Decolonising technological pedagogical content knowledge of first year mathematics students

Simon Bheki Khoza[1] · Audrey Thabile Biyela[2]

Abstract

Decolonising students' knowledge of technology, pedagogy, and mathematics content is important because it helps students understand their learning needs. Decolonisation is a process of critiquing and renewing the curriculum. Learning needs are circumstances that demand individuals' actions in order to address professional, personal, and/or social needs. The purpose of this article is to explore and decolonise students' knowledge of technology, pedagogy, and content in the learning of first year Bachelor of Education mathematics. Ten students learned a mathematics module at a South African university and were purposively selected to participate in this study. Semi-structured interviews, observation, and reflective activities/questionnaires, framed by critical action research, were used for data generation. The students' knowledge revealed that the technological pedagogical content knowledge (TPACK) was useful when used as the learning framework, which generated curriculum concepts for the module to support the student knowledge of technology, pedagogy, and content. The concepts were learning needs, content, goals, activities, time, environment, community, assessment, and GeoGebra resources. GeoGebra was the main learning resource that helped the students to integrate other resources into the module. The study concluded that, although the technological and content knowledge dominated the learning in other cases of the module, the pedagogical knowledge which was a result of their self-reflection to understand their identities, drove the module all the time. This study, consequently, recommends that students should use their knowledge of technology, pedagogy, and content as taxonomies of learning, in order to address mathematics, individual, and societal needs through the integration of technology.

Keywords Content · GeoGebra · Knowledge · Mathematics · Pedagogy · Technology

✉ Simon Bheki Khoza
    khozas@ukzn.ac.za

Extended author information available on the last page of the article

1 Introduction

We have been observing that students join higher education institutions (HEIs), bringing to such institutions differing knowledge of mathematics content, pedagogy, and technology from that of HEIs. On the one hand, students join the HEIs mostly with knowledge of social networks/media (Aydin 2012) that address societal needs (Budden 2017; Prensky 2001). The majority of the undergraduate students were born during the digital era (digital natives). This suggests that they have good knowledge of technology. On the other hand, HEIs mostly use Learning Management Systems (LMSs) that address Mathematics content needs (Fomunyam 2016b; Khoza and Manik 2015). Most of the students expect to learn future content (unstructured electronically driven content); while HEIs are dominated by legacy content (structured print-media-driven content) (Khoza 2019; Prensky and Berry 2001). As a result, there is a belief that the students' technological learning (socially driven), which is mostly different from that of the HEIs (content driven), causes a high failure rate of students (Czerniewicz and Brown 2014; Mpungose 2019a; Pather 2017). Although the majority of students are good at technology, they are limited in terms of using it to master the prescribed or structured content (legacy content) offered to students in order to pass their qualifications. Students are limited because they are captured by the love unstructured content (future) generated from various sources, some of which are not approved by their HEIs, who have to assess and grade them. No matter how impressive is the information generated through various digital technologies, it does not help students to pass their courses if it is not in line with the HEI prescribed content. The majority of students, especially those from disadvantaged communities, have to add more years of study in order to complete their qualifications. This is if they are not excluded from the qualifications by HEIs through progression rules (Clifford and Montgomery 2017; Waghid and Waghid 2016). The high failure rate of students, even if the students are perceived to be good in terms of using digital technology to communicate with various experts or people in their field of studies, is a cause of concern for HEIs. It becomes a concern if students are unable to align their knowledge and skills of generating unstructured or future content from various sources with HEI structured, prescribed, or legacy content (Cavus et al. 2007; Ngubane-Mokiwa 2013). Studies are limited that critique this challenge of knowledge being different with the aim of generating solutions (Audi and Gouia-Zarrad 2013). Critiquing and renewing the knowledge of curriculum is known as decolonisation of education (Keet 2012). This suggests that there is a need for studies that decolonise both the students' knowledge of learning mathematics and prescribed or structured HEI content, in order to address both the students' and the HEI's needs. This may help both the students and HEIs in searching for and understanding their identities; thereafter being able to serve their societies better. Such studies may be useful to mathematics students, lecturers, policymakers, HEI stakeholders, and education departments.

Therefore, this study intends to explore and decolonise first-year students' knowledge of technology, pedagogy, and content in learning mathematics at a South African university. The next sections of this article are literature review (technology, content, and pedagogy); research purpose, objective, and questions; critical paradigm with action research; purposive sampling with ethical consideration; data-generation methods; data analysis, findings with discussions; and conclusion with implications.

2 Literature review (knowledge of technology, content, and pedagogy)

Knowledge is a cognitive process driven by experiences/beliefs which produce actions within a specific curriculum/context. Curriculum is a plan for/of teaching and learning that provides knowledge for individual, societies, and professions (Berkvens et al. 2014; Khoza 2018). Curriculum as the plan, addresses needs which are personal (individual talents and character), societal (citizenship and socialization), and professional (mastering or advancement of discipline or subject content). As a result, the knowledge within the mathematics curriculum is divided into technological, mathematics content, and pedagogical knowledge (Koehler and Mishra 2009).

3 Technological knowledge

Technological knowledge is knowledge of any object or person that communicates learning (Govender and Khoza 2017). Technological knowledge is divided into hardware (HW) (machines such as computers, laptops, tablets, mobile phones, and others, used in teaching/learning), software (SW) (material such as application programmes, websites, and others, used in conjunction with hardware), and for the needs of the subconscious mind (Murphy 2008), technology of self or ideological-ware (IW) (thoughts, theories, and others that manage the use of HW/SW) (Foucault 2007; Khoza 2017). On the one hand, most students join HEIs with high technological knowledge of hardware (such as mobile phones or smart-phones, laptops, and others) and software (such Facebook, Twitter, WhatsApp, Instagram, YouTube, and others) (Budden 2017; Khoza and Manik 2015; Prensky 2001). However, ideological-ware or technologies of self that drive the HW and SW are not identified as part of the studies on technology. This suggests that the students' reasons for using such HW and SW are socially driven because there are no intended theories identified for the students to use these technologies in learning mathematics content. On the other hand, higher education institutions (HEIs) use HW; and SW such as learning management systems (LMSs), emails, and MACSYMA (Palmiter 1991), Virtual Manipulatives and Whiteboard (VMW) (Hwang et al. 2009); and others that drive Mathematics content (Bansilal 2015; Umugiraneza and Bansilal 2017). IW used by HEIs are theories such as Technological Pedagogical Content Knowledge (TPACK); Cultural Historical Activity Theory (CHAT); unified theory of acceptance and use of technology (UTAUT); Connectivism; situated learning theory; the Three Tree Rings Theory (TTTRT) (Khoza 2013), and others that were identified for formal teaching and learning of the mathematics curriculum. These theories are capable of driving any digital technology because they combine professional, societal, and personal issues.

The two technological knowledge utilizations (students and HEIs) suggest that there is a need for critiquing such utilizations in order to produce a new decolonised curriculum for technological knowledge. A study conducted by Chaka and Govender (2017) on the perceptions of students on the use of mobile learning in Nigeria, concluded that the majority of students had positive perceptions of mobile learning because mobile learning allowed them to socialise while they were learning. Although other studies (Bitner and Bitner 2002; Czerniewicz and Brown 2014; Pather 2017; Prensky 2001) support this study,

they emphasise the importance of training academics to overcome the fear of digital technology before the teaching and learning processes start. The training of academics needs to be driven by IW, because learning is about ideology (IW) and not technology (Budden 2017; Khoza 2019; Mpungose 2019a). The importance of theories (IW) in integrating technologies (HW/SW) into teaching and learning is evident in various studies (Budden 2017; Chaka and Govender 2017; Palmiter 1991; Umugiraneza and Bansilal 2017) that conclude that technologies improved student performances or results because they were driven by specific theories. This suggests that decolonisation (critique and renew) should focus more on theories than on HW/SW if HEIs need to do justice to the curriculum. Decolonisation of technological knowledge, especially IW/theories, may produce a good platform for content knowledge.

4 Mathematics content knowledge

A study conducted by Prensky and Berry (2001), identified future content and legacy content knowledge as the two types of content knowledge generated by the introduction of digital technology. Future content knowledge is the unstructured, electronically driven content (information in websites and other electronic media), mostly supported by students. Legacy content is the structured print-media-driven content (in books and articles) mostly supported by academics. HEIs use HW; and SW such as LMSs, emails, GeoGebra and others to store and display content. Mathematics content knowledge (future and legacy) is divided into algebra, geometry, and trigonometry (Gur 2009; Lavicza 2010; Palmiter 1991). These studies indicate that these three sections of Mathematics produce the frames of all other sections of Mathematics. Algebra, as the foundation of Mathematics (Akugizibwe and Ahn 2019; Palmiter 1991), produces habitual actions that help students to fulfil their personal needs. These habitual actions develop when they grow up so that they are able to count even when they are not concentrating on the counting processes. Geometry puts mathematics into practise because it needs specific skills which are driven by specific steps and actions. For example, when drawing a graph, one has to follow the direction of specific coordinates. This suggests that geometry addresses societal needs because it involves practical parts of mathematics that require drawing skills or competences (De Villiers 2004). A study conducted by Gur (2009) on misconceptions of trigonometry, concluded that students produce more errors and misconceptions (in concepts, process, and precepts) in trigonometry than in any other sections on mathematics; and that trigonometry is the most challenging section of mathematics. Trigonometry is learned in a linear method that needs much concentration (Lavicza 2010). The linear method suggests that it is learned to advance mathematics content, addressing subject/discipline/professional needs. Therefore, the decolonisation of mathematics content knowledge should focus on the three sections in order to address personal, societal, and professional needs through the objective or conscious mind (Murphy 2008). Decolonised content knowledge produces and guides the type of pedagogical knowledge required in learning (Fomunyam 2016a).

5 Pedagogical knowledge

Pedagogical knowledge is a combination of various curriculum concepts, driven by both the objective/conscious and subjective/subconscious minds (Murphy 2008), such as goals; assessment; time; environment; activities; teacher role; community; and vision (personal, societal, and discipline/professional) (Khoza 2018; Mpungose 2019b). HEIs plan and use these concepts which produce pedagogical knowledge for learning that helps students to find and understand their personal identities (Budden 2017; Fomunyam 2016a). When students understand their identities they learn better because they use relevant IW or theories to drive relevant HW and SW resources; in this way they master and understand their course content (Khoza 2019). Content is learned better through identified goals (Khoza 2018; Kisaka 2018).

Goals are actions that must be achieved through the learning process. Hyland et al. (2006), conducted a study on writing learning outcomes, which identified aims, objectives, and learning outcomes as the three types of goal in any curriculum. Aims are teachers' long-term goals, objectives are teachers' short-term goals, and learning outcomes are what students should achieve at the end of a lesson. Both academics and students should therefore be aware of their respective goals to be achieved, so that they use them as their guiding frameworks for teaching/learning. According to Tyler (2013), goals are the first steps to any curriculum/learning, measured through assessment. Assessment is a process of gathering and analysing data in order to establish whether the goals of a lesson were achieved. Assessment is divided into three types: formative (assessment for learning), summative (assessment of learning), and peer (assessment as learning). Although formative assessment and peer assessment may not have strict time allocation, being habitual and social in nature, respectively, summative assessment has strict time and place/environment that requires planning.

A learning environment is a platform for learning, divided into face-to-face, online, and blended learning. Environment determines the types of learning activities required in a lesson. Activities are either dominated by formal, informal, or non-formal approaches, in order to guide teachers in producing content of their subjects through different teacher roles (Ndlovu 2017). Academics' roles should be defined by whether they should teach as facilitators, researchers, instructors, and others, in order to be linked to the reason/s (societal, personal, or professional) for the lesson (Mabuza 2018; Makumane 2018; Shoba 2018). The reasons are determined by the type of students and the community of practice involved in the learning process. Students and the community are defined in terms of physical, financial, and cultural access to the course (Berkvens et al. 2014; Freire 1993). Decolonisation of pedagogical knowledge should therefore focus on these pedagogical concepts.

The discussion of the literature review raises two important points to be addressed before learning takes place. The questions that are asked apropos of driving decolonisation, are 'who is learning?' and 'why learning is taking place in particular ways?'. In other words, decolonization and technologies (whether social media and/or formal LMSs) should be directed to students whose personal identities are known, the reason/s for decolonisation being known. The discussion further produces three important frames of curriculum or learning knowledge (technology, content, and pedagogy). The three frames suggest the importance of technological pedagogical content knowledge (TPACK) (Koehler and Mishra 2009) as the framework for decolonising learning

or curriculum knowledge. Therefore, the three main principles of TPACK are used to create a relevant framework for this study. The three principles helped to frame the studies of knowledge that must be considered in the decolonisation of the curriculum. Although the application of TPACK was designed for teachers, it was relevant for this study, because these students (participants) were also teachers-in-the-making (student-teachers).

6 Research purpose, objective, and questions

The purpose of the study is to explore and decolonise students' technological, pedagogical, and content knowledge at a South Africa HEI.

- –What are students' technological, pedagogical, and content knowledge at a South African HEI?
- –How do students use technological, pedagogical, and content knowledge at a South African HEI?
- –What informs students' technological, pedagogical, and content knowledge at a South African HEI?

7 Critical paradigm with action research

A critical paradigm is a way of thinking that motivates researchers and participants to reflect on their experiences, in order to transform their situations. The main purpose of a critical paradigm is to explore, critique, and bring about changes, in order to liberate participants from ways that oppress them within their situations (Creswell 2014). The truth is constructed through the process of interrogating power relations in which participants are minors/oppressed by certain situations. Although the critical paradigm does not allow generalization of the findings, it allowed us to achieve in-depth descriptions of data that fulfil the purpose of this study. This was achieved through critical-action research (Esau 2017) as the research style/approach. The critical paradigm with action research is highly significant for this study because critical-action research aims to bring about transformation, liberating the minors (students) so that they can benefit from their learning environment (Esau 2017; Ramrathan 2017). The paradigm also aims at improving ones' practice. The process follows four steps: planning, action, observation, and reflection on the process and, decision-making for the next phase of action research. This study had two phases of action research.

8 Purposive sampling with ethical consideration

Purposive sampling with convenience sampling was used in this study to select the ten most accessible first-year mathematics education students. Purposive sampling is used through convenience sampling, when the purpose of the study is to represent a specific, unique group of participants (Aydin 2012; Creswell 2014). Participants approached us in 2017, needing support in integrating digital technology into their learning of mathematics

at a South African university. This process suggests the importance of purposive sampling with convenience, used when researchers intend to target a specific, unique group of participants (Amiel and Reeves 2008; Aydin 2012; Ramrathan 2017).

Although the participants approached us, we had to apply for an ethical clearance certificate from their university, in order to declare all the details of the study. Part of the application for ethical clearance was the consent letter signed by the participants. The consent letter explained the nature of the study, together with the ethical principles, such as confidentiality, anonymity, free participation, and benefits of participation. The names of the participants were replaced by pseudonyms (Students 1–10). There were six girls (Students 1, 3, 5, 7, 9, 10), and four boys (2, 4, 6, 8). Participants 5, 4, 7, and 10 were from outside South Africa. Most participants were Black-African, except Participants 2 (White), 3 (Indian), and 4, 5, and 9 (Coloured).

9 Data-generation methods

This study began with open-ended questionnaires (reflective activities) guided by the ten concepts of learning (learning needs, content, goals, activities, time, environment, community, assessment, teacher role, and technology) that are capable of helping researchers understand the nature of knowledge (Berkvens et al. 2014; Fomunyam 2016b). All the questions/items for the data generation were guided by these curriculum concepts of learning. The questionnaires were useful because they were emailed to the participants; the participants completed and returned them in their own time. Participants completed the questionnaires in our absence, and at leisure, which, according to Creswell (2014), is the advantage of the questionnaire. Semi-structured questionnaires allow participants to record their experiences without being constrained/restricted by closed-ended questions (Ramrathan 2017). However, semi-structured questionnaires are difficult to analyse, because the participants' responses may have nothing in common (Amiel and Reeves 2008). As a result, we have used curriculum concepts with propositions/categories under which we analysed the generated data. We administered the questionnaires once during each of the two phases of action research, to address the 'what' question (descriptive) of this study. Questionnaires were followed by participant observations that helped us to answer the 'how' question (operational) of this study.

We observed the participants in action to generate the answers on how they used their technological, pedagogical, content knowledge in learning mathematics. We performed two roles as participant observers: insiders and outsiders. One of us was working with the students on a daily basis (Mathematics Education) (insider); while the other one was not working with these students (outsider, participant observer). These two roles helped us to make sure that the insider was not subjective; and the participants do not hide important data from the outsider. Observations were followed by one-on-one semi-structured interviews, capable of probing and addressing the 'why' questions of research (Cohen et al. 2007).

An interview is a conversation between the researchers and their participants. We used semi-structured interviews with open-ended questions to generate data on what informs (why − philosophical) the students' technological, pedagogical, content knowledge. This allowed the participants to reflect on their planning and action stages. The interviews were helpful for this study, because they allowed us to probe the

participants, adding/rephrasing questions where we were not satisfied with the participants' responses. However, interviews do take extensive time; as such, they were conducted when the participants were not busy with tests/examinations.

10 Trustworthiness

According to Guba and Lincoln (2005), enhancement of trustworthiness consists of credibility, dependability, transferability and confirmability. These principles are used in qualitative research to avoid errors that may affect data. In this study we used TPACK principles and learning/curriculum concepts of knowledge to provide a clear structure that guided the study (credibility). A tape recorder was used to record the interviews for transcription ease and direct quotations from the interviews; and questionnaires were used to make sure that the findings reflect and represent the knowledge of the participants (dependability). We have provided all the details of the participants' context, so that, should other researchers wish to apply the findings of this study, they will be able to choose a relevant context, similar to the one for this study (transferability). In 2017, one of us was working with these students who were open enough to respond to questions. The lecturer's position when generating data did not affect the integrity of the data. Where there was any chance of her becoming subjective (insider), she was supported by one of us (outsider), thus ensuring that our positions did not affect the findings (confirmability). The three data-generation methods were used for the triangulation of findings (triangulation) (Hamilton and Cobert-Whittier 2013).

11 Data analysis

The guided analysis approach consists of qualitative (inductive) and quantitative (deductive) data both types used for data analysis in this study (Ramrathan 2017; Samuel 2009). The ten learning/curriculum concepts were used to generate the themes that framed the findings and discussions. The HEI had one curriculum document comprising ten sections on teaching/learning: visions (knowledge), content, goals, assessment, resources, activities, roles, communities, environment, and time. The results (quantitative) and findings (qualitative) from the students were framed by these concepts. Figures (quantitative), and descriptions were used for the presentation of the following findings.

12 Findings and discussions

The first figure presents the concepts of the content knowledge (Theme One). The second figure presents the concepts of technological knowledge (Theme Two). The third figure (Theme Three) presents pedagogical knowledge from both the HEI curriculum and the students. The results and findings for themes one and two were generated from Phase One of the action research. The results/findings for theme three were gathered and generated from Phase Two of the action research.

12.1 Theme one: Content knowledge

The results in Fig. 1 indicate the nine concepts used to compare higher education institution (HEI) content knowledge (CK) with that of first-year students who studied Mathematics Education towards a degree of Bachelor of Education (BEd) at a South African HEI. All the concepts of content knowledge were covered in the ten sections of the HEI Mathematics Education curriculum. However, only three students (mean of 3) (Students 1, 2, 3) had a good knowledge of the content knowledge concepts. The majority of the students had either neutral (mean of 3.8) or poor (mean of 3.2) content knowledge. The results indicate that the majority of the students were not familiar with content knowledge. This was because it was driven by mathematics content (legacy) more than technology (future). The results confirm the claim that students are digital natives who need future content (Prensky and Berry 2001).

During observation, when these students were taught to use GeoGebra to solve trigonometric functions/equations and draw graphs, most of them did not follow the lecturer's instructions: because they wanted to use their own resources for these functions/equations. The lecturer gave the students tasks to perform and steps to follow. Only three students (Student 1, 2, 3) properly understood and followed all the steps according to the lecturer's instructions. '…*I used GeoGebra at school to solve trigonometric equations and graphs. I used it when we had face-to-face four lessons for one hour each towards the end of the year when we were preparing for examination. Although our main teachers' objective was to help us to know how to use computer software to solve mathematics problems, it was not different from that of our university lecturer, which was to help us to understand the use of computer with GeoGebra…*' (Student 1). Students 2 and 3 agreed with Student 1's account because they came from the same secondary school where they used the same learning style. Other students supported Student 8 when he said '*I am not familiar with the lecturer's teaching style of imposing his knowledge to us, instead of allowing us to use our experiences in learning because we too many modules in the same day…*'. This suggests that the lecturer's
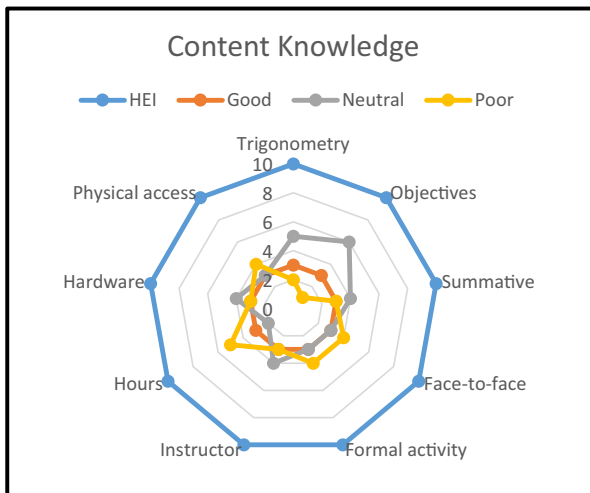

Fig. 1 Content Knowledge

objective system of conscious mind/thoughts was not compliant with that of the majority of the students, who were subjectively driven by subconscious mind/thoughts (Murphy 2008). As a result, the majority of students had a mean mark of 50% in their tests, while Students 1, 2, and 3 had an average mark of 85% in their tests.

12.2 Theme two: Technological knowledge

Findings in Fig. 2 indicate that only six sections of the ten presented geometry; all other concepts were presented in each of the six sections of the curriculum. However, students' technological knowledge (mean of 6.3) was higher than that of the HEI (mean of 5.1) because all the concepts, except geometry (content), were rated higher than that of the HEI. The mean of 2.9 students had neutral technological knowledge and the mean of 0.7 students had poor technological knowledge. The number of students (8 out of 10) who had good knowledge of online learning was higher than those who had a good grasp of other curriculum concepts. Fewer students had a good grasp of geometry (content) than other concepts, where greater knowledge was apparent.

We observed that the majority of the students enjoyed being given opportunities to use any computer software to draw straight-line graphs with various gradients/slopes. Microsoft Word, Microsoft Excel, Paints, and GeoGebra were among the computer software used by the students. Some students downloaded '*graph templates from the internet and adjust them according to the tasks given by the lecturer*' (Participant 6). '*…I enjoy if lecturers give me freedom to using any method/resource. The use my Facebook page to search for information from my friends, my friends also help me to check if my work is correct…*' (Student 4). The main outcome for the lesson was that, '*students will be able to change straight line equations to different forms, calculate co-ordinates, and draw straight line graphs*'. '*…I prefer online learning where lecturers facilitate with no time limit because technology allow me to communicate with the whole world for information through my social network…*' (Student 5). However, Student 2, supported by Students 1 and 3, used GeoGebra, which was prescribed by lecturers, as it was incorporated into the university's learning management system
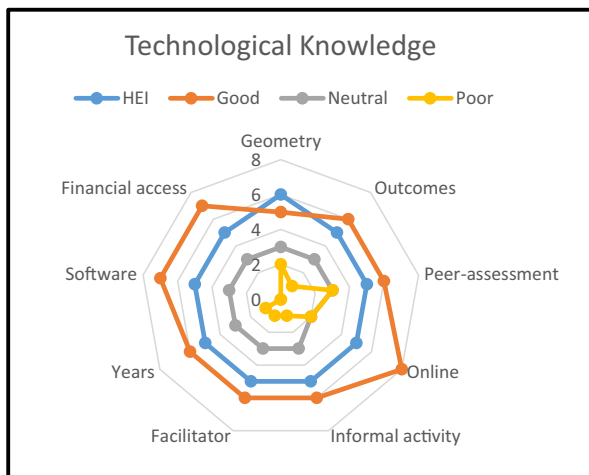

Fig. 2 Technological Knowledge

(LMS). '…*I mostly access the internet on campus because I do not have internet connection at home because my parents cannot afford it and I want to use prescribed software so that if I have a problem I contact the lecturers… I believe we can improve our results if we can do and finish only one module a month…*' (Student 3). The findings suggest that most of the students preferred the subjective/social/technological learning process of the subconscious mind (Murphy 2008). Consequently, the other seven students' results improved, when the lecturer facilitated learning.

12.3 Theme three: Pedagogical knowledge

The findings in Fig. 3 indicated the mean of 6.1 for the HEI curriculum; and the mean of 7.2 for the students who had good knowledge. The mean for the students with neutral pedagogical knowledge was 2.4; while the mean for the students with poor pedagogical knowledge was 0.3. The mean between the HEI and the students' knowledge of pedagogical knowledge was 1.1. Some HEI pedagogical knowledge concepts are equal to that of students with good pedagogical knowledge (algebra, aims, and theories of technology/resource). This suggests that pedagogical knowledge is a common platform on which content and technological knowledge can be equally used. In other words, if decolonisation of curriculum/education (Keet 2012) is to work, it will need the pedagogical knowledge platform which combines both the content and technological knowledge. Such will enable it to address personal/individual needs (personal identity) through training students' conscious and subconscious mind/thoughts (Murphy 2008).

The findings of Phase Two (action research) revealed that students had become aware that HEI education was dominated by content knowledge (objective); while their processes were mostly dominated by technological knowledge (subjective/subconscious mind). '…*as much as I enjoy learning online with my friends through social network I have no choice of following my lecturers in order to pass my modules…*' (Student 9, supported by Student 6). '…*it would be better if lecturers were to allow us to integrate our social networks into the formal learning management system in order to reduce formal learning stress…*' (Student 10, supported by Students 4, 5, 7, 8). '…*it does not matter whether lecturers work as*
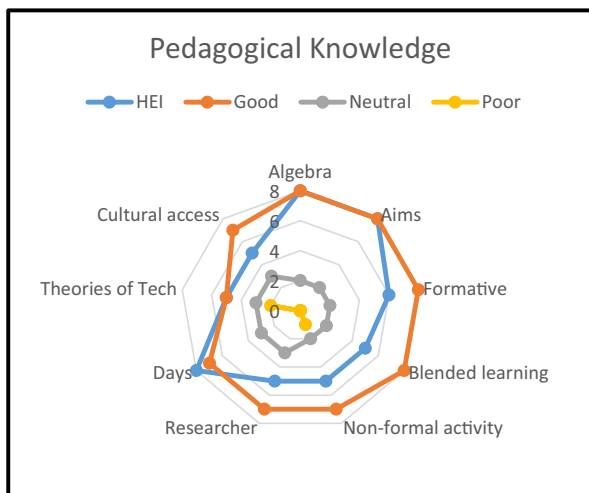

Fig. 3 Pedagogical Knowledge

instructors or facilitators, I always make sure that I understand their expectations/needs of the tasks at hand because they are the ones that give us the final marks…' (Student 3, supported by Students 1 and 2). These accounts suggest that the participants preferred the pedagogical knowledge which combines both the content (objective/conscious mind) and technological (subjective/subconscious mind) knowledge in learning (Fig. 4).

13 Conclusion and education implications

The results/findings of this study suggest the application of pedagogical/personal knowledge that produces pragmatic curriculum as the solution to the decolonisation of education. A pragmatic curriculum consists of habitual educational concepts (Czerniewicz and Brown 2014) generated and controlled by the conscious mind (shallow/objective knowledge) through the human senses (sight, smell, hear, taste, and feel). Such are in the form of thoughts/beliefs stored and retrieved from the subconscious mind in order to produce individual/personal actions that address the personal needs (Fomunyam 2016b; Murphy 2008). The habitual concepts of the pragmatic curriculum, as indicated in Fig. 4 as the interface between the performance (content) and competence-based (technological) curricula, are algebra, aims, formative assessment, blended learning, researcher role, cultural access, non-formal activities, theories of technology/ideological-ware, and days of learning.

Number counting as part of algebra is learned by students in their earliest years from families/societies (even before formal education). When the number-counting habits are approved by the conscious mind, they are stored in the subconscious mind (Murphy 2008) so that individuals are able to count even if they are not concentrating on the counting. All mathematics sections need an understanding of number counting and other parts of algebra as their first requirement/prerequisite before they are learnt (Akugizibwe and Ahn 2019; Bansilal 2015). Decolonisation of mathematics content should therefore start with algebra, in order to produce a platform for other sections with their aims. Aims, as the habitual long-term goals, broad enough to produce a
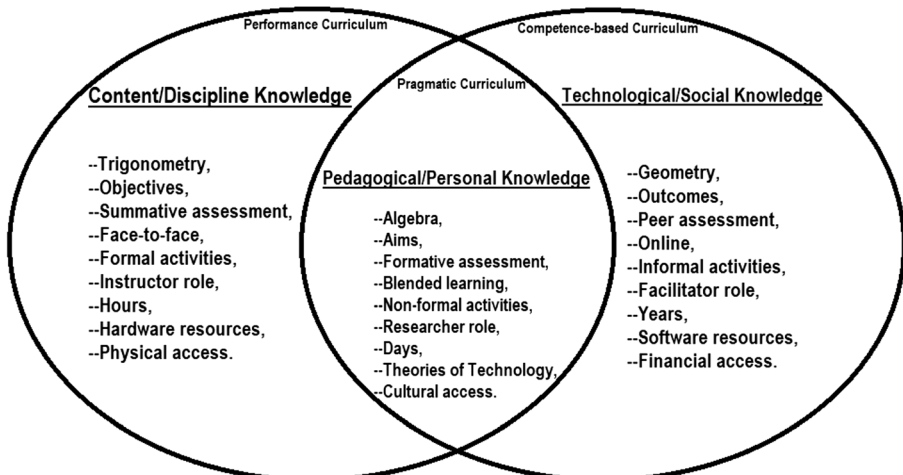

Fig. 4 Decolonised Teaching/Learning Knowledge

foundation for both the objectives and outcomes, are assessed through formative assessment (Hyland et al. 2006). Formative assessments are questions asked to establish whether individuals are ready to learn. For example, most lecturers habitually and formatively start by greeting their students to establish whether they are ready to learn before the lecturers teach. Teaching/learning thus begins with formative assessment in both the face-to-face and online (blended) learning.

Blended learning has become a solution in generating an educational environment/ platform for both digital immigrants and natives (Prensky 2001). It is becoming a habit in education for lecturers/students to use online in their face-to-face environment. This tends to be driven by non-formal activities (combination of formal and informal). Non-formal activities are driven by theories of technology that are aligned with the culture of learning communities (Pather 2017). Lecturers and students should therefore assume their teaching and learning roles as researchers whose research theories are relevant to their personal identities, every time they teach and learn, supported by digital technologies. In this study, the researcher role demanded that the students reflect, in order to understand their identities, before they learned in the second phase of the action research. As a result of the researcher role, self-reflections, and the second phase of action research, the students transformed, and were able to know and understand 'what they were learning' (descriptive question = content), 'how they were learning' (operational question = technological), 'who they were in learning' (personal question = identities), and 'why they were learning in particular ways' (philosophical question = pedagogical). Although the 'what' and 'how' questions dominated the third industrial revolution (3IR) and the 'who' and 'why' dominate the fourth industrial revolution (4IR) (Schwab 2016), the students (participants) needed to address all these questions in their learning in order to improve their academic performance. Therefore, these questions were used as taxonomies of learning that assisted students to understand their identities. Students were then able to address the contestation between what they were expecting from the HEI, and what the HEI expected from them.

References

Akugizibwe, E., & Ahn, J. Y. (2019). Perspectives for effective integration of e-learningtools in university mathematics instructionfor developing countries. *Education and Information Technologies, 2019*(1), 1–15.

Amiel, T., & Reeves, T. C. (2008). Design-based research and educational technology: Rethinking technology and the research agenda. *Educational Technology & Society, 11*(4), 29–40.

Audi, D., & Gouia-Zarrad, R. (2013). A new dimension to teaching mathematics using iPads. *Procedia-Social and Behavioral Sciences, 103*(2013), 51–54.

Aydin, S. (2012). A review of research on Facebook as an educational environment. *Educational Technology Research and Development, 60*(6), 1093–1106.

Bansilal, S. (2015). Exploring student teachers' perceptions of the influence of technology in learning and teaching mathematics. *South African Journal of Education, 35*(4), 1–8.

Berkvens, J. B. Y., van den Akker, J., & Brugman, M. (2014). *Addressing the quality challenge: Reflections on the Post-2015 UNESCO education agenda*. Enschede: Netherlands National Commission for UNESCO.

Bitner, N., & Bitner, J. (2002). Integrating technology into the classroom: Eight keys to success. *Journal of Technology and Teacher Education, 10*(1), 95–100.

Budden, R. (2017). *Exploration of factors that inform curriculum studies students to use e-resources in conducting masters of education dissertations at a south African university*. University of KwaZulu-Natal, Durban: Unpublished Full research.

Cavus, N., Uzunboylu, H., & Ibrahim, D. (2007). Assessing the success rate of students using a learning management system together with a collaborative tool in web-based teaching of programming languages. *Journal of Educational Computing Research, 36*(3), 301–321.

Chaka, J. O., & Govender, I. (2017). Students' perceptions and readiness towards mobile learning in colleges of education: A Nigerian perspective. *South African Journal of Education, 37*(1), 1–12.

Clifford, V., & Montgomery, C. (2017). Designing an internationationalised curriculum for higher education: Embracing the local and the global citizen. *Higher Education Research & Development, 36*(6), 1138–1151.

Cohen, L., Manion, C., & Morrison, K. (2007). *Research methods in education* (6th ed.). New York: Routledge.

Creswell, J. W. (2014). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). California: SAGE Publications, inc..

Czerniewicz, L., & Brown, C. (2014). The habitus and technological practices of rural students: A case study. *South African Journal of Education, 34*(1), 1–14.

De Villiers, M. (2004). Using dynamic geometry to expand mathematics teachers' understanding of proof. *International Journal of Mathematical Education in Science and Technology, 35*(5), 703–724.

Esau, O. (2017). Emancipatory action research. In L. Ramrathan, L. Le Grange & P. Higgs (Eds.), *Education Studies: for Initial Teacher Development* (pp. 444-455). Cape Town: Juta & Company (Pty) LTD.

Fomunyam, K. G. (2016a). *Content and ideology in literature modules taught in a Cameroonian university*. University of KwaZulu-Natal, Durban: Unpublished Full thesis.

Fomunyam, K. G. (2016b). Theorizing student constructions of quality education in a south African University. *Southern African Review of Education, 22*(1), 46–63.

Foucault, M. (2007). *Security, territory, population: Lectures at the Collége de France 1977–1978*. New York: Picador.

Freire, P. (1993). *Pedagogy of the oppressed* (20th ed.). New York: Continuum.

Govender, N., & Khoza, S. B. (2017). Technology in Education for teachers. In L. Ramrathan, L. Le Grange & P. Higgs (Eds.), *Education Studies for Initial Teacher Development* (pp. 66-79). Cape Town: Juta & Company (PTY) limited.

Guba, E. G., & Lincoln, Y. S. (2005). Paradigmatic controversies, contradictions, and emerging confluences. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (3rd ed., pp. 191–216). London: SAGE Publications.

Gur, H. (2009). Trigonometry learning. *New Horizons in Education, 57*(1), 67–80.

Hamilton, L., & Cobert-Whittier, C. (2013). *Using case study in education research*. London: SAGE Publications.

Hwang, W. Y., Su, J. H., Huang, Y. M., & Dong, J. J. (2009). A study of multi-representation of geometry problem solving with virtual Manipulatives and whiteboard system. *Educational Technology & Society, 12*(3), 229–247.

Hyland, A., Kennedy, D., & Ryan, N. (2006). *Writing and using learning outcomes: A practical guide*. European Higher Education Area (EHEA): Bologna.

Keet, A. (2012). Discourse, betrayal, critique. In C. Roux (Ed.), *CRITICAL ISSUES IN THE FUTURE OF LEARNING AND TEACHING, safe spaces: Human rights education in diverse contexts* (Vol. 5, pp. 7–27). Rotterdam: SensePublishers.

Khoza, S. B. (2013). Can they change from being digital immigrants to digital natives? *Progressio, 35*(1), 54–71.

Khoza, S. B. (2017). Master of education students' reflections: Which curriculum reasons are promoted or limited by Skype resources? *Progressio: South African Journal for Open and Distance Learning Practice, 39*(2), 1–19.

Khoza, S. B. (2018). Can teachers' reflections on digital and curriculum resources generate lessons? *Africa Education Review, 1*(2018), 1–16.

Khoza, S. B. (2019). Lecturers' reflections on curricular spider web concepts transformation strategies. In E. N. Ivala & C. L. Scott (Eds.), *Transformation of higher education institutions in post-apartheid South Africa* (Vol. 1, pp. 15–26). New York: Routledge - Taylor & Francis Group.

Khoza, S. B., & Manik, S. (2015). The recognition of 'digital technology refugees' amongst post graduate students in a higher education institution. *Alternation, 17*(2015), 190–208.

Kisaka, S. T. (2018). *An exploration of the use of Moodle in teaching MED students at a University in Kenya*. Durban: University of KwaZulu-Natal.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary issues in technology and teacher education, 9*(1), 60–70.

Lavicza, Z. (2010). Integrating technology into mathematics teaching at the university level. *Mathematics Education, 42*(1), 105–119.

Mabuza, D. C. (2018). *Educators' reflections of the Swaziland junior secondary integrated consumer science curriculum: Towards development of a unique content area*. University of KwaZulu-Natal, Durban: Unpublished Full Thesis.

Makumane, M. A. (2018). *Educators' enactment strategies of the French integrated curriculum: An action research of Lesotho educators*. University of KwaZulu-Natal, Durban: Unpublished Full Thesis.

Mpungose, C. B. (2019a). Is Moodle a platform to decolonise the university curriculum? Lecturers' reflections. *Africa Education Review, 2019*(1), 1–15.

Mpungose, C. B. (2019b). Is Moodle or WhatsApp the preferred e-learning platform at a south African university? First-year students' experiences. *Education and Information Technologies, 2019*(1), 1–15.

Murphy, J. (2008). *The POWER of Your Subconscious Mind*. New York: Prentice Hall Press.

Ndlovu, B. N. (2017). *Exploring teachers' understanding of pedagogic practices in teaching mathematical concepts in grade 1: A case study in south African primary schools*. University of KwaZulu-Natal, Durban: Unpublished Full thesis.

Ngubane-Mokiwa, S. A. (2013). *Information and communication technology as a learning tool: Experiences of students with blindness*. University of South Africa.

Palmiter, J. R. (1991). Effects of computer algebra systems on concept and skill acquisition in calculus. *Journal for Research in Mathematics Education, 22*(2), 151–156.

Pather, R. (2017). *Library spaces in higher education: Exploring academics' understanding*. University of KwaZulu-Natal, Durban: Unpublished Full thesis.

Prensky, M. (2001). Digital natives, digital immigrants part 1. *On the horizon, 9*(5), 1–6.

Prensky, M., & Berry, B. D. (2001). Do they really think differently. *On the horizon, 9*(6), 1–9.

Ramrathan, L. (2017). Educational research: Key concepts. In L. Ramrathan, L. Le Grange & P. Higgs (Eds.), *Education Studies: for Initial Teacher Development* (pp. 403-418). Cape Town: Juta & Company (Pty) LTD.

Samuel, M. A. (2009). *On becoming a Teacher: Life history research and the force-field model of Teacher Development in Dhnupath, R. and Samuel, M.A. (Eds.). Life history research-Epistemology, methodology and representation*. Rotterdam: Sense publishers.

Schwab, K. (2016). *The Fourth Industrial Revolution*. Cologny: World economic forum®.

Shoba, M. E. (2018). *Exploring teachers' experiences of teaching English-speaking skill to second language learners in three KwaNdengezi township primary schools*. University of KwaZulu-Natal, Durban: Unpublished Full Thesis.

Tyler, R. W. (2013). *Basic principles of curriculum and instruction*. Illinois: University of Chicago press.

Umugiraneza, O., & Bansilal, S. (2017). Exploring teachers' practices in teaching mathematics and statistics in KwaZulu-Natal schools. *South African Journal of Education, 37*(2), 1–13.

Waghid, Z., & Waghid, F. (2016). Examining. *Digital Technology for (Higher) Education through Action Research and Critical Discourse Analysis South African Journal of Higher Education, 30*(1), 265–284.

Affiliations

Simon Bheki Khoza[1] · **Audrey Thabile Biyela**[2]

Audrey Thabile Biyela
217060048@stuukznac.onmicrosoft.com; 217060048@stu.ukzn.ac.za;
audreybiyela2014@gmail.com

[1]   Discipline of Curriculum Studies & Educational Technology, School of Education, University of KwaZulu-Natal, Private Bag X03, Ashwood, Durban 3605, South Africa

[2]   Discipline of Curriculum Studies & Mathematics Education, School of Education, University of KwaZulu-Natal, Private Bag X03, Ashwood, Durban 3605, South Africa