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Lecturers' Experiences of Teaching STEM to Students with Disabilities

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Abstract: Innovative teaching is a concept based on student-centred teaching strategies. Access to Science, Technology, Engineering and Mathematics (STEM) subjects has not been equitable due to use of traditional teaching strategies. These strategies tend to exclude students with disabilities who can effectively learn in environments that appropriately and innovatively integrate technology. Better use of technology in teaching also requires teachers to have the relevant skills to take advantage of the devices in their disposal. This article provides an overview of the literature and experiences of lecturers on the use of technology to facilitate access to STEM subjects at Technical and Vocational Education and Training (TVET) institutions. Using two TVET colleges as case studies, it seeks to clarify how technology is currently used in vocational training. Data gathering was done through in-depth e-interviews and observation of classes. Purposive convenience sampling was used to select the most accessible teachers that teach students with disabilities for this study. Understanding of prior practices and current teacher technological competency are the initial points in the development of TVET technology integration model. In this article, the experiences of teachers were used to guide the development of an inclusive and equitable technology integration model.

Keywords: Access, Disability, Post-schooling, Teacher development, Technology integration, TVET.

Introduction

The teaching of Science, Technology, Engineering and Mathematics (STEM) subjects has always been designed based on methods that require both the teacher and the student to have similar physical abilities (Khoza, 2015d). These abilities would enable the students to write formulas, equations, draw diagrams and even handle scientific apparatus and physically perform scientific experiments (Bansilal, 2015). During the apartheid era, teacher training was divided according to race and also according to learner profile. There were teacher training colleges for whites, blacks, Indians and those of mixed race; the three non-white groups could mix depending on the regional arrangements. This also meant that there were teachers who were trained to teach learners with disabilities (called Special Needs Education) and teachers trained to teach learners with no disabilities. This historical legacy poses a challenge in higher education where teaching is not separate. It means lecturers have no or limited skills on how to design innovatively to allow those with different abilities to actively participate in learning (Lumadi & Maguvhe, 2012). This challenge is greater in the Technical Vocational Education and Training (TVET) context where the teachers have to find ways of delivering

practical components of their course in formats that can be accessible to students with disabilities. An example one can use is that of a Mechanical Engineering student using a wheelchair who has to find ways of inspecting a vehicle. How can this be done? The advent of technology provides possible solutions to this problem but the question is how competent are TVET teachers in technology integration? This suggests a need for a study that explores the question of technology integration competency amongst TVET teachers.

TVET institutions have been highlighted in the White Paper for Post-Schooling and Training that was prepared by Dr Blade Nzimande, the Minister of Higher Education in 2014. The resulting policy stipulates that:

> The DHET's highest priority is to strengthen and expand the public TVET colleges and turn them into attractive institutions of choice for school leavers. … Key objectives in strengthening colleges include improving their management and governance, developing the quality of teaching and learning, increasing their responsiveness to local labour markets, improving student support services, and developing their infrastructure (Republic of South Africa, 2013).

According to Finch and Crunkilton (1999) TVET institutions offer education and training that is meant to prepare students to provide practical services for a productive economy. Berkvens, van den Akker, and Brugman (2014) state that the Seoul Congress called for TVET education that is accessible to all, which addresses the notions of sustainable development and provides opportunity for lifelong learning. Similarly, the International Council of Associations for Science Education (2013) announced the Kuching Declaration on Science and Technology Education redirecting researchers, policy developers and teachers towards the promotion of STEM subjects (Kennedy & Odell, 2014). The Kuching Declaration states:

> Access to high quality education is a fundamental right to all. In times of global vulnerability, issues such as sustainability, health, peace, poverty alleviation, gender equity, and biodiversity conservation need to be at the forefront of thinking, planning and actions related to strengthening STEM education. While the relative balance and emphasis of these disciplines varies around the world, it is the interrelatedness and combination of these that will propel progress (International Council of Associations for Science Education, 2013, p. 1).

The above-mentioned policies and declarations indicate the importance to all citizens of the world, including people with disabilities, in getting full access to STEM subjects so that they participate in the design of the world they live in.

Research Problem

Recently, the higher education sector has turned its focus to enhancing access to TVET institutions but the introduced initiatives rarely focus on how access can be enhanced for students with disabilities. Fichten, Asuncion, and Scapin (2014) highlight the scarcity of empirical research on the postsecondary experiences of students with disabilities. The research problem that this article addresses is how TVET teachers experience teaching STEM subjects to students with disabilities in South Africa. South Africa, as one of the countries that work with

United Nations Educational, Scientific and Cultural Organization (UNESCO), has to respond to the call for addressing quality challenges beyond 2015. According to Berkvens et al. (2014), this call from UNESCO emphasises access to quality and relevant education through technology integration. The integration of technology needs relevant theory or theories to guide the process. As a result this study uses the Technological, Pedagogical and Content Knowledge (TPACK) framework to frame the lecturers' experiences.

Theoretical Framework

Studies have indicated that the integration of technology in education needs relevant theories because learning is not about technology (hardware/software) but it is about ideology (pedagogical approaches select relevant technology for the course content) (Amory, 2010; Khoza, 2015b; Mishra & Koehler, 2006). These studies on technology integration agree that teachers should have pedagogical knowledge that is relevant to their subject content in order to select relevant technology. According to Mishra and Koehler (2006) TPACK is divided into technological knowledge (knowledge of selecting relevant technology based on the course content and pedagogy), pedagogical knowledge (knowledge of pedagogical approaches based on the course content) and content knowledge (knowledge of specific subject content). Among theories from these studies TPACK proves to be the most important framework because it presents the components of knowledge that are specific to teachers of learners with disabilities. As a result of the pedagogical component of TPACK, Sreedevi and Sudhir (2011) propose the approach of innovative science teaching, which they postulate is grounded in the constructivist pedagogical/ learning approaches. Innovative science teaching involves the use of teaching strategies like discovery or inquiry based learning, peer tutoring, simulation, experiential learning, team activities and cognitive apprenticeship (Sreedevi & Sudhir, 2011). Each of these approaches offers an opportunity for the teacher and the learner to engage better with the learning material. Amongst them, simulations would work well in the technical and vocational education and training environment, where the students with disabilities tend to be limited. Currently, the TVET facilities within which we have worked and conducted research do have computer laboratories which can easily be equipped with assistive technologies. The cost of assistive technologies would be affordable compared to converting the available physical laboratory facilities and making them accessible. Simulations would work well as a safe and feasible approach to teach science using inclusive approaches. Simulative lessons should be based on real STEM concepts that the students with disabilities can relate to, hence leading to authentic learning.

Student-centred TVET Education

Ngubane-Mokiwa (2014) proposes the development of a responsive TVET education that is student centred and responds to the labour market. As with South Africa, Goldney, Murphy, Fien, and Kent (2007) report that, in Australia, the significant barriers to the success of TVET institutions impede national future visions; inadequate resources; inadequate TVET skills at different levels of the sector and lack of innovative pedagogy. The concerns they raise are also applicable in the South African context where the teaching staffs lack ideas on how to move from standard teaching strategies to innovative teaching and assessment strategies (Ngubane-Mokiwa, 2013). Felder, Woods, Stice, and Rugarcia (2000) point out that innovation in teaching has not been formulated in ways that make

vocational and technical fields more accessible. However, they stress that innovation should not dilute content knowledge as STEM field is not based on opinions. Felder et al. (2000) propose that innovative teaching of science subjects should be guided by modern theories of learning, problem-based learning, applicable technology integration techniques and the maintenance of a balance between abstract and concrete concepts.

Exclusion of Students with Disabilities in STEM

Street et al. (2012) conducted an investigation on STEM barriers that confront postsecondary students with learning disabilities. Their research results revealed that students with disabilities did not actively engage in the STEM subjects due to "systemic barriers to participation" (Street et al., 2012, p. 363). This study further reveals that the systemic challenges begin at the school level where "teachers do not prepare them to have problem-solving skills" (Street et al., 2012, p. 364). This is in line with the assertion of Lumadi and Maguvhe (2012) and Jensen, McCrary, Krampe, and Cooper (2004) that teachers do not realize the importance of developing their inclusive teaching strategies.

Role of TVET Education in Sustainable Living

Powell (2012a) conducted a study questioning the role of vocational education and training in alleviating poverty. This qualitative study revealed that vocational education has an important role in poverty alleviation but there was a need to employ innovative and dynamic techniques that adopt capability approaches in order to reduce dependency. Powell (2012b) postulates that TVETs should see themselves training people to be employable, and training people to be innovative and self-sustaining. Powell (2012b) also points out that TVETs should also be seen as formations that promote social justice by opening access to education and employment. King (2011) also questions the relevance of TVETs, highlighting that TVET have been in existence for a long time with very little significant effect on skills acquisition and job creation. McGrath (2012) agrees with the notion of TVETs' perceived insignificance in skills development in Africa and suggests "reimagining the purpose" (McGrath, 2012, p. 36) as the remedy to the situation. Views from the research field suggest that reconfiguring the teaching approaches could contribute towards making TVETs more accessible and relevant. McGrath (2012) also calls for a shift from a production focus to capability approach. Capability approach adopts flexible and innovative approaches so as to enable all people to live life to the fullest. This means that people with disabilities would not have limited career and life choices, they would have an opportunity to be creative and to experiment. According to McGrath (2012) and Bonvin and Galster (2010) opening opportunities for people makes them more content and happy. We contend that students can be more open to learning and experimenting when teaching approaches are more innovative and student-centred. Figgis (2009) conducted 24 case studies with an aim of understanding teaching excellence. The results of this study revealed that teaching excellence was perceived as the use of learner-centred approaches, forming partnerships and providing pastoral care to the learners.

Looking at the reviewed literature demonstrates several gaps which are; paucity of research on the teaching and learning of students with disabilities at TVET institutions, lack of clear techniques on

how to teach STEM subjects innovatively and methodologies for creating sustainable education development.

Research Purpose and Research Questions

This article explores TVET lecturers' experiences in teaching students with disabilities. The data generation was organised to respond to the following research question related to TVET teachers of students with disabilities:

- What are the experiences of TVET teachers of teaching STEM subjects to students with disabilities?

Research Design and Methodology

This article is based on a study that was located within the interpretive paradigm. Qualitative data were generated over a period of one year from six lecturers in two TVET Colleges in Durban. The lecturers were teaching students with disabilities. The choice of approach was the result of a need to understand the challenges facing lecturers of students with disabilities. The unit of analysis was thus lecturers of students with disabilities at two TVET colleges. Holistically, the study sought to unpack the experiences of TVET lecturers of teaching STEM subjects to students with disabilities. In studying lecturers' experiences, this study is aligned with what Polzer (2007) explains as comprising of research 'from below', namely gaining insights into understanding the experiences from the participants' perspectives.

Purposive convenience sampling was used to generate the data. Lecturers of students with disabilities were given two options either to email back the reflective activities or submit them in person to us. The data generation methods included reflective activity in the form of questionnaires with open ended questions which was administered three times. The observation with lesson analysis was done twice at about one hour each. The semi-structured interview was also conducted twice about one hour each. Multiple sources of data were also used for the purpose of enhancing the authenticity of data and achieving measures of trustworthiness. The sample size consisted of six teachers of students with disabilities in total. Issues of ethics were observed according to the Rand Afrikaans University (2002) guidelines. As a result, participants' real names were not used (Table 1).

In terms of data analysis, this study used framework analysis where the themes were generated from the data through TPACK and the relevant literature. The findings are presented thematically, largely by means of using direct quotations to give value to the voices of lecturers of students with disabilities and the corresponding discussions to provide 'thick description' (Creswell, 2014).

Table 1 indicates that the six participants were from two TVET Colleges (4 from college A and 2 from college B). Two participants had Advanced Certificates in Education (ACE), one had a National Professional Diploma in Education (NPDE), one had a National Technical Diploma (N 6) and the other two had Bachelor of Education Honours. The subjects were Engineering science, Mathematics (N3, N4 & NCV NQF Level 3) and Civil Technology. There were three males and three females.

Table 1: Participants' Profiles

Name	College	Qualification	Subject	Experience	Gender
Participant A1	TVET A	NPDE	Engineering science	10 Years	Female
Participant A2	TVET A	ACE	Mathematics N 3	08 Years	Male
Participant A3	TVET A	ACE	Civil Technology	16 Years	Male
Participant A4	TVET A	B.Ed Hons	Mathematics NCV NQF 3	11 Years	Female
Participant B1	TVET B	B.Ed Hons	Mathematics NCV NQF 3	12 Years	Female
Participant B2	TVET B	NTC 6	Mathematics N 4	09 Years	Male

Findings and Discussions

The findings in Table 2 are presented according to the three themes and categories.

Table 2: Findings (Themes and Categories)

Themes	Categories
Technological knowledge	• Hardware and Software • Learning approaches
Pedagogical knowledge	• Teaching reasons • Goals • Assessment
Content knowledge	• Algebra • Trigonometry • Geometry • Forces • Structures

Technological Knowledge

Technological knowledge is the first competency that we engaged the lecturers about; the research results revealed that lecturers experienced challenges with regards to hardware, software and resources on learning theories and approaches that can be used to enhance the learning of students with disabilities.

Hardware and Software

The participants (teachers) agreed that they lack relevant technological knowledge of hardware and software resources used in the teaching of students with disabilities:

> I always combine my students when I teach without designing any separate or special resources for students with disabilities… I do not have any training in teaching students with disabilities but I have been teaching them… I work better with blind students because they use tape recorders to record my presentations and use their technology called Braille and JAWS to type their notes from the presentations… (Participant A1).

This response is in line with Hutchison, Beschorner, and Schmidt-Crawford (2012) who also reveal that their research indicated that teachers struggle to integrate technology (hardware/ software) into their teaching. Though their research was not focused on students with disabilities, we assert that finding it difficult to integrate mainstream technology is indicative that one would find it more difficult to incorporate assistive technologies and innovative teaching. Furthermore, assuming that a tape recorder would be an effective technological tool to teach vocational skills to blind students is indicative of lack of knowledge of appropriate technologies for a specific learning goal.

The second research participant indicated that he was comfortable with teaching students with a hearing impairment. He stated that:

> While I find it difficult to use technology to make easier for the students with disabilities because I do not have special training but I have started to enjoy working with deaf students because I use common technology like PowerPoint, word and internet resources to communicate learning with them… (Participant A2).

Participants A3, B1 and B2 appeared to be confident in their mainstream technological knowledge but expressed unease when it came to assistive technologies. In explaining their limited knowledge they mentioned that they were never trained to teach students with disabilities. According to Bansilal (2015), most teachers use technologies for learning but not for teaching. This point is further emphasized by Lumadi and Maguvhe (2012) who argue that most lecturers have limited knowledge and skills on how to teach science subjects to students with disabilities:

> When I have students with disabilities I really do not feel comfortable because I always know that I will not do justice in teaching them because they deserve special treatment which I do not have as I was not trained to teach them in a way that take them to the main stream… (Participant A3).

> Unfortunately, none of us has any training in teaching students with disabilities we are just trying… (Participant B1).

> Even the common digital technology is difficult for me it is worse if I have to master or adjust it to be in line with students with disabilities… (Participant B2).

Teaching Approaches

The participants were not aware of teaching approaches or methods used in the teaching of students with disabilities. According to Khoza (2015d) any person or object that communicates teaching/ learning, identifies teaching approaches, experiences, competences, ideas, research findings can be identified as learning approaches based on theoretical underpinnings of different types (see Amory,

2010; Khoza, 2015b; Percival & Ellington, 1988). These are most importance resources because they "permit the individual to self-manage a number of operations on their bodies" (Khoza, 2015d, p. 125). Khoza (2015d) concludes that teaching/ learning works only if teachers/students are in possession of relevant resources of learning approaches that identify relevant hardware/software. In this study Participants A1 and A2 and B2 indicated that they did not have knowledge of any particular approach to teaching students with disabilities. They further revealed that they did not possess any knowledge of learning theories that could guide their inclusive teaching:

> I teach all my students in the same way as before I have the students with disabilities and I do not have a specific teaching or learning theory… (Participant A1).

> Specific approaches or theories are used by those who were trained to teach students with disabilities… I do not know them but I did read somewhere that there are teachers somewhere who were trained to teach students with disabilities but I am not one of them… (Participant A2).

> I do not have any special approach for the students with disabilities… (Participant B2).

However, Participants A3, A4 and B1 indicated that they used constructivism, demonstration and drilling methods to enhance their students' understanding of what they are teaching. It must be noted though that they did not give any specific details on how they demonstrate concepts for a student with a specific disability like blindness or a learning disability:

> I sometimes use constructivism learning theory in order to allow students with disabilities to show me their challenges that need to be addressed… (Participant A3).

> In my teaching I use demonstration and drilling methods to allow all my students to understand what I am teaching…this has been helping me to support students with disabilities… (Participant A4).

> I use telling methods and drilling sometimes… (Participant B1).

Pedagogical Knowledge (Reasons, Goals and Assessment)

According to Berkvens et al. (2014), teaching reasons are divided into pedagogical (personal interest), content (metacognition development) and societal preparation (social skills development) reasons. However, the participants' responses only address pedagogical reasons and societal preparation reasons. None of them indicated content reasons (metacognition development):

> I enjoy teaching science because it is practical and help us to produce engineers although the practical component is difficult for students with disabilities … (Participant A1).
> I teach mathematics because it is very important in South Africa as it is compulsory even to students with disabilities… (Participant A2).

> I teach Civil Technology because it helps students with basic issues of Civil Engineering…students with disabilities find it difficult because civil trades (bricklaying, carpentry and plumbing) need strong people as they work outside… (Participant A3).

> …people respect you if you teach mathematics… (Participant A4).
>
> …the college has few mathematics teachers but many students especially with disabilities who need more attention… (Participant B1).
>
> 'I was encouraged by my lecturer to come back and teach mathematics because I was good in mathematics in my N6… (Participant B2).

Goals are divided into aims, objectives and outcomes (Hyland, Kennedy, & Ryan, 2006). Aims are broad statements that indicate long term goals according to lecturers' intentions. Objectives are specific statements that are smaller than the aims. On the other hand outcomes are specific statements that are smaller than the objectives and they are achieved by students.

Participants A1 and A2 were not aware of the difference between aims, objectives and outcomes. They, however, stated that they do recognize them when they are stated in the learning syllabus. Participant A2 goes a step further by incorporating assessment in order to see if the students have become competent in the specified goals.

> I always achieve aims with my students. Aims, objectives and outcomes are the same for me. Students with disabilities have to achieve the same objectives as other general students… (Participant A1).
>
> I use the aims or objectives to measure my students' success but it takes time for the students with disabilities to achieve the aims or objectives of my subjects… (Participant A2).
>
> I am not sure about aims or objectives because our books have some specified learning outcomes to be achieved by all of us in the subject… (Participant A3).
>
> I do not concentrate on goals because I just teach my students… (Participant A4).
>
> I do not think that I have to specify aims or objectives… (Participant B1).
>
> …students with disabilities achieve simpler objectives… (Participant B2).

Assessment is divided into formative assessment and summative assessment. Formative assessment is also called assessment for learning because it is not for grading students but for assessing how they are learning. Summative assessment is known as assessment of learning because it *is* for grading students.

All the participants were aware of the purpose of both formative assessment and summative assessment:

> Others students with disabilities use technology when they write test or examinations… (Participant A1).

> Most of my students use weblogs or Facebook if they want to have some discussions before they write tests or examinations… (Participant A2).
>
> I use both formal and informal assessment… (Participant A3).
>
> Students with disabilities need more support in order to pass the test and examinations… (Participant A4).
>
> Even students with disabilities write all the specified tests and examinations but they are slower than the general students… (Participant B1).
>
> Students with disabilities are struggling but we are unable to help because we do not have relevant technology to help them, as a result they are treated like any other general students… (Participant B2).

Content Knowledge

Mathematics teachers (participants) believed that they have strong content knowledge of algebra, trigonometry and geometry. However, they pointed out that students with disabilities have challenges with geometry and trigonometry due to lack of a basic foundation from earlier schooling.

> Students with disabilities have a problem with geometry because they do not have strong foundation of algebra… (Participant A2).
>
> We were given a CD to use in order to help students with algebra to build a strong foundation of geometry and trigonometry but the CD was not effective because the foundation should be facilitated at the school level… (Participant A4).

Other participants also highlighted that it does not help for a teacher to have the content knowledge when they do not have the relevant technology which they can use to facilitate their inclusive teaching. Participant B2 stated that the high cost of assistive technologies and the learners' specific needs for them makes it difficult for the TVET colleges to purchase all the relevant technologies.

> Students with disabilities should be given more time and relevant technology should be used to support them but our colleges do not have relevant technology systems that support them… (Participant B1).
>
> Technology that support students with disabilities should start at school level so that by the time they come to us they are used to their relevant technology and demand it when they come to colleges because we do not know what can work effectively for them… and colleges cannot buy technologies that are not in demand… (Participant B2).

Participant 1 believes that *'if colleges wish to support students with disabilities they should avail technologies that help students to learn different types of forces… such technology should help them with both theoretical and practical components…'*

Participant 3 believes that '*if investment has to be made by colleges they should have a strong system for students with disabilities that build a strong foundation of structures (slabs, beams and others)…*'

Conclusion

The findings on the lecturers' technological knowledge indicate that there was a serious lack of technological knowledge from the lecturers' side, especially regarding teaching approaches resources. This suggests that the teachers cannot teach across the three main approaches - teacher-centred, content-centred and learner-centred. Understanding whether the curriculum is driven by teacher-centred, learner-centred or a content-centred approach increases chances of achieving a positive attained curriculum because of good alignment between the intended and implemented curriculum (Hoadley & Jansen, 2014). As result of this lecturers' lack of specific teaching approaches and resources in teaching, it appears that learners with disabilities are not technologically supported in terms of their learning. The same challenge is evident when one looks at the findings of the pedagogical knowledge (rationale, goals and assessment).

The findings on rationale indicate that the teachers were not aware of the rationale of their teaching (whether personal, societal or content reason). Personal reason for teaching is to create an environment that helps learners to construct their own unique individual identities (Khoza, 2015b). When teachers create this supportive environment they include experiential and subjective activities that support the learners in order to construct and reconstruct knowledge repeatedly and, hence, take the form of personal meaning (identity). According to Schiro (2013) personal meanings make up the knowledge that is unique to each individual that possesses it and holds personal significance to each person, since the particular environmental context in which it is assimilated or constructed is a result of experiences in a particular teaching/ learning environment at a particular time. As a result, knowledge is viewed as a fundamental or basic part of learning because it is not a separate entity that has to be learned from outside the individual learner. Personal reasons influence societal reasons.

Societal reasons are about the achievement of observable/ measurable outcomes which is the major practice in this type of curriculum rationale. Levels of outcomes (lower, middle or higher order) are not important but the most important element is the achievement of outcomes which becomes an end in itself. As a result, it is mostly influenced by opinions, local every day or general knowledge and oral conversation. In this type of curriculum, knowledge is mostly generated horizontally from simple sources or local known sources (Bernstein, 1999). On the other hand content reasons also known as performance curriculum rationale is about the cognitive domain. In the performance curriculum recorded facts, school knowledge and international standards are used in making decisions. While performance curriculum may assess what students/ learners have learned, it mostly concentrates on what students should have achieved. In other words it looks for what is still cognitively missing because students are expected to learn from the lowest content (knowledge) to the highest content (knowledge) of the subject. Sometimes teaching rationale/ reasons are confused with goals.

The findings on goals indicate that the teachers did not understand the difference between aims, objectives and outcomes of their subjects. This suggests that the teachers were unable to measure their

own performance, which is measured through the learners' achievement of observable/ measurable learning outcomes (Khoza, 2015c). However, they tried to use certain types of commonly used assessment. The findings on assessment indicate that the teachers used formative assessment and summative assessment, although they were not aware of their reasons for using these types of assessments (a habit of doing assessment without being aware of what they are capable of producing). If teachers are not aware of their assessment rationale, learners do not learn through the assessment process which is capable of helping the learners to learn and in turn becomes assessment as learning (Khoza, 2015a). Most importantly, all these curriculum concepts involve the subject content which suggests the importance of content subject knowledge.

The findings on subject content knowledge indicate that while they had their subject content knowledge, they were unable to use this knowledge to identify the most suitable goals, assessment and teaching/learning resources (technologies). What appeared to be confusing to the teachers was that TVET colleges use two different types of curricula competence curriculum and performance curriculum simultaneously. It is always a problem for teachers if they work with these two curricula because competence curriculum follows a horizontal approach (driven by learning outcomes) while performance curriculum follows a vertical approach (driven by subject content) (Bernstein, 1999). Therefore, it will always be difficult for TVET college teachers to support learners with disabilities if they do not have technological knowledge, pedagogical knowledge and content knowledge because the two curricula (competence and performance) demand these three types of knowledge (Khoza, 2015c).

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