teaching and learning.

Teachers mentioned a variety of challenges that hindered ICT integration into teaching and learning. They mentioned safety and security, learners without digital devices, connectivity-related issues, technology failing during the lesson, vandalism, school policies and power blackouts. These views are encapsulated in the following interview excerpts:

> Yes, there are quite a number of those challenges, for example, not having fully functional Wi-Fi, learners not having gadgets that can integrate within their lessons. Some learners have these gadgets but they are scared of bringing them because they are mugged on their way to school or on their way from school. We have loadshedding (power outages). The smartboard can also freeze in

> the middle of the lesson. We have problems with troubleshooting software updates, etc. (Mr. Kuna).
>
> We have load shedding, and it sometimes happens that you play something in the smartboard, and it shuts out. It's not responding, and you expected it to respond, and another challenge is burglary. (Mr. Gcina).

Due to the mentioned challenges, teachers indicated that they ended up resorting to the traditional ways of teaching.

Theme 5: ICTs in teaching and learning Life Sciences.

This theme was focussed on how teachers integrate ICT in their teaching of Life Sciences. Firstly, the following question was posed: "How do you normally integrate technology in the teaching of Life Sciences?" This was followed: "Some people think that technology is beneficial in education. What do you say about this statement"? In the following excepts it is clear that teachers recognize that ICT plays a role in supporting learners' conceptual understanding.

> Yes, it's beneficial. The learners are using phones that are very advanced so if we introduce ICT, it means they can spend more time on their phones while doing educational things (Mr. Bheki).
>
> I also share the same sentiment with others that ICT plays a vital role in education. It enhances learners' understanding. Yes, we can use textbooks we can come to teach them, but now if we integrate ICT, like your YouTube, your slides, and so on, it simplifies information and enhances their understanding (Mr. Gcina).

From the following responses it is inferred that teachers use ICT in a traditional manner to transmit knowledge to learners.

> We do have videos that we play or presentations that we prepare on the smart board so that we show learners pictures like when we are talking about a particular topic and extra resource, we do show them pictures, videos, and links where they can access more information about that topic that we'll be looking at–even question papers they are there on the website they can access them with ICT (Mr. Kuna).
>
> As I indicated earlier, now and then, every topic that I'm teaching is to ensure that there is a video clip. If it's not a video clip, it's slides, and PowerPoint so that I can draw learners' attention. Yes, I'm teaching using textbooks and talking to them verbally, but at the same time, I ensure that I play a clip (Mr. Bheki).
>
> Yes, I do; for instance, we do the quiz now and then, so I use quiz lit, puzzles, and technology. I do, I do. Crosswords, they do it on the smartboard, so I do (Mr. Gcina).

In brief, these Life Sciences teachers used technology in the classroom as a presentation tool. Only Mr. Gcina administered quizzes using cellphones. The teachers used strategies that are associated with a traditional classroom.

Theme 6: Teacher development.

The teachers highlighted the need for development to more effectively integrate ICT in Life Sciences teaching. While they confirmed that teacher development workshops are organized, they expressed the need for development in more innovative practices. This is show below in Mr. Gcina's comment.

> What I would like to learn more is how to share information from the phone to the smartboard to the learner. And I would like to learn more on how to code, how to or where learners can get information from home–if from home, working from there, how they can respond to me. Something of that nature (Mr. Gcina).

Discussion of findings

The teachers' teaching practices were aligned with teacher-centeredness. All the lessons that were observed and analyzed using the TDOP were teacher-centered. The teachers dominated the lessons by purely lecturing with pre-made visuals, lecturing while writing on the whiteboard, asking rhetoric and comprehension questions, and frequently using smartboards and powerpoint presentations. The activities are in line with that of a traditional pedagogical belief informed learning environment that is associated with the teacher taking full control of the classroom environment, content, and organization (Deng et al., 2014; Ertmer et al., 2014; Liu et al., 2017; Taimalu and Luik, 2019).

Although learners did respond to the teachers' questions they were not supported in constructing knowledge. The approach resembled the Initiate-Response-Evaluate (IRE) model of questioning that is a traditional teacher lead question and answer session. Learners were answering teachers' questions, repeating their utterances, copying notes, and listening attentively without demonstrating their understanding. All the above-mentioned qualify the lesson to be teacher-centered or traditional. Learner-centered approaches that allow interaction, such as group work, were not observed in any of the lessons.

The teachers connected learners to real-life cases occurring within the school premises, homes, and communities. Learners were encouraged to engage in discussions about what was happening in their community and nation. The three teachers also tested learners' prior knowledge by asking questions at the beginning of the lesson. Learners were also given an opportunity, although limited, to solve complex problems and teachers encouraged their learners to participate. All activities above support a constructivist learning environment (Hirumi, 2002; Emiere, 2021). However, they only featured for a limited time. The researcher did not observe approaches consistent with science education, such as inquiry-based or cooperative learning (Applefield et al., 2001). The evidence discussed above allowed learners to learn in context and enhance their understanding of the subject content (Liu et al., 2017; McLeod, 2019). It therefore follows that the same teachers also practice constructivist approaches but this is at a minimal level.

Teachers frequently used smartboards and powerpoint presentations. The focus was on transmitting knowledge, which is the main characteristic of a traditional learning environment (Fives and Gill, 2015; Agakar, 2019). Teachers also integrate technology in Life Sciences by using videos to explain abstract concepts. Videos allow for multimodal presentation, which enhances understanding. In addition, the literature review also asserted that the ICTs, as mentioned above, are associated with teacher-centered instruction (Hora, 2015). Furthermore, from the observations, teachers indicated that they

would share slides and activities via WhatsApp. In this regard, they were using ICTs as a communication tool and as information-sharing tools that would allow ubiquitous learning to take place (Cope and Kalantzis, 2014). However, the use of ICTs as cognitive tools was not observed. Nkula and Krauss (2014) concurred with this finding, in that teachers use ICTs to represent knowledge while no construction of new knowledge takes place. In the lessons that were observed, it was evident that teachers are not developing 21st-century skills in learners. In this regard, the goal of the South African White paper on e-Education (Department of Education, 2004), CAPS Life Sciences (Department of Basic Education, 2011) and the SGD 4 of providing quality education that prepares the current learners to be productive in the 4IR will remain a pipedream.

Evidence from the analysis of interviews suggested that Life Sciences teachers involved in this study practice the traditional teaching approach more than the constructive one. Emanating from the interviews, they were aware of technology's affordances and demonstrated a passion for integrating technology. Teachers indicated that they use smartboards and powerpoint presentations, rely on prescribed textbooks and handouts, and assess learning by conducting tests. Hora (2015) argued that such supports are associated with teachers possessing traditional beliefs.

Studies show that teachers use ICTs aligned to their pedagogical beliefs (Ertmer, 2005) or use ICTs in both ways, traditional and constructivist (Tubin, 2006). The reason is that ICTs are versatile as pedagogical tools. They can be used under different teaching approaches, traditional or constructivist (Chai, 2010). For example, quizzes mentioned during interviews are meant to support traditional teaching, while multimodal presentations like the use of videos are intended to support the constructivist approach. Based on the above discussion, these teachers sometimes practice constructivist beliefs.

Pedagogical beliefs are not the only factors hindering effective technology integration. Evidence presented from interviews provided several challenges experiences by teachers in ICT integration: learners do not have smart devices, connectivity is for teachers only, the school code of conduct prohibits or limits the use of phones within the school premises, sometimes technology fails during a period, and vandalism is an issue. These findings on challenges to ICT integration were revealed in other studies. Mwapwele et al. (2019) found that school policies prohibited learners from using phones at school. WiFi was only available for administrators and teachers, not learners (Greunen et al., 2021). Ramorola (2013) flagged maintenance and technical problems, as well as security problems as impacting ICT integration. School policies contradict the goals of the White Paper on e-Education that all stakeholders in schools should be connected and that teachers and learners should advance learning using ICTs.

Contributions to theory and practice

The findings of this research add to the existing body of knowledge on the relationship between teachers' pedagogical beliefs and their practice when integrating ICT by adding credence to other studies that point to the crucial role teachers' pedagogical beliefs play in shaping their pedagogical decisions to integrate technology. As pointed out before, there is a dearth of research on the this relationship when it comes to the teaching and learning of Science, and so this study makes a contribution that knowledge. A theoretical assumption of this study was that beliefs, unlike knowledge do not require a "truth condition." While this cannot be disputed, the findings of this research do suggest teachers' pedagogical beliefs is a formidable entity that wields an enormous influence on teachers' classroom practices. This empirical investigation was framed on the theoretical position that beliefs cannot be quantified but that inferences can be made on beliefs based on lessons taught by teachers and what teachers say when interviewed. The findings from this study would enable the researchers to make inferences based on what was observed in the science classroom and the explanations offered by teachers on their classrooms practices when interviewed thus validating this theoretical position.

Although much resources for ICT integration are found in many schools, these are not being optimally employed as cognitive tools. The insights generated in this study could be used for teacher professional development efforts by the education ministry so that teachers may be empowered with pedagogical knowledge to enhance their constructivist classroom practices in using ICT in their science teaching. However, due to pedagogical beliefs having an influence on classroom practices, school leaders and policymakers should engage teachers on their existing beliefs. Although pedagogical beliefs tend to remain stable (Meschede et al., 2017), research has shown that reflection is a powerful intervention in changing beliefs (Olson and Marti Singer, 1994; Sansom, 2020) hence and this aspect should be incorporated in developing the teacher professional curriculum.

Limitations of the study

The study focused on three Grade 11 Life Sciences teachers working in schools in the Ekurhuleni South District, South Africa. The population and schools' contexts cannot be a representation of the diversity of the population and schools in South Africa. Therefore, the results cannot be generalized to other contexts. There is a need to upscale this research to a larger sample that has a more diverse representation of schools across other contexts in South Africa. Nevertheless, the findings do inform on the complex relationship between teacher pedagogical beliefs and their practices in ICT integration.

Conclusion

This study investigated the influence of grade 11 Life Sciences teachers' pedagogical beliefs on ICT integration in their teaching practice by collecting data from classroom observations and interviews. The two data sources are triangulated to reveal that teachers hold both traditional beliefs to a larger extent than constructivist beliefs. Their practice of ICT integration is aligned with a traditional approach. Research indicates that teachers' pedagogical beliefs influence lesson planning, delivery, assessment, interactions with learners, and the way they integrate ICTs in learning (Ertmer, 2005; Chan, 2010; Tondeur et al., 2017). As pointed out in previous studies, the findings also suggested a strong relationship between teacher pedagogical beliefs and ICT integration (Ertmer and Ottenbreight-Leftwich, 2010; Deng et al., 2014; Tondeur et al., 2017). This study shows that there is some alignment between teachers' pedagogical beliefs and their practice of ICT integration, especially in relation to traditionalist beliefs and traditional approach to ICT integrations. However, it would appear that contextual factors play a role in the manner in which ICT is integrated. This study found that effective ICT integration in teaching is hindered by the following: ICTs not correctly working, smartboards vandalized,

learners not having smart devices because they cannot afford or the school policies prohibiting them from using the devices within the school premises, and teachers lacking skills and knowledge on how to integrate ICTs effectively in teaching. These factors are similar to those identified in other South African studies such Hart (2023) and Ndlovu-Gatsheni (2015).

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

UR conceptualized the research concept. RN conducted the study and did the analysis. TT gave suggestive comments. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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