The Journal for Transdisciplinary Research in Southern Africa
ISSN: (Online) 2415-2005, (Print) 1817-4434

Use of information and communication technologies in mathematics education lecturers: Implications for preservice teachers

Authors:
Alton Dewa[1]
Nokulunga S. Ndlovu[1]

Affiliations:
[1]Department of Education, Faculty of Humanities, University of the Witwatersrand, Johannesburg, South Africa

Corresponding author:
Nokulunga Ndlovu,
Nokulunga.ndlovu@wits.ac.za

Dates:
Received: 22 Oct. 2021
Accepted: 02 June 2022
Published: 31 Oct. 2022

How to cite this article:
Dewa A, Ndlovu NS. Use of information and communication technologies in mathematics education lecturers: Implications for preservice teachers. J transdiscipl res S Afr. 2022;18(1), a1165. https://doi.org/10.4102/td.v18i1.1165

The availability and use of educational resources in classrooms has increased remarkably; however, preservice teachers graduate from initial teacher education institutions (ITEIs) and join the profession without the skills for teaching in these new learning environments. This qualitative study was conducted in four South African public ITEIs. It is aimed at examining mathematics lecturers' integration of information and communication technologies (ICTs) into teaching and its implications for preservice teachers' readiness to teach in contemporary classrooms. Individual interviews were conducted with 12 mathematics education lecturers and 20 fourth-year students in five focus groups. The findings revealed that whilst the lecturers had some knowledge of how to teach with digital technologies in lecture rooms, they did not model specialised mathematics teaching skills to their students. Informed by activity theory, this study identified institutional gaps in the implementation of digital technologies for teaching. Institutions seemed to view access to technology as sufficient for effective use by lecturers. Initial teacher education institutions should therefore establish and regulate structures that equip and support lecturers with desired ICT pedagogical skills if preservice teachers are to be prepared for the modern classrooms.

Transdisciplinarity Contribution: This research contributes to literature on the use of ICTs in Initial Teacher Education. Although it focuses on Mathematics Education, its findings demonstrate the importance of Professional Development if the Scholarship of Teaching and Learning (SoTL) of lecturers in these institutions will adequately prepare preservice teachers for the modern classroom.

Keywords: ICT pedagogical integration; initial teacher education institutions; mathematics education lecturers; preservice teacher readiness; pedagogic skills; activity theory.

Introduction

Information and communication technologies (ICTs) can be seen as a set of digital technological resources that help in the functioning of 'business processes, scientific research and teaching and learning'[1] through the interfacing of hardware and software, including telecommunications facilities. The COVID-19 pandemic has proven that limited knowledge in the use of these resources can bring the functions of a nation's organs to a halt. Eyes are turned to educational institutions as agents of change, and it therefore behooves teacher educators to prepare preservice teachers for the contemporary classroom,[2,3] where learners can be prepared to operate in a digital world. Several studies indicate that lecturers have low ICT competency levels, resulting in graduates leaving their training institutions inadequately prepared to teach with ICT, which is a recent tool of the trade for the teaching profession.[4,5]

When mathematics lecturers exhibit meaningful use of ICTs in their lecture rooms, preservice teachers can develop the desired cognitive and pedagogic skills they need for their prospective teaching environments.[6] Mathematics curriculum delivery that is divorced from its contextual use (i.e. classroom teaching) in this era is bound to create a gap in the knowledge package that graduates need to be relevant for the contemporary classroom.

The relationship between a preservice teacher and a lecturer can be equated to that of a master and an apprentice. It is a cognitive apprenticeship wherein the master (in this case the mathematics education lecturer) guides the apprentice (the preservice teacher) through modelling and coaching until scaffolds are removed at graduation, when they take new roles as teachers who are ready to use ICTs in their teaching context.[7] Apprenticeship occurs when an expert and a novice socially interact whilst focused on completing a task.[8] This concept should be applied in the teaching of mathematics. Lecturers in mathematics education exhibit limited sound knowledge and teaching abilities while utilising a variety of media and ICT capabilities.[9] Mathematics education lecturers should endeavour to use ICT to mediate or support the learning process in the twenty-first century. ICT holds the possibility of brand-new solutions to the problems that mathematics students face. Mathematics lecturers' success in modelling good teaching practice with ICTs depends on their ability to navigate existing barriers. Information and communication technology integration barriers can be divided into two categories,[10] namely external and internal barriers. External barriers include the availability of computers, level of administrative support and ICT professional development opportunities. Internal barriers are teachers' attitudes and beliefs about what it takes to learn or teach with ICTs. An appropriate ICT professional development programme for lecturers and appropriate support structures can alleviate both barriers.

Educators' lack of pedagogical training results in low ICT competency skills, confidence and thus leads to internal barriers such as negative attitudes towards the use of the digital technologies. Initial teacher education (ITE) lecturers may have suitable educational software, but if preservice teachers have limited access to ICT because of rigid structures of traditional education systems and restrictive curricula barriers, it becomes difficult for them to use ICTs later for educational[11] purposes.

South African mathematics education lecturers are not immune to these barriers. An amalgamation of technology knowledge, content knowledge and pedagogical knowledge contribute as key players in preparing preservice teachers for the effective use of ICTs in the classroom.[12] An inclusion of these knowledge domains in the ITE programme facilitates learning spaces that do not only prepare preservice teachers but compel mathematics education lecturers to enhance their practices through ICT policy and frameworks. It is then that South African mathematics education lecturers can model and teach knowledge and skills needed to promote effective integration of digital technologies in mathematics classrooms.[13]

> Education mathematics lecturers hardly integrate ICT into their lecture rooms. This is because, "South African preservice teacher education in mathematics is still dominated by textbook teaching" (p. 6)[14]. Additionally, they may not have sufficient skill to integrate ICTs in their teaching or they lack a guide to direct them on how to integrate ICT.

Some South African mathematics education lecturers do not implement ICT integration because they prefer to teach without them, as they are doing well without using these technologies.[15] Although South Africa may have national and provincial ICT policies, these do not specify how mathematics teaching should be taught with these digital technologies. There is a gap in policy for initial teacher education institutions (ITEIs) and their instructors, who are expected to prepare preservice teachers for using ICTs for teaching.[16]

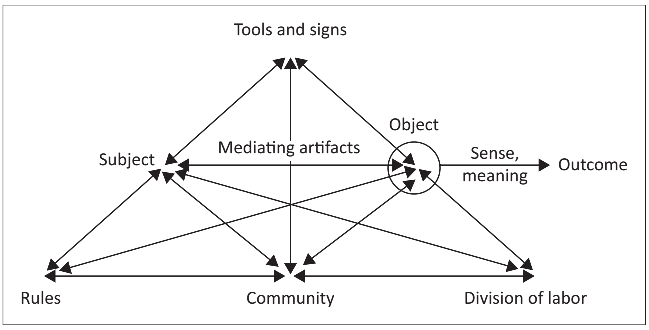
A strategy for the institutionalisation of the use of ICTs in all educational institutions can aid in achieving the goal of preparing preservice teachers, and this should start at the policy level.[17] A South African national ICT policy would serve to provide guidance at the macro level, and if there is a gap in the design and implementation of educational institutional policies at the implementation level, there is a slim chance of the imperatives being realised at the micro level. The institution carries the mandate to establish and infuse the intervention into its culture and operations that provide support necessary for the successful adoption and implementation of ICT use for teaching and learning. The activity theory adopted in this study helps to capture all that may have potential to contribute to and support activities that may lead to a successful preparation of mathematics preservice teachers for ICT use for teaching and learning by their lecturers.

Theoretical framework

Activity theory emphasises that human action is interactive and fundamentally uses tools that are socially situated for mediation in order to achieve set objectives.[18,19] At the heart of the theory is the idea that internal activities, such as thinking, emerge out of practical external activity, and therefore, goal achievement is implemented by individuals who are defined by their cultural context.[20]

The individuals in this study are mathematics education lecturers and preservice teachers, and the cultural context refers to the ITEIs where the activity of teaching and learning is taking place. Fundamentally, 'tools mediate the processes between subject and object; rules mediate the processes between subject and community and division of labour mediates the processes between community and object'.[20] Figure 1 outlines the features of activity theory.

The model is systemic, and all the elements are related to each other as they work towards producing the desired outcome. These elements contain mutual relationships between subject, object and community (presented in the upper part of Table 1), as the stakeholders make decisions that drive the process within the activity with the help of the other constructs, which are enablers such as rules, division of labour, tools and signs and mediating artefacts.[22]



Source: Engeström Y. Expansive learning at work: Toward an activity theoretical reconceptualization. Journal of Education and Work. 2001 Feb 1; 14(1):133-–156. https://doi.org/10.1080/13639080020028747

FIGURE 1: Activity theory.[21]

TABLE 1: Adapted descriptions of constructs in activity theory.

Constructs	Descriptions
Roles or responsibilities	
Community	*University stakeholders* Coordination of mathematics ICT lecturers, students, leadership (head of division, school or faculty), administrators and ICT support providers
Subject	*Mathematics lecturers* Preparation of preservice teachers for the contemporary classroom
Object	*Mathematics education preservice teacher* Exposed to good ICT practices in mathematics teaching
Enablers	
Rules	*University policies* ICT policies related to teaching and learning at university level
Division of labour	*Development of an ICT adoption strategy that involves all stakeholders* Seamless implementation of strategy
Tools and signs	*ICTs* Mathematics application software and ICT multimedia to model and mediate teaching and learning
Outcome	*Students ready to teach in contemporary classrooms* Sufficient preparation of preservice teachers by lecturers

ICT, information and communication technologies.

This article has customised the descriptions of the activity theory constructs in Table 1 in order to contextualise the constructs.

Table 1 shows that the main role of the first three constructs (community, subject and object) is to intentionally create a learning environment that facilitates the achievement of the outcome through the last three constructs (division of labour, tools and signs and outcome).[23] Once equipped with these capabilities, there is a high chance that teacher lecturers can harness ICTs' potential to enhance teaching and learning and thus transfer good practices to the student teachers.

This article aims to examine mathematics education lecturers' use of ICTs to teach and also to determine if it prepares preservice teachers for teaching with these technologies. Understanding why the lecturers use ICTs the way they do may help ITEIs to create integrated strategies that create conducive learning environments that promote the advancement of ITEI lecturers in the use of ICTs and, by so doing, prepare preservice teachers for the contemporary classroom.

The research questions are:

- How does the ICT use of mathematics education lecturers prepare preservice teachers for teaching with these technologies?
- What factors influence the use of ICTs by the mathematics education lecturers?

Research methods and design

This is a case study because it 'involves an investigation into a present-day phenomenon occurring within a bounded, real-world situation, adding that contextual factors largely determine the nature of the situation within which the phenomenon manifests'.[24] This study uses qualitative research methods to collect data through interviews with 12 mathematics education lecturers and 20 further education and training BEd fourth-year mathematics major preservice teachers in South African schools, which were utilised as the research tool. Twelve mathematics education lecturers were purposively sampled whilst 20 BEd fourth-year mathematics major preservice teachers were chosen at random from the mathematics head of department's list. A list of all the population of students in each participating institution was compiled, and each one was assigned a unique number (e.g. if there are *n* students, then they will be numbered from 1 to *n*). Random number generator software was used to select random samples from this population. Random number generator software was preferred because it eliminates the need for human intervention in the sample generation process. The purpose of the interview was to find out how ICT is used in the lecture rooms from a pedagogical standpoint.[19] This enabled the researchers to gather and explore various pieces of information on how preservice teachers majoring in mathematics are prepared to integrate ICTs in their future teaching careers. The identification of themes supported alignment with activity theory constructs to help determine how mathematics education lecturers use ICTs. Students' responses were used to validate lecturer perceptions on the factors that influenced their use of ICTs and to illuminate the implications on their ICT readiness thereof.

Permission letters were sought from the ITEIs, and informed consent was given by the participants (lecturers and students) in this study. Mathematics education lecturers and preservice teachers from the ITEIs were provided with details of the study and were made aware that participation was voluntary before they volunteered their consent to participate. Ethical clearance was obtained from the university that gave consent for this study.

Ethical considerations

The study received informed consent from the participants prior to conducting the study. Both authors of this manuscript have given the journal consent to publish this article. Ethical clearance was granted by the University of the Witwatersrand Ethics Committee in 2017 (ref. no. 2017ECE031D). To ensure that participants remain anonymous, letters of the alphabet were used for the 4 institutions (A - D). L was used for lecturers, S for students and M or F represented gender.

Results

There is a low uptake of digital technologies in teaching by the mathematics education lecturers. Their pedagogical integration of ICTs seems to be influenced by both external and internal constraints. The students' responses in the focus groups confirmed the lecturers' perceptions about their ICT usage and how the institutions contribute to the constraints. The data from both lecturers and students demonstrate that failure to achieve the 'activity' outcome (preservice teachers' readiness to use ICTs to teach) is a result of attributes related to the subject (lecturer) and the community (institution). These two constructs determine the extent to which the other constructs contribute to the activity. We begin with the subject in the activity.

Subject: Mathematics education lecturers' use of information and communication technologies

The espoused practices of all 12 participating mathematics education lecturers concurred on the importance of integrating ICTs into mathematics curricula. However, most of them only used presentation software to present content without engaging students with digital technologies for different purposes during the lectures. Students in all four institutions agreed that lecturers still teach 'using the traditional way', with some using chalk and talk (Institute A, S1, F; Institute A S3; Institute B, S1, M; Institute D, S1, M). This reflects students' conception of ICT integration that excludes the use of nondigital technologies, which is associated with the smart classroom where modern technology is mainly used in the classroom to teach. This research considers the use of smart classrooms as a higher level of utilising ICTs for teaching and learning, as it means that more advanced technology is used in the classroom. However, the level of cognitive engagement in its use depends on how the teacher engages the technology.[25]

Use of information and communication technologies as a mediation tool

Lecturers also assigned value to their use of applications for enabling multimodality that include the use of text, images and videos that enhance their explanations. One out of the 12 lecturers used a subject-specific software called GeoGebra and explained his use of the software as follows:

> 'Information and communication technologies [*are*] used as a resource; for example, in geometry, I will show them with software [*GeoGebra*] how to do graphing, again in trigonometry, teaching the transformation of the graph, and I will show them with software if you change the amplitude or if I look at minimum and maximum values and how to change the degrees at the end using the software. It is a tool that mediates learning and consolidates learning, particularly if the concept has been taught using the usual method of teaching.' (Institution A, L3, M)

In the context of activity theory, the lecturer uses presentation software to present content- and subject-specific software (GeoGebra) as a mediation tool. Although this type of usage does not necessarily translate to a demonstration of teaching learners in schools (modelling), preservice teachers are exposed to smart ways of learning and resolving geometry problems with digital technology. The knowledge that students gain as they learn influences how they teach in their classrooms.[26] Therefore, students in such lecture rooms have a high chance of using the same or similar software when they teach in schools.

As was the case with most lecturers in this study, their focus as they teach preservice teachers is to create learning experiences through ICTs to promote cognitive engagement with content, as one of the lecturers indicated:

> '[…*H*]owever, I am of the opinion that ICT acts as a mediating tool that enables student teachers to think critically and understand the subject matter. Technically, that is how I use ICT.' (Institution B, L1, F)

Whilst there is no elaboration of how ICT is used to promote critical thinking, it is evident that the *tool's* use is confined to the lecturer mediating content and not necessarily and explicitly the way it should be taught in the classroom.

Use of information and communication technologies as a tool to supplement teaching and learning

Some of the lecturers simply refer students to mathematical software sites and other online tools such as YouTube videos to supplement their teaching. Over time, as preservice teachers visit the referred sites and other digital resources, they get accustomed to using the Internet to research and extend their learning. Unintentionally, this activity contributes to the achievement of the 'outcome' as students interact with the content through the technology. The benefits are twofold, and they are: (1) skills in navigating different sites and technology and (2) extension of their understanding of the concepts.

Inadvertently, the lecturers inculcate a culture of research on students as they learn to deal with their mathematical problems through exposure to various methods and explanations available on the Internet. Whilst the lecturers' strategy could be considered as pushing their responsibility onto others (online content presenters), this approach can be seen as encouraging future teachers to become researchers and is a desirable attribute. In this case, cognitive apprenticeship happens not through modelling but through discovery as the students expose themselves to online resources.

Preservice teachers' perceptions on the type of information and communication technologies use by lecturers

Students feel that lecturers' limited use of ICTs in their lectures prepares them inadequately to teach in modern mathematics classrooms. For instance, a student expressed discomfort in going into classrooms with students who are more familiar with ICTs than him, as he added:

> 'So as much as they give us access to some resources here on campus, for the fact that the learners are already being taught using ICT, when we qualify, we will be expected to be at a higher level compared with the learners so that we can teach effectively. So with us leaning on ourselves here, I don't think it will be enough for us to be able to adjust into the system of technology because they [*the learners*] are already immersed in it.' (Institution D, S1, M)

The student's concern is valid, because interactive whiteboards have been installed in Gauteng schools (the province where the four participating institutions are located), and yet the preservice teachers' knowledge of using the ICT in teaching and learning is not adequate according to a female student from institution A. In his response, student 1 at institution D stated that he has no option but to imitate the teaching methods that have been modelled to him by his lecturers in his future teaching classroom, because he is not familiar with pedagogical integrating ICTs in his subject. Nevertheless, this student acknowledged that doing so makes him appear irrelevant to a digitally immersed 21st century classroom.

In addition to the given reality, preservice teachers in this study expressed their dissatisfaction with the lack of modelling on how to use these tools for teaching mathematics. A student stated:

> '[…*T*]hey do tell you that you can use Phantom but don't show you how to. So you have to go and learn it yourself. So I am going to consume more time learning how to use a software than actually using it. My level of confidence when teaching when I am using that software is not going to be high; it's going to be low, because I might be scared that what if I do something wrong? The kids will laugh at me.' (Institution A, S1, F)

Preservice teachers' confidence is presented as a disabler in the adoption of ICTs for use in schools, and this reflects on the disadvantage of lecturers not creating opportunities for their students to use digital technology in the lecture rooms as they learn and as they play teaching roles in their training.[2]

There seems to be a disjuncture in the students' expectations of their lecturers' use of technology and what they experience in their lecture rooms. Their lecturers' use of ICTs is aimed at enhancing students' understanding and developing desired thinking skills to the exclusion of intentionally modelling and giving them opportunities to use them for teaching. In the absence of institutional policies (rules) in the scope of this study, it would be difficult to know what was expected of them. However, without an ICT adoption and implementation strategy (division of labour) it becomes difficult for lecturers' (subject) activities to align with the achievement of the outcome (students' preparedness for ICT use in the classroom). In other words, preservice teachers' incapacities are a reflection on the extent to which the institution stakeholders (communities) fail to carry out their mandate of ensuring that they support mathematics lecturers within the educating ecosystem.

Community: Institutional efforts

All participating institutions have adopted a learning management system (LMS) that gives lecturers and students access to more digital tools that can be used for teaching and learning. There is a need to know if lecturers have the capacity to utilise the tools in a way that helps achieve intended learner and learning goals.

Lecturer utilisation of available information and communication technologies for teaching and learning

Whilst lecturers may have access to different software, they disclosed that their institutions have not done enough to prepare them for integrating it into the teaching and learning of mathematics, as indicated in the following extracts:

> 'We find it difficult to use software, because we do not know how to use the application.' (Institution C, L2, M)

> 'Our university has never organised a training workshop for such software. At the same time, we are encouraged to use such software when teaching topics such as geometry, trigonometry and so on.' Institution D, L3, M)

In addition, some of these lecturers have the software, but because they do not know how it works, they do not use it. The institutions seem to assume that once lecturers have the software, they will automatically use it.

The fluidity of the tool complicates the situation. The ever-evolving developments in software make it difficult to adopt and adapt to using the technology without regular training. Unless lecturers are trained on how (and when) to use mathematical software applications to teach various concepts, they will shun their usage and the relationship between the subject and the tool is therefore compromised in the context of the activity outcome.

In the absence of professional development, professional learning communities could be an alternative, as lecturers can support each other in their endeavour to use digital technologies for teaching and learning. A lecturer elaborated on this as follows:

> 'We do not have knowledge-sharing committees here. We definitely need the platforms [*and*] forums to share ideas. In fact, we have asked one of the lecturers to do that for the department. The identified lecturer has volunteered to train all mathematics teacher educators. Unfortunately, the training kept on being postponed, and to date we have not been trained.' (Institution B, L2, F)

Lecturers who possess mathematical software knowledge and skills can share this knowledge with their colleagues at their ITEI and at other ITEIs. These professional learning communities can work together to ensure there is consistent sharing of resources and strategies regarding how to infuse these technologies at the subject level, and this would alleviate pressure (as described by lecturer 1 from institution C) on the limited technical support that lecturers may have in their divisions.

The fear that some mathematics education lecturers expressed is related to lack of confidence that can be alleviated by training as expressed by a lecturer from institution B. As a result of the lecturers' frustration with technical challenges, seven participating mathematics education lecturers are not keen on using ICTs in their teaching. They do not believe it adds value to their teaching or learning. In addition, some still do not perceive ICTs as useful in teaching mathematics. One lecturer from institution B, for instance, believes that mathematics' subject structure is not compatible with the use of ICTs, an argument that is described as a code clash between the two.[23] Thus, the lecturer made the following remark:

> 'Many people believe mathematics is an abstract subject; it's not a human subject. Technology is seen as associated with human being doing something. It's a practical subject, yet mathematics is seen as abstract. That is a reason why it cannot be taught using technology.' (Institution B, L1, F)

This is to be expected if the organisation introduces innovations without instituting change management programmes that can help address misconceptions and provide guidelines on the implementation processes to ensure the lecturer, who is the agent of change or the main actor in this context, is prepared to play his or her role efficiently in the activity.

Preservice teachers' perceptions on their access to information and communication technologies

Whilst preservice teachers may have access to the standard technology offered by their institutions, they only benefit from its use (e.g. LMSs) as recipients and not as instructors. One student described their participation as follows:

> 'As preservice teachers, we access Sakai to view teaching materials uploaded in preparation for the lecture or for further reading. Our lecturers also use this platform to communicate and give feedback for the exercises we would have written. One lecturer used to set multiple choice questions on Sakai and instructed us to write it on Sakai. The advantage it had was that it could mark the exercise and provide the feedback instantly.' (Institution A, S1, F)

This student values this software for communication and automated assessments. Lecturers use the top-down approach to engage these affordances, as they use the LMS for giving instruction, content and assessment. Whilst institutionalising this type of software by the lecturers and students has potential to improve the efficiency of the activity within this learning context, its value in preparing preservice teachers for use of the same tool is not present. Being a recipient in the activity does not necessarily give one an idea of how the back-end functions, once one shifts roles and becomes the instructor in the learning environment. There is therefore a gap between the object and the desired outcome, as expressed by a student, who added:

> 'We have never had a lesson on how to teach mathematics using slides or how to teach mathematics using technology or anything like that.' (Institution B, S1, M)

This student alluded to the lecturers' interpretations of their use of the ICTs that is limited to their use as mediation tools. There is, therefore, a gap in the application of the cognitive apprenticeship model[6] that should lead to the institution's activity outcome as envisaged in this study.

It is evident that the two main constructs (the community and the subject) hold the reins in the activity of preparing mathematics preservice teachers for teaching in modern classrooms. Engagement with data suggests that whilst lecturers as subjects in the activity might be directly involved in preparing preservice teachers, they seem to limit their role to delivering subject matter. Students in these institutions are expected to graduate with content knowledge, and that could be the reason why lecturers are committed to ensuring they understand mathematical concepts before they leave the ITEIs. It is expected of lecturers to demonstrate, to students, how to teach mathematics in a clear and understandable manner. Instructions on how to give courses and convey knowledge using ICTs should be part of the strategy. By employing this strategy, they will equip students with tools they can utilize when they leave their training institutions. As a result of external and internal barriers,[15] lecturers do not adequately prepare mathematics preservice teachers for teaching with ICTs.

Discussion

There is evidence that the gaps identified in the functions of the institution's activity compromise the seamless operation that should make certain that all its organs work efficiently to ensure the achievement of the outcome. In the context of this study, the community seems to view the activity as linear. Once lecturers as key players have access to different digital tools, they will use them effectively as they prepare preservice teachers for their careers, and this includes how to use them for teaching. Such a view only engages the subject, the tool and the object, with the hope that the outcome will be achieved. As a result, the subject is not capacitated and supported to play its role efficiently.

Without capacitation, mathematics lecturers are not inclined to perceive ICTs as easy to use and useful in the teaching and learning of mathematics.[27] Although the tools and signs may be present, with a weak subject in the activity system, it becomes critical to identify support mechanisms that can empower and sustain it if the outcome is to be achieved.

Lecturers in this study show that they have some knowledge on the use of ICTs in a learning context; however, they assign its worth to mediation of the content they teach. Beyond that, they refer students to online resources. Whilst this could be viewed as working towards achieving the desired outcome, students perceive this as futile in preparing them for mathematics classrooms with digital technology. Preservice teachers are therefore not adequately prepared for ICT use in schools,[18] even though they have access to the technologies.

Whilst students may be exposed to the use of these technologies, they need to be intentionally taught how to use them as mediation tools in the mathematics classroom.[24] They need to be made aware of the principles that need to be followed when selecting the tools and how to integrate them into mathematics teaching. According to this study, the outcomes for not doing so are as follows:

- ICT use is not (intentionally) modelled by lecturers
- Students are not exposed to the knowledge, skills and tools they need to teach mathematics in the classroom and they are therefore not confident to use them
- Students see themselves using traditional ways of teaching that do not integrate ICTs into teaching and learning.

With this outcome, these students are expected to teach the way they were taught[25] and thus perpetuate the low ICT uptake in mathematical instruction[1] in schools.

Participating institutions seem to have contributed to eliminating external barriers by giving access to both hardware and software as teaching and learning tools, but because they do not include the rest of the package, which is support and professional development,[18] their activity is insufficient to afford the desired outcome. There is an indication that the omission of rules and division of labour renders the credibility of the activity futile.

Data in this study reveal that if ITEI policies do not address the what, how and when of using ICTs,[6] and there are no monitoring mechanisms that can be drawn from the division of labour, the tools that the community provides can easily become a white elephant as both the subject (mathematics lecturer) and the object (preservice teachers) do not utilise them to sufficiently achieve their obligation. In addition to providing preservice teachers with content, lecturers should expose them to the pedagogical skills they need to operate what is becoming the 'tool of the trade'. It makes the activity within the institution effective in ensuring that the outcome is achieved, as mathematics students would be ready to teach in their prospective classrooms.

Conclusion

ITEIs of the participants in this study have limited their activity to providing access to the tools required for the achievement of the outcome. As there is no indication of instituted policies (rules) that stipulate guidelines that can be used to develop ICT strategies to be applied by stakeholders (division of labour), effective and efficient utilisation of available signs and tools by mathematics lecturers (subjects) and students (objects) is compromised.

The findings of this study highlight the critical role that institutions need to play in ensuring that they develop strategies that sustain the intended running of the activity that should ensure that lecturers are prepared to model and intentionally prepare preservice teachers for the modern classroom.

Acknowledgements

The authors would like to acknowledge the 12 mathematics education lecturers and the 20 fourth-year students from the four universities who made this study possible. The University of the Witwatersrand is acknowledged for affording this study by granting it ethics clearance.

Competing interest

The authors declare that no competing interest exists.

Authors' contributions

The data used in this study were collected by A.D. The conception, design and writing were a collaboration of the two authors. Sections were allocated as follows: A.D. wrote the first draft of the article; N.S.N. wrote the abstract and refined the paper by adding to the literature review and the findings. The summary of the findings were performed by N.S.N. N.S.N. used her funding from the University of Witwatersrand for the article's editing. Otherwise, the research was not funded.

Funding information

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Data availability

Data are available from A.D. on request.

Disclaimer

The views and opinions expressed in this statement are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors.

References

1. França RP, Iano Y, Monteiro AC, Arthur R. Improvement of the transmission of information for ICT techniques through CBEDE methodology. In: Ghavifer S, Athirah W, Rosdy W, editors. Utilizing educational data mining techniques for improved learning: Emerging research and opportunities. Hershey PA: IGI Global, 2020; p. 13–34.
2. Tondeur J, Aesaert K, Pynoo B, Van Braak J, Fraeyman N, Erstad O. Developing a validated instrument to measure preservice teachers' ICT competencies: Meeting the demands of the 21st century. Br J Educ Technol. 2017;48(2):462–472. https://doi.org/10.1111/bjet.12380
3. Department of Education. White paper on e-education. Pretoria: Government Gazette; 2004.
4. Chitiyo R, Harmon SW. An analysis of the integration of instructional technology in pre-service teacher education in Zimbabwe. Educ Technol Res Dev. 2009;57(6):807–830. https://doi.org/10.1007/s11423-009-9136-7
5. Price J, Roth M, Shott S, Andrews S. Preparing pre-service teachers: A faculty review strategy. In: Society for information technology & teacher education international conference; 2012 Mar 5. Waynesville, NC: Association for the Advancement of Computing in Education (AACE); 2012. p. 2068–2076.
6. UNESCO. Information and communication technologies in teacher education. New York, NY: UNESCO; 2002.
7. Lave J, Wenger E. Situated learning: Legitimate peripheral participation. London: Cambridge University Press; 1991.
8. Dennen VP, editor. Virtual professional development and informal learning via social networks. Florida, FL: IGI Global; 2012.
9. Hardman J, Dlamini R, Dumas C, et al. Teaching with information and communication technology (ICT). Cape Town: Oxford University Press; 2018.
10. Ertmer PA, Paul A, Molly L, Eva R, Denise W. Examining teachers' beliefs about the role of technology in the elementary classroom. J Res Comput Educ. 1999;32(1):54–72. https://doi.org/10.1080/08886504.1999.10782269
11. Zaldívar-Colado A, Alvarado-Vázquez RI, Rubio-Patrón DE. Evaluation of using mathematics educational software for the learning of first-year primary school students. Educ Sci. 2017;7(4):79. https://doi.org/10.3390/educsci7040079
12. Mishra P, Koehler MJ. Technological pedagogical content knowledge: A framework for teacher knowledge. Teach Coll Rec. 2006;108(6):1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x
13. McCulloch AW, Hollebrands K, Lee H, Harrison T, Mutlu A. Factors that influence secondary mathematics teachers' integration of technology in mathematics lessons. Comput Educ. 2018;123(4):26–40. https://doi.org/10.1016/j.compedu.2018.04.008
14. Dewa A. Stocktaking to support information and communication technology integration into mathematics teaching in initial teacher education [doctoral dissertation]. Johannesburg: University of the Witwatersrand, Faculty of Humanities, School of Education; 2019.
15. Makonye JP. Integrating electronic technologies in mathematics teaching and learning. A case study of the University of the Witwatersrand, South Africa. In: Maringe F, Ojo E, editors. Sustainable transformation in African higher education. Rotterdam: Sense Publishers; 2017; p. 203–214.
16. MRTEQ. National Qualifications Framework Act, 2008 (Act No. 67 of 2008). Volume 596. Pretoria: Department of Higher Education and Training; 2015.
17. Jaffer S, Ng'ambi D, Czerniewicz L. The role of ICTs in higher education in South Africa: One strategy for addressing teaching and learning challenges. Int J Educ Dev Using ICT. 2007;3(4):131–142.
18. Cole M, Engeström Y. A cultural-historical approach to distributed cognition. In: Salomon G, editors. Distributed cognitions: Psychological and educational considerations. Cambridge: Cambridge University Press, 1993; p. 1–46.
19. Engeström Y. Activity theory and individual and social transformation. In: Engestrom Y, Miettinen R, Punamaki RL, editors. Perspectives on activity theory. Cambridge: Cambridge University Press, 1999; p. 19–38.
20. Rizzo A. Activity centred professional development and teachers' take-up of ICT. In: Proceedings of the 3.1 and 3.3 working groups conference on International

federation for information processing. Melbourne: ICT and the teacher of the future. Volume 23; 2003 Jan 1; p. 105–108.

21. Engeström Y. Expansive learning at work: Toward an activity theoretical reconceptualization. J Educ Work. 2001;14(1):133–156. https://doi.org/10.1080/13639080020028747
22. Kuutti K. Activity theory as a potential framework for human-computer interaction research. In: Nardi B, editor. Context and consciousness: Activity theory and human-computer interaction. Cambridge: MIT Press; 1996, p. 17–44.
23. Howard S, Maton KA. Theorising knowledge practices: A missing piece of the educational technology puzzle. Res Learn Technol. 2011;19(3):191–206. https://doi.org/10.1080/21567069
24. Jarzabkowski P, Wolf C. An activity-theory approach to strategy as practice. In: Golsorkhi D, Rouleau L, Seidl D, Vaara E, editors. Cambridge handbook of strategy as practice. Cambridge: Cambridge University Press, 2010; p. 127–140.
25. Oleson A, Hora MT. Teaching the way they were taught? Revisiting the sources of teaching knowledge and the role of prior experience in shaping faculty teaching practices. High Educ. 2014;68(1):29–45. https://doi.org/10.1177/0047117814552140
26. Yin KR. Case study research design and methods. Thousand Oaks, CA: Sage; 2014.
27. Freeman D, Johnson KE. Comments on Robert Yates and Dennis Muchisky's 'On reconceptualizing teacher education'. Readers react... Common misconceptions about the quiet revolution. TESOL Q. 2004;38(1):119–127. https://doi.org/10.2307/3588261