Rapid research on the use of ICT in education RFP-15/1116

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Acronyms and Abbreviations

CPTD	**Continuous Professional Development of Teachers**
DBE	**Department of Basic Education**
DoE	**Department of Education**
DST	**Department of Science and Technology**
ETD	**Education, Training and Development (sector)**
HSRC	**Human Sciences Research Council**
IPET	**Initial Professional Development of Teachers**
LTSM	**Learning and Teaching Support Materials**
NECT	**National Education Collaborations Trust**
NIMB	**Notions of learning, ICT in education, Model for learning design, and Bloom's modified taxonomy framework**
RPL	**Recognition of Prior Learning**
Saide	**South African Institute for Distance Education**
SACE	**South African Council of Educators**
SAQA	**South African Qualifications Authority**
SETA	**Sector Education and Training Authority**
SITES	**Second International Technology in Education Study**
TED	**Teacher Education Development**
TPACK	**Technological Pedagogical Content Knowledge**

Executive summary

This desktop research is about understanding the roles Information and Communication Technologies play in education to support the Department of Basic Education's Big Fasts Results (BFR) methodological investigation known as Operation Phakisa. A number of principles underpin this research: Teachers are more important to teaching and learning than is technology; appropriate pedagogical uses of technology enhance teaching, learning, assessment, management and professional development activities; and it is a responsibility of all sectors of society to support the development of ICT-literate citizens. Against the background of the role that ICT plays in the current education system, the research identifies challenges; develops a model to better understand ways in which technology is used in teaching and learning; uses the model to evaluate a number of reports that investigate the use of ICT in teaching and learning over the past five years; identified successful uses of ICT in education; discusses professional development requirement; and presents strategies to support the use of educational technologies in education.

Exploring the challenges associated with the use of ICT in education the research identified that a well-funded, managed and supported school ICT environment is the foundation to support teaching and learning with technology; management at the educational micro-, macro- and meso-levels is required to maximise the use of ICT aligned with national and local policies; and the development of attitudes, skill and knowledge (both technical and pedagogical) of pre- and in-service teachers is a prerequisite for successful use of technology in the classroom.

The framework, called NIMB (pronounced nimble), consisting of notions of learning (acquisition, participation and contribution), use of ICT in education (instructive, cognitive, mediative), and models for learning design (reproductive, interactive, conversational and transformative) evaluated teaching and learning outcomes (Bloom's modified taxonomy: remember, understand, apply, evaluate and create). The independent variable ICT in education mediated the contribution of the models for learning design variable and is, therefore, an important factor contributing to the development of higher order thinking objectives, such as creativity. Evaluations of international practices predominantly use a participatory approach, which made use of ICT to foster all forms of thinking skills and objectives ranging from remembering to creation clustered around the notions of using technology as a cognitive tool. The most used models aligned with interactive and conversational approaches. Drill-and-practice ICT tools support memorisation of information and development of skills. However, ICT used to mediate learning fosters the development of higher order skills required to be creative.

Successful practice, illustrated the use of participatory approaches, supporting outcomes ranging from remembering to creation with technology use as a cognitive or mediative tool. Some examples of drill-and-practice illustrate that this approach work well in the development of skills.

Best practice associated with professional development of teachers posited that: teachers need time to master skills required to learn technology integration strategies and make learn to support their students; sharing among teachers allow teachers to take ownership of the technology and develop confidence; choices of technology needs to be affordable, free, and easy to access; use of technology literacy programme can support the development of technical skills; support from more knowledgeable colleagues and leaders is helpful; understanding the alignment between classroom activities and standards is vital; an

appropriate technology integration framework should include technology skill development and the pedagogical use of technology; a virtual learning community where teachers can share their successes and challenges provides good support; scaffolded professional development opportunities should be provided for using technology as a cognitive tool; and that templates should be provided to help teachers organise their use and development of cognitive ICT tools.

The alignment of the Operation Phakisa streams, the UNESCO ICT-CFT and the NIMB frameworks creates a comprehensive model to structure the strategic objectives discussion. The principles identified by this research are used to highlight important concepts and findings of the research. Objectives for the macro-, meso- and micro-levels of the education system are given for each element of the ICT-CFT-NIMB, namely: vision, policy and planning; professional development; curriculum content; assessment; ICT and connectivity; and management and systems.

Introduction

While this research is about understanding the roles Information and Communication Technologies (ICTs) can play in education, the work presented here includes the identification of the priority needs and the process associated in formulating practice and policy development for the Department of Basic Education's Big Fasts Results (BFR) methodological investigation known as Operation Phakisa for the. It is well documented that educational ICT can play important roles in teaching, learning, assessment, management and professional development, technology in itself supports skills development but can never supplant the importance of a teacher. Moreover, pedagogical approaches to the use of ICT in education are more important than the technology itself – educational technology is viewed as a tool to enhance teaching, learning, assessment, management and professional development. ICT literacy is a pre-requisite to work in a knowledge society. Therefore, the primary principles that are embedded in this research include:

1.1. Teachers are more important to teaching and learning than is technology.

1.2. Appropriate pedagogical uses of technology enhance teaching, learning, assessment, management and professional development activities.

1.3. It is a responsibility of all sectors of society to support the development of ICT-literate citizens.

It is understood that these globally attested-to principles are in accordance with those stakeholders interested in this research. The objectives for the project, as described by the Terms of Reference, are given below. Thereafter, a model to support systemic change, guide the investigation and support the objectives, is highlighted.

Objectives and scope of the project

The objectives stated in the Terms of Reference for this "Rapid research on the use of ICT in education" (RFP-15/1116) include:

1. What has been documented, successes and failures of using ICT in education, in South Africa and internationally, i.e. what is the importance of using ICT in education, and what are barriers at school level and at institutional level?
2. What are the requirements for effective implementation for ICT in education and what the roles are of different stakeholders involved (both public and private) i.e. What needs to be prioritised before implementation? What should be avoided that would hinder effective and efficient implementation?
3. What knowledge, skills and attitudes needed by teachers for a successful implementation of ICT at schools?
4. Do local and international higher education institutions incorporate the use of ICT in education when designing curriculum for initial and continuous teacher development?
5. What has been the impact of using ICT in various subjects particularly, Maths Science and Technology (MST) subjects?

In meeting the above objectives, where applicable reference must be made to the five dimensions of the Phakisa Lab, namely: management systems, curriculum content, teacher professional development, ICT infrastructure and connectivity.

Further more, the Terms of Reference required the report to include the following sections:

1. Context of ICT in education and systemic barriers / challenges to implementation.
2. Global scan of successful ICT initiatives.
3. Validated design principles (synthesized list of strategic guidelines that will be a foundation for generating ideas throughout the Lab process).
4. Lessons learned in implemented ICT initiatives in education (locally and globally).

Within each sub-section, where applicable, reference must be made to the five dimensions of the Phakisa Lab, as listed above. These sections are highlighted as part of the narrative on this research.

In order to systematically explore the role that ICT does, and might, play in education, it is necessary to frame the research within an appropriate framework to support a systematic and systemic change to a complex system.

About systemic change

Ways to explore complex systems, such as education, is often difficult because they can be examined from multiple perspectives (Hmelo, Holton & Kolodner, 2000) and require consensus and collective planning with many stakeholders (Innes & Booher, 1999). Reed (2006) proposed a research approach to identify the principle constraints related to rural poverty and improved natural resource management that operates at the micro-, meso- and macro-levels. This approach, referred to as the 3xM Approach and is based on four principles:

1. To build effective interventions it is necessary to undertake analysis across the micro-, meso- and macro-levels[1];
2. Obstacles need to be first removed at the local level so as to improve management and thereby improve the well-being of all participants;
3. Align policies and institutional activities at the meso- and macro-levels in order to allow local initiatives to flourish; and
4. Build communities at all levels that are representative of all stakeholders.

In addition, this model includes both analytical and intervention approaches. The analytical steps of the 3xM Approach includes: analysing the problems at the local micro-level; analysing the influences of meso-level institutions; establishing linkages to macro- and national institutions; and interpreting the results. Thereafter the intervention component of the 3xM Approach is undertaken and includes four steps: translating the analysis into intervention plans; organising direct interventions at local level; influencing meso- and sub-national institutional arrangements; and Influencing national level policies and institutions.

Therefore, the research undertake on the use of ICT in education includes analysis and intervention phases. The analysis phase includes:

- The context of the use of education ICT in South Africa;
- Implementation barriers;
- Development and application of a model to determine design principles, international trends and successful approaches for the use of ICTs in teaching and learning;
- Approaches to teacher professional development aligned to international trends.

With respect to the intervention phase, the research will highlight findings and suggest strategies to support the use of ICTs in education.

[1] This research defines the micro-level to include all the components at the school level: management members, governing

Materials and methods

Research data was collected from a number of sources, including:

- Reference lists and pertinent reports from the Department of Basic Education;
- Identification of relevant research papers from 2010 to 2015 using Google Scholar with keywords related to ICT, education, teaching and professional development;
- Saide resources; and
- Researchers' personal research archives.

A total of 222 research papers and reports were collected. The majority of the papers were scanned for the relevant information and recorded in a database. Those papers that included reported the uses of ICT to influence educational outcomes were rated using a framework developed for this project (see below).

The context of the study

Towards a holistic understanding of effective use of ICT

Much has been written about the promise that ICT holds for invigorating economies and societies through providing access to essential services, enhancing connectivity, enabling employment opportunities, improving education (Kremer, Brannen & Glennerster, 2013) and being the fuel for innovation (Noor-Ul-Amin, 2013; Ponelis & Holmner, 2015). The rapid development of technology faster connectivity speeds, enhanced mobile technologies with affordable sophisticated devices, cloud computing along with the prolific production of open education resources provides many opportunities to exploit the potential of ICT to transform education (JISC 2011). In developed economies with low student to computer ratios, descriptions of innovative teaching practices are published yearly in documents such as the New Media Consortium Horizon reports (Johnson, 2014), the Intel Transforming Education for the Next Generation Guide (n.d.) and the EduSummit report (Voogt, Knezek & Searson, 2014).

However, despite the promise of ICT in improving education, the evidence of success is mixed (Fairlie & Robinson, 2013; Cristia, Cueto, Ibarrarán, Santiago & Severín, 2012; Spietsma, 2012 as cited in UNESCO, 2015). Studies underline the importance of carefully considering the ecosystem in which ICT is implemented. Otherwise ICT can increase inequality. In addition it is asserted that the "technology should serve, rather than drive, education strategies" (UNESCO, 2015, p. 38). Key findings from the eLearning Africa 2012 survey (Isaacs & Hollow, 2012) identify the following factors that impact on the eLearning sector: lack of bandwidth, access to appropriate content, government policy as the most important change agents, and improving the quality of teaching as the top motivation for using ICT.

The latest global ICT report (Dutta, Geiger & Lanvin, 2015), which provides a comprehensive country-based assessment of networked readiness, highlights the fact that the ICT revolution appears to have benefited mostly the wealthier countries with 61% of the world's population still not being connected despite expanding Internet access. Moreover it alludes to the complex causal relationships within the ICT landscape that impact upon socio-economic performance and underscores this effect as the primary concern, on which all efforts to use technology effectively should be focused. Interestingly the report describes a necessary shift in emphasis from ensuring mere access as a key to ICT to a concern for how to make appropriate use of ICT in order to "improve business innovation, governance, citizens' political participation, and social cohesion". The report is therefore significant in moving away from mere enthusiasm for ICT use to discussion of effective ICT use (Leaning, 2005, p. 4).

The Council on Higher Education study reviewing the ICT landscape in higher education (Czerniewicz, 2006) adopted a similar lens in reviewing the current state of play of ICT use in the South African Higher Education landscape. The study found that "context" plays a significant role in determining how ICT are adopted. The extent to which it impacts teaching and learning is determined largely by the broader social and educational contexts of each specific institution. Ramah (2015) also supports the idea that context and conceptualization affect learning.

The importance of a holistic understanding of ICT use is evident also in the ranking of countries in terms of ICT readiness. In the recent global ICT report (Dutta, Geiger & Lanvin, 2015) South Africa is placed five notches below its former 70th place out of 143 countries globally. In terms of network readiness, it is now ranked third in Africa (75), below Mauritius (45) and Seychelles (74). South Africa has a high rating in the Environment sub-index (31), but it falls down in terms of the overall market conditions and regulatory environment conducive to supporting entrepreneurship, innovation and ICT development. This shows the importance of *readiness* (the infrastructure as well as the skills required to leverage ICT optimally), and of *usage (*the extent of ICT adoption by government,

business and individuals) in ensuring that ICT can meaningfully impact on and transform economies and societies.

Clearly South Africa has made significant strides in its policy environment as attested by its high ranking in the Environment sub-index mentioned above. There are a number of policy documents referring to the use of ICT in education. These include:

- National Education Policy Act (27/1996): The National Policy Framework for Teacher Education and Development in South Africa[2].
- White Paper 7 on E-education (1869/2004): Transforming Learning and Teaching through Information and Communication Technologies (ICT)[3].
- Action Plan to 2019. Towards the realisation of Schooling 2030. Taking forward South Africa's. National Development Plan 2030[4].
- National Integrated ICT Policy Green Paper[5]

These documents provide for the deployment of ICT to every school in SA, a full integration of ICT in the curricula and an e-skilled educator workforce – all geared to the aim of improving the quality of education.

However, implementation of these policies is a challenge (Mlitwa & Koranteng, 2013; Vandeyar, 2015). According to a Business Day online report (Phakathi, 2014) statistics released by the DBE in 2014 suggest that only 6,000 of the country's 25,870 schools were ICT-ready citing factors such as funding constraints, limited connectivity, high cost of connectivity and inadequate staff training. The Global Competitiveness Report 2015 (Schwab, 2015) ranks South Africa at 117 out of 144 countries based on access to Internet in schools. It ranks the quality of our Mathematics and Science education at a dismal 144. Thus, as confirmed by the Global indexes, South Africa has substantial challenges in achieving the transformational potential of ICT in education.

These challenges have been further unpacked in a various policy and research discussions

In September 2014, a Policy Dialogue on ICT in Education (HSRC, 2014) was convened with participants from the DBE, DST and HSRC. Whilst acknowledging the progress made since the publication of the E-education White Paper in areas of school administration and the provision of teaching and learning, they recognised that impact was compromised due to slow and uncoordinated implementation.

Similar issues were raised in a study commissioned in 2010 by the Gauteng Department of Education (GDE) to investigate e-maturity and e-readiness in GDE schools. The challenges identified at the time were: reliable connectivity, lack of leadership and vision on the part of school administrators in integrating ICT as an integral component of their function, lack of ICT skills on the part of educators and limited learner access to ICT for teaching and learning. A number of recommendations followed, the main one calling for the GDE to shift its role from mere delivery of ICT to enabling school-driven ICT use with a responsive support service tailored to specific needs. The recommendation is in line with global educational practices that advocate the decentralisation of instruction, curriculum and organisational structure, so as to nurture agency and innovation at the local level (Bocconi, 2013). (see also Czerniewicz, 2006; Hodgkinson-Williams, Sieborger & Terzoli, 2007).

Analysis

[2] http://www.education.gov.za/LinkClick.aspx?fileticket=12uDPCW6hsg%3d&tabid=390&mid=1124

[3] http://www.education.gov.za/LinkClick.aspx?fileticket=Keu0%2fBkee%2bM%3d&tabid=191&mid=484

[4] http://www.education.gov.za/LinkClick.aspx?fileticket=HHmKnb78Z7Q%3D&tabid=75&mid=1167

[5] http://www.gov.za/sites/www.gov.za/files/37261_gon44.pdf

Flowing from these studies, four separate but interrelated areas have been identified to provide a holistic overview of the current state of ICT use in education in the South African context: Professional Development; Content and Curriculum; Management of Systems; and ICT Infrastructure and Connectivity.

Professional development

In South Africa, ICT professional development of teachers is described in the National Framework for Professional Teacher Education and Development (NFPTED, 2006) (which pays cursory homage to the importance of ICT as a *medium* for furthering professional development) and the Guidelines for Teacher Training and Professional Development in ICT, which was last updated in 2007. The Integrated Strategic Planning Framework for Teacher Education and Development in South Africa (DBE and DHET, 2011) represents another significant development that proposed a National Institute for Curriculum and Professional Development with professional development opportunities to be made available on a Teacher Education and Development (TED) ICT platform. The Plan makes provision for the professional development to be managed by the South African Council of Educators (SACE) through linking the TED ICT system to the SACE CPTD System where professional development courses/activities will be endorsed and teachers allocated professional development points for completion. This system is gradually being implemented. However there appears to be no evidence as to the status of the progress on this matter.

Thus whilst there appears to be use of ICT for the execution of professional development opportunities there is however no national curriculum drafted for teacher professional development *in ICT use* to date (HSRC, 2014). The Minimum Requirements for Teacher Education and Development (DOE, 2015) do however recognise the ability to use ICTs competently as well as the utilisation of ICT's for innovative teaching and enhanced learning as fundamental in the context of teacher education. Hence, despite the paucity of a regulatory framework governing the contents of such a curriculum or the curriculum itself, the offering of ICT educational opportunities for educators however has proceeded in various ways with ICT professional development having been integrated into pre-service teacher education programmes offered by certain higher education institutes whilst various NGO's offer in service training opportunities. However, there is a need to develop schools' capacity to procure their required professional development services (KPMG, 2009; Saide, 2010) with the district office facilitating and co-ordinating the services relevant to the whole district.

The recommendations of the above studies, as well as that of the international work alluded to further in the report, find resonance in the HSRC Policy Dialogue Workshop (2014). Participants at this workshop acknowledged that teacher development should be seen as a continuum from initial/pre-service to continuing/in-service, and conceptualised as ongoing. The participants recommended the development of a national training model with updated guidelines taking into account best practices and new evidence as well as incorporating a holistic change management strategy aimed at promoting transformational teaching practices. It was suggested that the training should be applied to all stakeholders in the provincial educational departments i.e. teachers, school principals, district officers and managers. Moreover, it was recommended that the role of the ICT champions in schools should be extended to assisting teachers in ICT integration rather than only providing ICT support. The Workshop also called for the formation of a forum for input into professional development and content resource development. Elsewhere this has been has been described as a cost- effective measure of providing professional development with increased teacher confidence and willingness to share and contribute evidenced by those participating as online users (Souter, Adam, Butcher, Sibthorpe and Tusubira, 2014).

While recognising the significant strides in the development of policy related to administering of professional developments services, there is no incorporation of ICT in the national curriculum, lack of the implementation of the co-ordinating framework for in-and pre-service teacher professional development, and lack of evidence of the role out of the administrative system.

Curriculum content

The creation, warehousing and delivery of content are seen as an important part of any e-learning strategy (Adu & Olatundun, 2013; Ostrowick, 2015). In response to the challenges regarding content, highlighted in the White Paper on E-education (2004), the DBE has made considerable effort to provide electronic content. In addition, there are a number of initiatives with service providers on the development and production of electronic testing and e-learning and teaching support materials (LTSM). However there is concern about the quality of these resources. Furthermore, developers often make use of platform specific software (for example Flash that does not run on Apple devices) and use proprietary software that require additional licensing costs. In addition, content development appears not to be related to strategic objectives. NGO solutions tend to deliver vast amounts of e-LTSM resources to schools without clearly categorising, sorting, vetting or curating the content in ways that makes the content accessible (Ostrowick, 2015).

The lack of the use of open standards, which support inter-operability between different devices and operating systems, is one of the greatest problems limiting the use of e-resources. The e-education plan of the DBE outlines strategies to address such challenges that include but are not limited to: the provision of a public access centralised portal for learning-data production, storage and distribution; use of Open Education Resources and Creative Common licensing; making available all existing content through Open Access principles; and provision of an appropriate platform to support teaching and learning online (DBE, 2014). Evidence around the use or uptake of these initiatives would be useful in this regard.

Besides the DBE, other initiatives collate and provide access to useful e-resources. For example, the Center for Education Innovation (CEI, 2015) provides a database of approximately 130 educational technology programs from low and middle-income countries, with 72 initiatives from Sub Saharan Africa. These programs are aimed at assisting learners prepare for specific school subjects as well as providing a network for peers in support of teaching and learning. They include: access to learning materials; delivering software and content for free or at a reduced rate; offering instructional materials for teacher training; providing a platform for students around the world to interact with each other; delivering work skill lessons; and acting as a 'school-in-a-box'. Other initiatives include the Nolwazi Open Educational Resource (OER) repository for educators, learners, school management and district officials. The aim of this collection is to provide the widest and richest possible collection of OER, sourced, quality assured, curriculum-aligned and curated by South African teachers. It is delivered via a local kiosk or server, both offline or online, and via a web-based application. Further providers of content include Mindset Network and the Train the Brain educational technology programme from MIB Technology.

It is clear from the above that content provision is not an issue in the South African context as demonstrated by the ample contributions from various service providers. However, access to education, the raison d'etre for most ICT use in education, is not the same as access to information. Ndlovu and Lawrence (2012) cite Oppenheimer's contention that schooling is not about mere information dissemination but about making learners "…think about information. It's about knowledge and understanding and wisdom". Applying the South African Teacher Development Framework (DOE, 2007) to South African teachers in under-resourced schools, they found that teachers are at the lowest two levels of the framework (entry and adoption). This shows very little use of ICT for generation of, or interaction with, knowledge. Whilst acknowledging the importance of the provision of material resources, the authors assert that in addition, there is a need for the teachers' capacity to be developed so that they can engage with ICT tools, even in resource poor settings, to empower learners to develop cognitive skills. They conclude that teachers require subject content knowledge as well as pedagogical knowledge in order to transform the content for learners (TPACK model – see below). The key for quality use of ICT relies not on how many tools there are but on teachers' capacity to teach effectively with or without technologies (Ndlovu and Lawrence, 2012).

In a study on teacher assessment practices in South Africa, Kanjee, Molefe, Makgamatha, & Claassen, (2010) cite the Second International Technology in Education Study (SITES) conducted in 2006 across 400 South African schools which found that whilst there appeared to be widespread use of ICT in schools and a significant use of varied assessment practices, there was limited use of ICT for supporting teachers' assessment practices. The call for additional research by the authors on this issue is instructive as there appears to be a dearth of information on assessment with ICT in the South African context.

Management of systems

There is consensus that leadership and organizational culture are central to an effective ICT implementation plan, with management perceptions of ICT identified as a key determinant of the extent to which ICT is adopted and integrated with teaching and learning (Bialobrzeska & Cohen, 2005; Hodgkinson-Williams, Sieborger & Terzoli, 2007; Saide, 2010; Minty, 2014). In 2004 Saide published "Managing ICT in SA schools - A Guide for School Principals" (Bialobrzeska & Cohen, 2005) and it was made available to schools nationally. This Guide flowed from findings of research that Saide had undertaken in the use of computers in South African schools.

Despite the availability of the Guide, the 2010 Saide Audit of e-maturity and e-readiness in Gauteng schools (Saide, 2010) identified one of the key challenges as lack of integration of ICT into the organizational culture of schools and districts. It was found that school governing bodies (SGBs) and school management teams (SMTs) made little use of ICT in the execution of their responsibilities, there was very little support given to teachers in ICT integration, management of computer labs was poor, the districts had low expectations of schools in respect of ICT use, and SMTs were not empowered to choose and manage their software.

Another study showed that teachers and principals were isolated from the district e-learning units leading to their superficial knowledge of the E-education policy and incoherent actions (Vandeyar, 2015). It was therefore not surprising that the HSRC Policy Dialogue workshop participants recommended the establishment of a national coordinating agency for ICT in education, comprising all the stakeholders with the objective of improving implementation through streamlined and co-ordinated efforts.

The School Administration and Management Systems (SA-SAMS) is a computer application designed to meet the administrative, management and governance needs of SA schools and is the core management information system of data from schools that the DBE utilises for its Education Management Information System (EMIS). Whilst Gxwati (2011) contends that EMIS, "through the use of SA-SAMS, has improved the capturing of data at school level and that this has contributed to an improvement in the quality of data contained in the provincial database" it appears that SA-SAMS is due for an overhaul as the technology platform on which the system is built will no longer be supported by the Microsoft (Zenex, pers comm). Furthermore the system is not web-enabled and hence collection of data is costly and inefficient. Also it is found that the modules on the system are under-utilised whilst school personnel also question the reliability of the data stored.

Sello (2014) reports on SA-SAMS as being poorly adopted by schools in the Limpopo province based on a survey conducted amongst the Dinaledi schools. These findings echo the previous sentiments (Saide, 2010) regarding the need for management support as being a crucial element when introducing new innovations. Furthermore a change management plan and project management skills are highlighted as key considerations for a new system implementation. In addition the study also underscored the importance of customised professional development opportunities and inclusion of stakeholders/end users in training. This emphasizes the "human factor" more than technical considerations when implementing a new system.

The Data Driven Districts (3D) approach, a partnership-driven programme of the DBE has yielded useful findings over the last three years in collating data on achievement and attendance on more

than 600 000 learners from over 1000 schools in seven districts across the Gauteng, Limpopo and Free state (MSDF, 2015). Introduced as a response to identified data use challenges in South African schools, the intervention provides a methodology and a set of management tools to assist district officials in engaging more productively with schools and providing better support to schools. To date key achievements include a usable, scalable online platform that stores key learner and educator data; sustainable data practices which include tailored data collection processes that have resulted in improved quality of data collected and reduced time; as well as enhanced data use routines to drive decision making and intervention through intensive coaching and training sessions. Overall there appears to be a marked enthusiasm for the approach with a visible sense of ownership given the increased demand from the provinces to extend the roll out.

ICT infrastructure and connectivity

With regard to infrastructure, an investigation conducted by KPMG in 2009 found that only 15 per cent of schools had a computer for teaching and learning purposes. However, this figure has been challenged. Ostrowick (2015) pointed out that elsewhere in this report it is stated that 22.6 per cent of schools nationally had computers for teaching and learning whilst 50.86 per cent of schools had computers for administrative purposes. Whatever the exact figures, there is clearly a need to improve infrastructure, particularly in rural areas. The HRSC Policy Dialogue participants highlighted this in their call to government to provide for the ICT infrastructural needs in marginalized and under-resourced areas.

Saide (2010) found that most Gauteng schools enjoyed relatively good access to computers, with availability mainly through computer laboratories, of which approximately 80 per cent of schools had at least one computer laboratory. Whilst administrative staff had relatively good access, with an average of 3.57 computers for administration per school, learner access to computers appeared to be limited to one lesson per week via the laboratory, with teachers also having limited access. In a similar study in Gauteng, Amory (2012) found that the student to computer ratio was very high relative to international norms with quintile 5 schools better resourced in ICT infrastructure compared to poorer schools.

The E-education plan (2014) confirm that computing facilities are limited to schools in quintile 3 and above only, due to costs. The HSRC Policy Dialogue points to a lack of government leadership on this. Improvement of teacher access to computing devices however appears to be in process with the revised 2013 Teacher Laptop Initiative currently under way. This initiative seeks to address the previous low uptake of educators by removing the need for individual teachers to purchase their own devices.

Devices for learners have also assumed centre stage in current national discussions. According to Ostrowick (2015), the preferred model (advocated by KPMG in 2009) is mobile computer labs, consisting of laptops, 2-in-1 devices, or tablet devices stored in a trolley for charging and protection purposes. This is supported by other research proposing the use of mobile devices and wireless connectivity (Amory, 2012). However, Tamim, Borokhovski, Pickup and Bernard (2015) in a study involving two South African small-scale initiatives cautioned that it was the hype around tablet devices that steered their deployment, rather than their use as tools to achieve learning goals. Current studies suggest that higher learning gains are not entirely dependent on a lower student to-device ratio; the key is professional development, which, if inadequate, limits students learning with technology (Haßler, Major & Hennessy, 2015).

The E-education plan also mentions the usefulness of public-private partnerships (for example, SchoolNet/Intel, Gauteng Online, and the Cofimvaba project) in rolling out infrastructure. However there is concern that these partnerships are not adequately coordinated by government departments (at all levels). State Owned Enterprises were also criticised on their insufficient presence, lack of commitment and the problematic overlapping roles within this entity.

It is widely held that South Africa's slow Internet speeds and high costs contribute to the slow uptake of ICT use in Education (DoE, 2004; Saide 2010; HSRC 2014). Ostrowick (2015) contends that despite the cost, Internet access is important in realising the full potential of ICT use in teaching and learning. The HRSC Policy Dialogue challenged the assumption that schools require only low levels of bandwidth. The recent draft National Broadband Policy called "South Africa Connect: Creating Opportunities: Ensuring Inclusion" proposes ways to mitigate challenges posed by poor connectivity. Ostrowick (2015) outlines ways for rural schools to connect to the Internet through service providers such as SANRen (using TENET ISP service and SANRen fibre optic cable network), VSAT (using satellite connectivity which includes Mindset offering through Intelsat but limited to unidirectional connectivity only) and Wireless Mesh. Thus, connectivity "is not an impassable barrier" and is "merely one aspect of e-education" (Jacobs, 2013).

Howie (2010)'s reflections on the SITES study of 2006 draw on the Chilean experience. Since Chile participated in the study along with South Africa and is similar in terms of context and economy, there are lessons to be learnt for the South African context. Most of these have already been incorporated into the existing policies. However, worth mentioning are: the need to use the existing telecommunications structure where possible (assuming of course that the basic set up has been done) before investing substantial resources in putting new infrastructure; as well as the need to focus on teachers and their professional development and not merely on the technology (Howie, 2010).

Challenges

Provision of the infrastructure to support the use of ICT in teaching, learning, assessment and management requires a concerted effort, not only with regard to the technical challenges, but also the challenges associated with the pedagogical use of technology.

There are conflicting views on whether computers have positively or negatively affected student learning (Burns, 2013). Part of the reason is that in most instances technology has been used poorly in schools, particularly in low-resource areas.

The review by Khalid and Buss (2013) of barriers associated with integration and adaptation of education technologies using a macro-meso-micro level analysis highlights the challenges in education systems situated in their external environment. They reported that barriers were associated with the experiences of stakeholders (teachers, administrators, students and parents), type of organisation (institutions versus national educational organisations) and external conditions.

There is a need for facilitation from the national (macro) entities for longer term hands-on training, resource allocation, greater funding, objective of student-centered learning as opposed to state test score, and development of trainers. Institutional (meso) level should have IT policy, plan and procedure for sustainable change, leadership for integration, separate IT budget for operations and maintenance, and prompt technological and pedagogical support. Individual (micro) level barriers are either the recurrent experiences of the macro or meso level barriers or the perceptions developed from the practices within the learning environments, across formal, non-formal and informal spaces (p. 18).

These findings support the work of Khan, Hasan and Clement (2012) who reported that barriers to the implementation of ICT in the Bangladesh education system include lack of funds, budgetary allocation to defence rather than education, limited vision and plans at macro- and micro-levels, social and cultural factors such as language proficiency, corruption, and teachers' attitudes and beliefs about the nature of learning (ontology and epistemology), knowledge and skills and a lack of time.

Therefore, although challenges associated with the integration of technology may, in part, be due to funding and infrastructure issues, teachers generally lack sufficient technological literacy to use the technology in meaningful ways and to get learners to be excited about it. There are also no clear underlying pedagogical principles for introducing technology in schools.

What happens in teacher training is key. The expectations and attitudes of pre-service teachers towards the integration of technology into teaching and learning are affected by availability and use of ICT in teacher education programmes and in placement schools (Martinovic & Zhang, 2012). Studies conducted amongst pre-service teachers through online surveys and focus group meetings confirm that there is general lack of modelling of appropriate pedagogical use of ICT during teacher training. At the same time, these teachers are not exposed to technology in the schools in which they are eventually deployed after training. Thus, shortcomings in teacher training coupled with limited access to ICT in schools lead to lack of confidence in using ICT in teaching and learning, misconceptions around the educational value of using ICT, and passive resistance to change by pre-service teachers. For all these reasons, working with technology does not become part of teachers' day-to-day activities.

Bourdieu's concepts of habitus and cultural capital help us understand teachers' practices in as far as technology integration is concerned. Habitus incorporates not only the way teachers think and behave but also particular investments they make in certain forms of knowledge and ways of acting. Where technological infrastructure is lacking, exposure to technological tools is limited and technology does not become part of teachers' cultural capital. However, the converse is also true.

For example, despite having well equipped institutions, educational ICT use in the Gulf Cooperation Council countries is not used for knowledge development because of limitations related to cultural contexts (Wiseman & Anderson, 2012).

A study carried out in 53 Flemish schools (Belgium), showed that the main variables affecting ICT integration in schools are professional development, ICT competence, developmental educational beliefs, and schools' ICT vision and policy. Where these variables are absent, ICT integration is constrained, and the converse is also true (Vanderline, Aesaert & Braak, 2015). School-related policies, such as an ICT plan, ICT support and ICT training have a significant effect on class use of ICT. Research shows that school policies are often underdeveloped and underutilised, and this is a significant challenge faced in many schools with regards to integration of ICT.

School leadership is the most important single factor determining whether or not the afore-mentioned variables obtain in a school. School leadership determines how ICT is implemented in a school, and its subsequent impact on learning outcomes. The attitude of school leadership towards ICT, its commitment and ability to champion implementation positively influence the extent to which ICT are integrated in the school curriculum (Mingaine, 2013). Apart from demonstrating leadership and mobilising resources, school leaders need to have a vision for technology integration in the curriculum. In a study conducted amongst 311 school principals in the south western region of the United States of America, principals with 12 or more years of experience perceived technology as a tool for instruction, data sharing and management, and administrative tasks more than principals with less than 12 years of experience (Waxman, Boriack, Yuan-Hsuan & MacNeil, 2013). The results also showed that it was mainly male principals who felt that technology was used as a resource and for administrative tasks. Thus, in this context, both gender and years of experience have influence on technology implementation in schools.

Rabah (2015) reports on a study that was conducted on the perceptions of educational consultants and teachers on the benefits of integrating ICT in Quebec English schools. Interestingly, even in this developed contexts, participants highlighted the following challenges: lack of supporting school leadership, inconsistent investments in ICT equipment, infrastructure and resources, inflexibility of funding, the need for additional professional development and support and incorporation of technology in evaluations and curricular plans (Rabah, 2015). An important conclusion drawn from this study is that while ICT has great potential to enhance teaching and learning processes, turning that into reality is a complex and multifaceted job.

Proper integration of ICT in the classroom entails change on the part of teachers and the entire school system, and therefore change management is a critical aspect of the process of ICT adoption. In the majority of schools, lack of change management is therefore one of the biggest impediments to the integration of technology.

There is no doubt that access to and management of technology are important components of support for the use of technology in teaching and learning. However, it is teacher development (both pre- and in-service) and human capital management that is of greater importance.

Therefore, a number of principles related to the challenges of the implementing and appropriate pedagogical use of educational technology include:

2.1. A well-funded, managed and supported school ICT environment is the foundation to support teaching and learning with technology;

2.2. Management is required at the educational micro-, macro- and meso-levels to maximise the use of ICT that is aligned with national and local policies; and

2.3. The development of attitudes, skill and knowledge (both technical and pedagogical) of pre- and in-service teachers is a prerequisite for successful use of technology in the classroom.

Global scan of successful ICT initiatives

As can be seen from the extracts below, it is understood globally that the rollout of technology and associated resources into schools does not necessarily lead to improved teaching and learning outcomes.

"Despite initial certainty of political purpose and considerable optimism regarding its effects on teaching and learning, the evidence of school inspector reports in the USA, Scotland and England suggests that information and communications technology (ICT) remains, at the beginning of the 21stCentury, a marginal force in the education of 5–12 year-olds" Robertson (2003, p. 323).

"Through analysis of the evolution of ICT in education in China, two stages have been identified, namely, the technology-dominated stage from 1986 to 2000 and a symmetric stage between technology and education used from 2000 till now (Wang & Song, 2002). In the first stage, ICT hardware, such as computers, printers, and projectors, is determined and ordered by school administrators and teachers. The main difficulties at this stage were that teachers' competency of ICT could not support its application in education, for little useful research had been conducted and minimal effective software developed, which caused significant frustration for teachers' enthusiasm for applying ICT in education. When educational practitioners realized the weaknesses of the hardware-dominated approach, some remedial strategies were implemented to refine the effectiveness of ICT in education, e.g., facilitating ICT integration in education, teacher training, and designing and developing educational resources, which became the second stage of ICT's evolution in education" Zhao and Xu (2010, p. 51).

Therefore, considering the "unresolved debate over whether ICT should be conceived of as supporting delivery of a traditional or a radically different vision of pedagogy based on soft skills and new digital literacies" (Livingstone, 2012, p. 9), the rhetoric that the power of technology improves learning outcomes, and the associated challenges, it is necessary to explore ways that ICT might play a role in teaching and learning.

Understanding the use of ICT in teaching and learning

The lack of direct evidence that ICT can improve the quality of education (Price & Kirkwood, 2010; Luu & Freeman, 2011) hinders policy makers (UNESCO, 2009). It might be due to a number of factors including ontology (ways of understanding reality and how things work) and epistemology (the origin, nature, and limits of human knowledge) (Hodgkinson-Williams, 2006), teaching ideology (instructivism versus constructivism) (Amory, 2007), research methodology (positivism, critical theory, pragmatic and constructivism) (Reeves & Hedberg, 2003), concepts of learning (Yanf & Tsai, 2010; Enrique Hinostroza, Labbé, Brun, & Matamala, 2011), and accessibility (van Rooij & Zirkle, 2016). Findings such as that prior exposure to e-learning improves learning (Havirila, 2011) but should not be used frequently in the class (Kadijevick, 2015) can be understood by an analysis of the associated ideological and research paradigms.

These issues are explored in this section to create an easy-to-use framework to better understand the ways in which technology is used in teaching and learning. Thereafter, the framework is used to evaluate a number of reports that investigate the use of ICT in teaching and learning over the past five years.

First, a way of describing learning is explored.

In Table 1 below three perspectives on learning – acquisition, participation, and contribution are presented.

Table 1. Transformative stance perspective: implications for the notion of learning (from Stetsenko, 2008)

	Acquisition	Participation	Contribution
Key definition of learning	Information processing; obtaining knowledge; individual process 'in the head'	Participation, i.e. becoming a member of a community; the permanence of having gives way to the constant flux of doing	Contributing to collaborative practices of humanity: continuing, while simultaneously transforming them
Key words	Knowledge, concepts, meaning, fact, contents; acquisition, internalization, transmission, attainment, accumulation	Apprenticeship, situatedness, contextuality, cultural embeddedness, discourse, communication, social constructivism, cooperation	Contribution, transformation, history as collaborative practices, cultural tools; vision and directionality; activism and commitment
Stress on	The individual mind and what goes into it; test and control of acquisition outcomes	The evolving bonds between the individual and others; the dialectic nature of learning interaction: The whole and the parts affect and inform each other	Dialectics of continuity and transformation, tradition and innovation; Knowledge for and as action; learning-for-change Ideal Individualized learning Mutuality and community building Contribution through self-development and community development
Role of teacher	Delivering, conveying, inculcating, clarifying	Facilitator, mentor; Expert participant, preserver of practice/discourse	Activist open to collaboration and dialogue; agent of a collaborative change
Nature of knowing	Having, possessing facts and skills	Belonging, participating, communicating	Collaboratively transforming the past in view of present conditions and future goals
Time line	Carrying out past experiences into the present; future is irrelevant	Focus on the presently evolving patterns of participation; the past is irrelevant and no future	Interface of the past, the present, and the future; the past and present are known through positioning visa`- vis the future
Agency	No agency for social change	Collaborative agency	Co-evolving individual and collaborative agency
Who develops?	Individual learner	Community	Learners-through-humanity and humanity-through-learners
Where is mind	In the head	In patterns of participation	In continuous flow of transformative action
Key goals of learning	Knowledge of facts and skills	Ability to communicate in the language of community and act according to its norms	Knowing the past in order to be able to transform it; emphasis on the vision for the future from which the past can be known

The acquisition perspective defines learning as obtaining knowledge through information processing in an individual mind. This is an instructivist approach, the dominant form of learning worldwide, an important component of formal education and the most widely used pedagogy (Laurillard, 2012). When learning is defined as participatory, it is concerned with bonds between the individual and others (dialectic approach) in a community of practice. Stetsenko argues that the third category of learning, defined as contributing to collaborative practices of humanity for individual and community transformation, supports human community development. It should be understood that even in the contribution paradigm, the acquisition of information and participation are important components of learning. However it is the overall outcome, the transformation of individuals and thereby their community, which is of paramount importance. The African philosophy of 'ubuntu' that is the "potential for being human, to value the good of the community above self interest, … to strive to help people in the spirit of service, to show respect to others and to be honest and trustworthy" resonates with the contribution perspective on learning.

These perspectives can also be directly related to ontological, epistemological and methodological paradigms. *Acquisition* of learning is directly linked to positivism: there is an objective reality and a world understood through the laws that governs the universe; scientific discourse is derived from the philosophical notions of positivism and realism; and the predominant research approach is experimental and deductive. The *participation* perspective aligns with the idea that the world and knowledge are created by social understanding in which each person's worldview might be known through the use of qualitative methods (for example, narrative investigations, interviews, observations, ethnography, and phenomenological research approaches). In the contribution perspective, reality exists and has been created by a social bias. Contradictory conditions of activities are explored that may be hidden or distorted in order to improve social conditions. Critical analyses, historical reviews and participatory research approaches are often associated with this perspective. The three perspectives are collectively called notions of learning and can be depicted on a vector moving from acquisition through participation to contribution (Fig. 1).

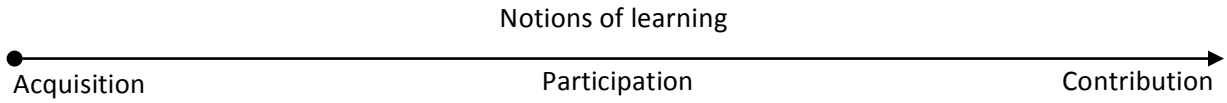

Figure 1. The notions of learning vector.

A second way of describing learning in relation to use of ICT in education is in terms of the instructivist-constructivist ideological dialectic.

Teachers who integrate technology in a passive and teacher-centred manner replicate the traditional instructivist approach (Dutton, Cheong, & Park, 2004; Blin & Munro, 2008; Yueh & Hsu, 2008), focus on technical issues (Dutton et al, 2004), emphasise remediation ICT and drill-and-practice applications (Smeets, 2005), and believe that information is more important that the learning process (Paulsen, 2003). This can be described as a learning teaching pedagogy *from* technology approach (Jonassen & Reeves, 1996).

Noor-Ul-Amin (2013) posited that while ICT has fundamentally changed processes and practices associated with business and government, only small changes are apparent in education, mainly related to supporting a more student-centred learning setting. The works of educational theorists and practitioners of the past century (including John Dewey, Jean Piaget, Lev Vygotsky, Jerome Bruner, Paulo Freire, Terry Winograd, Seymour Papert, Lauren Resnick, John Seely Brown, Roger Säljö, John Biggs and Jean Lave) all argue that the learner must be an active agent in the process of learning (Laurillard, 2012). Achievement of learning outcomes appear to be dependent on social interactions (Noor-Ul-Amin, 2013; Paily, 2013; Kožuh, Jeremić, Sarjaš, Bele, Devedžić & Debevcand, 2015) and collaboration between students and between teachers and students (Trna & Trnova, 2010; Báez,Cristina & Segovia, 2013; Yuan-Hsuan, Waxman, Jiun-Yu, Michko,& Lin, 2013; Gu, Chen & Lin, 2015). Recent social network analysis research shows that participation in learning communities improves academic performance (Gašević, Zouaq, & Janzen, 2013; Rizzuto, LeDoux, & Hatala, 2009), persistence (Thomas, 2000), retention (Eckles & Stradley, 2011), and creativity (Dawson, Tan, & McWilliam, 2011; Perry-Smith & Shalley, 2003). Pittman and Gaines (2015) argue that the use of sociocultural learning theories allied to the appropriate integration of ICT can support learning. For example, a constructivist problem-based learning approach supported the development of socially connected groups of students (Baturay, & Bay, 2010) and developed learner autonomy and motivation (Barber, King & Buchanan, 2015). Situated learning environments that include authentic contexts, activities, expert performances and integrated assessment improve student performance (Pérez-Sanagustín, Muñoz-Merino, Alario-Hoyos, Soldani & Kloos, 2015). Therefore, constructivist approaches to the use of ICT in teaching and learning emphasise the use of technology as a cognitive, or "mindtool" (Jonassen, 1994; Herrington & Kervin, 2007). This could be referred to as a learning *with* technology approach (Jonassen & Reeves, 1996).

However, technology can also act as a tool to mediate knowledge construction: a social constructivist view. Vygotsky (1978) described tools from two perspectives: the physical tools (such as pencils and technological artefacts), and the psychological signs and symbols (especially language). Tools are oriented to material activity, while signs and symbols are part of social and intrapersonal interaction used to solve problems (that is, part of higher cognitive functions). But, dependent on the context, a material tool can function as a tool, a sign or both. All tools can therefore be seen as both material and conceptual: they are parts of our world and shaped by human activity (Cole, 1996).

For Wertsch (2007) mediation can be explained as either explicit or implicit. Explicit mediation is the intentional use of objects, people or signs by an individual that "overtly and intentionally introduces a 'stimulus means' into and ongoing stream of activity" (Wertsch, 2007, p. 180) that is obvious and non-transitory. Implicit mediation, on the other hand, is less obvious but "involves signs, especially naturally language, whose primary function is communication" (p. 181), and does "not readily become the object of consciousness or reflection" (p. 185). Whether mediation operates through direct intervention, or through language and signs, individual transformation, by necessity, includes both the explicit (tools and signs operating on other minds) and the implicit (internal tools and signs actions) operating modes of mediation.

Therefore, depending on ideological positions, technological tools can be used in different ways in teaching and learning. ICT tools can be used for instruction (learning from technology), or as a mindtool to support either cognition or to mediate individual transformation (learning with technology) (Fig. 2).

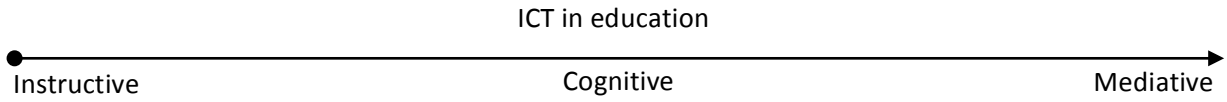

Figure 2. The uses of ICT in education vector.

Notions of learning and use of ICT in education could be seen as abstract ways of representing learning. While concrete actions are associated with each dimension, the use of conceptual and practical models can support the design of learning activities. Hence, in the discussion below a number of models are presented to illustrate concrete ways in which ICT can be integrated into teaching and learning. The models are aligned with the notions of learning and uses of ICT in education vectors developed above.

The P3 model (Khan, 2004) supports the development of e-learning content and associated delivery and maintenance processes. The model describes people, products and processes. People are involved in planning, design, production and evaluation to support the related processes. Products include a project plan, storyboard for material development, the learning materials and after evaluation, revised learning materials. The process component is often associated with 'deep learning', that is a branch of machine learning where the computer replaces a teacher. Deep learning is positively associated with background knowledge and previously read text (Clinton, 2014). However, Huntley-Moore and O'Connor (2014) reported that over a three year period only few nursing students were able to demonstrate that they use deep learning approaches, which included an understanding of the subject material, ability to engage with the material to make links to new information and previous experience and knowledge, deepen their interest in the course and read beyond course requirements. Swabey, Babauee and Prosser (2014) argued that this model is useful in the design of e-portfolio learning but they felt it necessary to include constructivism in the design. It is clear, therefore, that this model is concerned with machine learning - a learning from technology approach - and when used successfully, requires that the process component of the system needs to be aligned to constructivist learning principles.

ADDIE is another model aligned to machine teaching and intended to guide instructional design (Merrill, 2002). It includes a number of phases: analysis of the learning problem (what you want the students to know); design of the instructional approaches; development of content, assignments and assessments; testing the solution (implementation); and evaluation, both formative and summative (Merrill, 2002; Molenda, 2003; Davies, 2013). While the model includes problem solving, Merrill (2015) considered it necessary to modify the approach to include authentic tasks (Brown, Collins, & Duguid, 1989; Newmann, Bryk, & Nagaoka, 2001; Reeves, Herrington & Oliver, 2004; Smeets, 2005). The model is widely used in different educational settings, but is most prominent in corporate and institutional training.

A very influential model is the TPACK framework, which shows the relationship between Technological Knowledge, Pedagogical Knowledge and Content Knowledge.

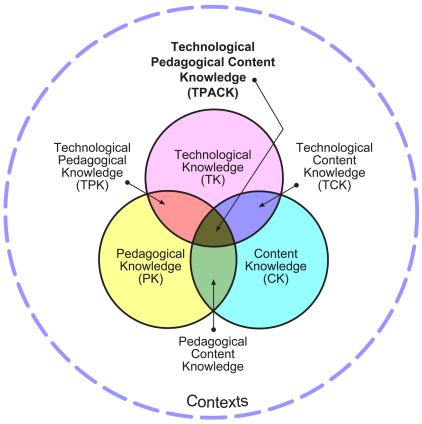

Figure 3. The TPACK framework and its knowledge components

Koehler and Mishra (2009) describe it as follows:

TPACK is the basis of effective teaching with technology, requiring an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge to develop new epistemologies or strengthen old ones (Koehler & Mishra, 2009, p. 1029).

Phillips (2014) posited that the use of TPACK (Fig. 3) in schools is neither widespread nor well researched. In addition, the challenges faced by teachers when using the model are not fully understood (Koh, Chai & Tsai, 2014). For example, pedagogical and content knowledge of participants directly impacted on their ability to work within the TPACK model (Chai, Koh & Tsai, 2010; Chai, Koh, Tsai & Tan, 2011). Several researchers have shown that the framework guided the integration of technology into teaching and learning (Harris & Hofer, 2011; Khan, 2014; Ay, Engin, & Bahaddin Acat, 2015; Chuang, Wen, & Huang, 2015). Others have pointed out that in this framework technological tools should support cognitive development rahther than information acquisition (Landry, 2010; Mishra, Koehler, & Henriksen, 2010). The framework has allowed teachers to align their practical approaches and theoretical ideas (Wetzel & Marshall, 2011), but to help teachers make better use of it, Avidiv-Ungar and Eshet-Alkalai (2014) suggested the framework should be part of the teachers' school vision and include an affective component.

Perhaps most influential in higher education is the conversational model developed by Laurillard (2014). This includes interaction between teachers' concepts, teachers' constructed learning environments, students' concepts and students' specific actions (related to learning tasks). She stresses that for higher level learning, dialogue must take place at both a theoretical and practical

level. In face-to-face teaching, many interactions are so spontaneous and intuitive that they can be overlooked in the design of technology supported teaching. Therefore, Laurillard made these interactions explicit and explored learning from a number of different perspectives, namely learning through acquisition, inquiry, discussion, practice, collaboration and/or production. Each of these ways of learning is associated with different types of technology or media. Learning through acquisition includes narrative presentation, books and videos, or, in their digital form), podcasts, web resources and online videos. In learning through acquisition, students mostly play a passive role. In the learning through inquiry approach, students work either individually, or together, to develop their own ideas. However, for such an approach to work, the teacher must be integral to the process to guide students to develop appropriate understanding of a particular topic. Technologies that support this type of learning include online resources, digital libraries, websites and the use of search engines. Learning through discussion is effective for conceptual development as the students are required to express, argue, defend and reconsider their ideas. Effective use of discussion requires a skilled teacher-facilitator. Online conferences, forums, chat rooms and social networking systems support this form of learning. In the learning through practice paradigm, students need to make use of their knowledge, skills and attitudes to solve a particular task. Often the teacher is absent and students learn through doing (imitation or apprenticeship). Theoretical approaches to learning through practice include constructionism (students learning about the world by making something in the world), authentic and situated learning (part of constructivism and situated in a real-world context) and experiential learning (includes concrete experience, reflective observation, abstract conceptualisation and active experimentation). Intrinsic and extrinsic feedback to students is an important component of this approach. Technologies useful to learning through practice include adaptive tutoring programs, MicroWorlds, simulation environments, role-play simulations, serious games and immersive environments. Often allied with learning through discussion is learning through collaboration. This has been shown to be a most beneficial teaching and learning technique. Laurillard (2014) describes learning through collaboration as a combination of learning through practice and discussion. Furthermore, the use of such an approach provides a technological model that could give learners feedback that also promotes higher forms of learner interaction. This conversational model clearly identifies pedagogical approaches and argues that specific approaches use technology in different ways.

Allied to Laurillard's model is the transformative education pedagogy framework. Central to this model is the use of authentic tasks in teaching and learning. Authentic learning designs (Reeves, Herrington & Oliver, 2004; Herrington, Reeves & Oliver, 2014) have real-world relevance, are ill-defined and complex; provide opportunities to examine ideas from different perspectives, and for collaboration and reflection; are integrated across different subject areas; include integrated assessments; yield polished products; and allow for competing solutions and outcomes. These principles have been used to design a blended learning environment (Tan & Neo, 2015), task-based platform to teach English (Chen, Nurkhamid, Yang, Lu & Chang, 2013), adventure games with authentic puzzles (Amory, 2010, 2011), postgraduate course (Amory, 2014) and professional development (Amory 2013). In each of these reports, student performance was improved and support tool-mediated created outputs. Bozalek, Ng'ambi, Wood, Herrington, Hardman and Amory (2015) described the alignment of authentic learning tasks with emerging technologies acting to mediate learning as a transformative pedagogy.

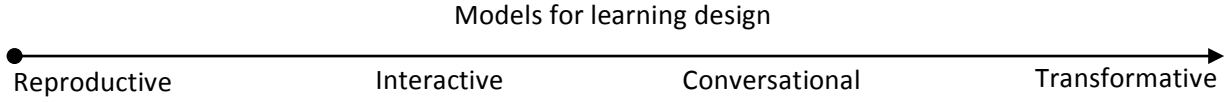

Figure 4. The model of learning vector.

Framework for evaluating the use of ICT in teaching and learning

The conceptual framework for the evaluation of the use of ICT in teaching and learning proposed in this paper requires both independent and dependent variables. The notions of learning, ICT in education, and models for learning design described in the previous section are three independent variables of the evaluation framework.

However, to evaluate the impact, if any, of the use of ICT in teaching and learning, it is necessary to include a dependant variable. Bloom's taxonomy, developed in the 1950's, includes categorised cognitive skills and objectives from lower- to higher order. This was revised by Anderson (Anderson, Krathwohl, Airasian, Cruikshank, Mayer, Pintrich, Rath, & Wittrock, 2001) to use categories for forms of thinking with associated key verbs:

- Remembering
  Recognising, listing, describing, identifying, retrieving, naming, locating, finding
- Understanding
  Interpreting, summarising, inferring, paraphrasing, classifying, comparing, explaining, exemplifying
- Applying
  Implementing, carrying out, using, executing
- Analysing
  Comparing, organising, deconstructing, attributing, outlining, finding, structuring, integrating
- Evaluating
  Checking, hypothesising, critiquing, experimenting, judging, testing, detecting, monitoring
- Creating
  Designing, constructing, planning, producing, inventing, devising, making

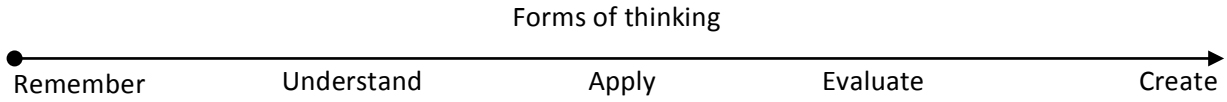

Figure 5. The forms of thinking vector.

Five of these revised categories (remembering, understanding, applying, evaluating and creating) are part of the forms of thinking vector (Fig. 5). The four vectors (notions of learning, ICT in education, model for learning design, and Bloom's modified taxonomy) comprise the framework that is referred to as NIMB (pronounced nimble). The main objectives for the development of the framework were firstly to describe the complex and various ways in which ICT are being used in teaching and learning, and secondly, to identify international trends associated with the use of technology in teaching and learning. Therefore, analyses are presented in two ways:

- The relationship between the forms of thinking (dependent variable) and notions of learning, ICT in education and models for learning design (independent variable) were determined. The data consisted of 61 research reports, with 56 of these published since, and including, 2010. SPSS descriptive statistics and linear regression techniques were used to analyse the data.
- Mean values and standard errors were calculated for each year for all the vectors (notions of learning, ICT in education, model for learning design and forms of thinking). Linear trendlines are added to the graphs.

To investigate the relationships of the different components (vectors) of the NIMB model a multiple linear regression was calculated to predict forms of thinking based on notions of learning, ICT in education and models for learning design. A significant regression equations was found ($F(3,57) =$

37.643, $p < .000$), with an $R^2 = 0.665$. The predicted form of thinking is equal to 0.801+ 0.356(notions of learning) + 0.287(ICT in education) + 0.184(models for learning design). Notions of learning was found to be a significant predictor of forms of thinking, and ICT in education and models of learning design were interrelated.

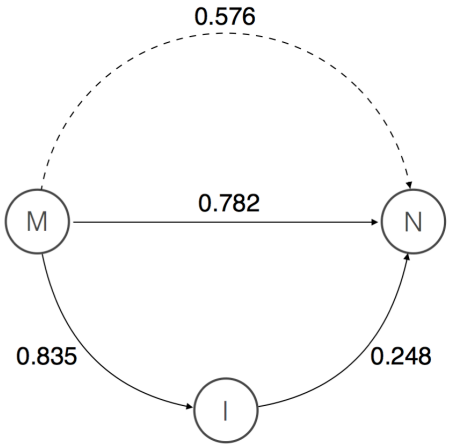

Figure 6. Standardised coefficients of the relationship between the models of learning design (M), ICT in education (I) and notions of learning (L) (- - - relationship between M and N controlling for I).

Standardised coefficients, a measure that estimates which of the independent variables have a greater effect on the dependent variable, were calculated and relationships determined (Fig. 6). The variable ICT in education appears to mediate the relationship between the models of learning design and notions of learning when controlling for I coefficient between M and N is reduced from 0.782 to 0.576.

To further explore the relationships linear regressions were calculated for each of the independent variables to the forms of learning (dependent variable) (Fig. 7-9).

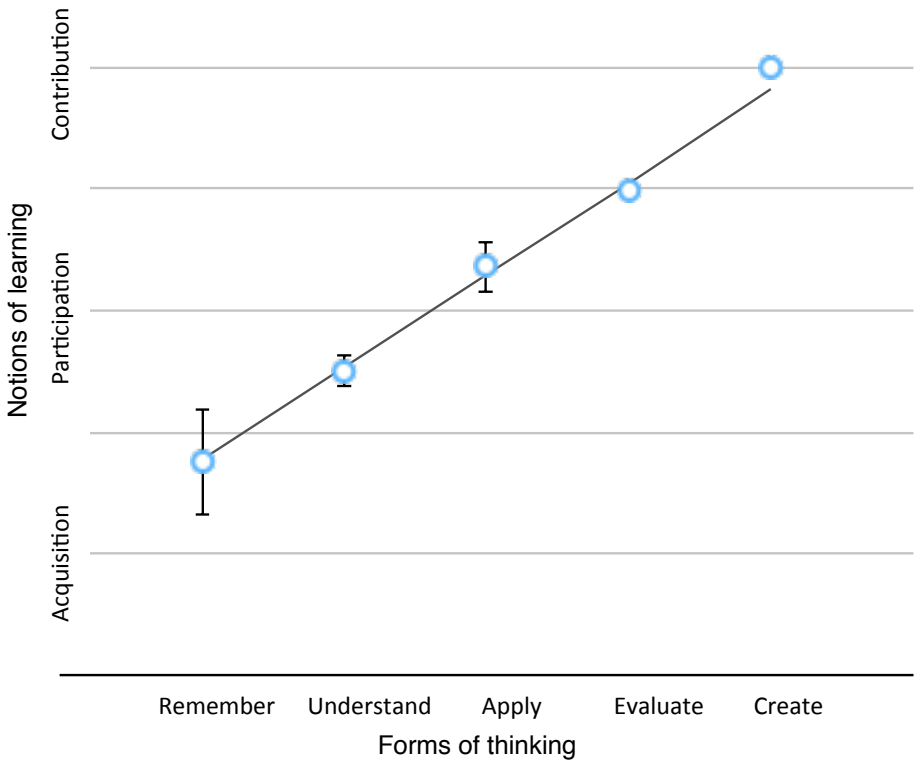

Figure 7. **Evaluation of the notions of learning in relation to forms of thinking (*n*=61; bar=standard error of the mean; a significant regression equation was found (F(1,59) = 76.257, *p* < .000), with a R^2 of 0.556 and y = 1.01 + 0.761x).**

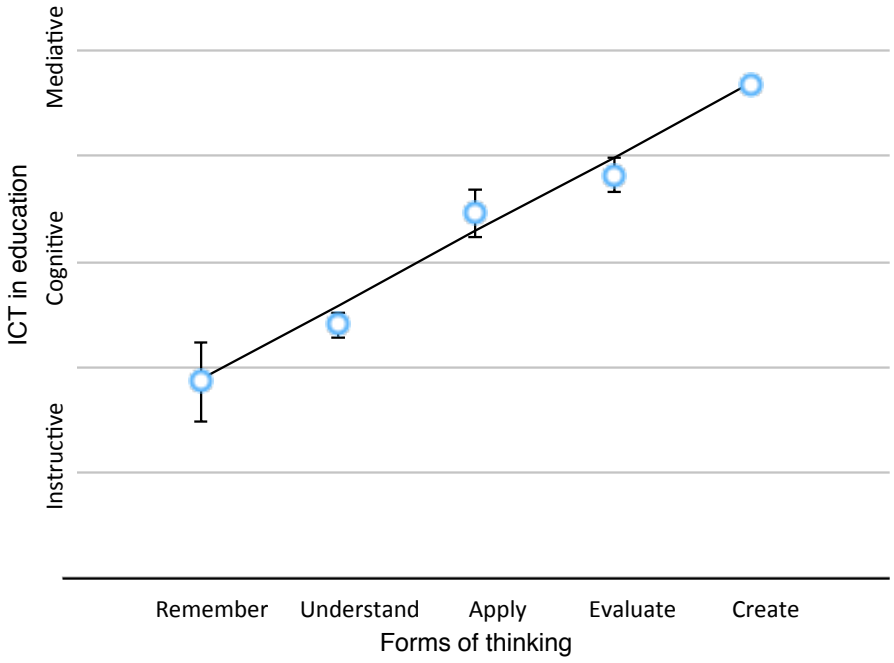

Figure 8. **Evaluation of the use of ICT in education in relation to forms of thinking (*n*=61; bar=standard error of the mean; a significant regression equation was found (F(1,59) = 76.046, *p* < .000), with a R^2 of 0.563 and y = 1.184 + 0.701x).**

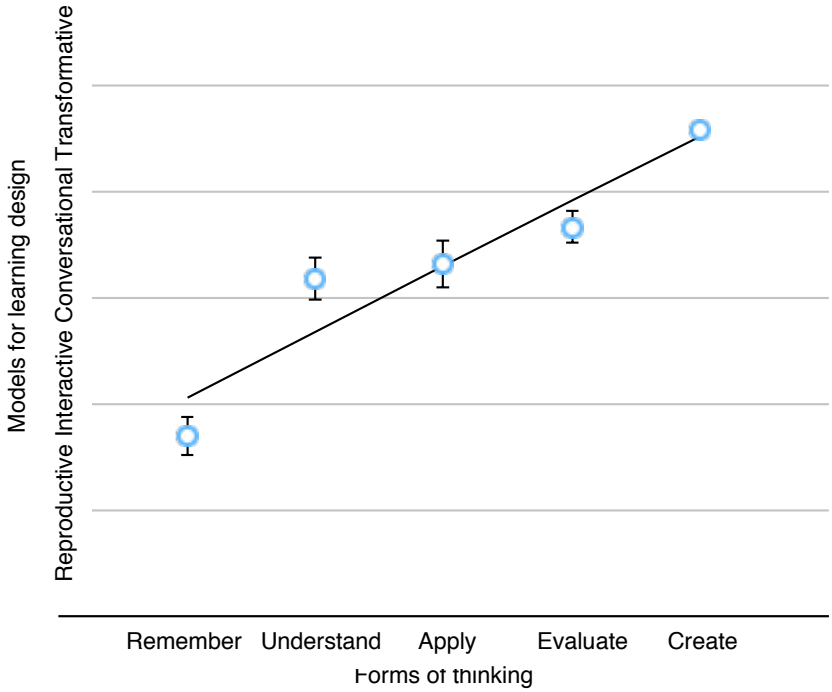

Figure 9. Evaluation of the use of models for learning design in relation to forms of thinking (*n*=61; bar=standard error of the mean; a significant regression equation was found (F(1,59) = 78.671, *p* < .000), with a R^2 of 0.571 and y = 1.441 + 0.617x).

There are statistically valid linear relationships between the forms of thinking and the independent variables of notions of learning (Fig. 7), use of ICT in education (Fig. 8) and models for learning design (Fig. 9). The design of the NIMB model aligning the *remember* item with *acquisition*, *instruction* and *reproduction*, as well as the *create* item with *contribution*, *create* and *transformation* is appropriate.

It is, therefore, important to understand that in the design of a learning event a number of criteria should be taken into account. Learning is about the acquisition of new information, development of a shared knowing of the world we live in, and learning to support the development of communities (notions of learning). In addition, learning outcomes are about remembering, understanding, application, evaluation and creation of information and knowledge. The NIMB model argues that a different teaching approach is needed to realization of each of these cognitive skills and learning objectives. Therefor, the use of ICT to support different skill development and learning objective is different. Remembering and understanding is best developed through the use of ICT as an instruction devices, whereas ICTs as cognitive tools support the development of application and evaluation skills, and the use of transformative pedagogy that includes technology to mediate create learning outcomes.

The question now arises if the model can help in the identification of the international trends in the use of ICT to support teaching and learning?

Application of the framework

The question now arises if the framework can help in the identification of the international trends in the use of ICT to support teaching and learning? The four vectors associated with the model articles from 2010 to 2015 were analysed with time as the dependant variable.

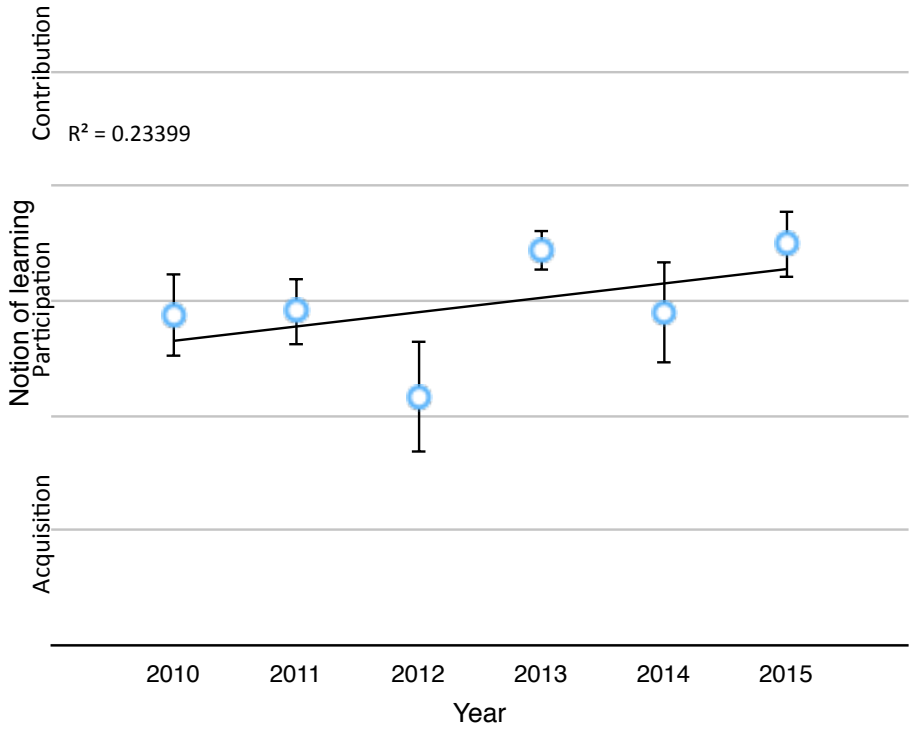

Figure 10. **Evaluation the notions of learning associated with research of the use of ICT to support teaching and learning (*n*=56; bar=standard error of the mean).**

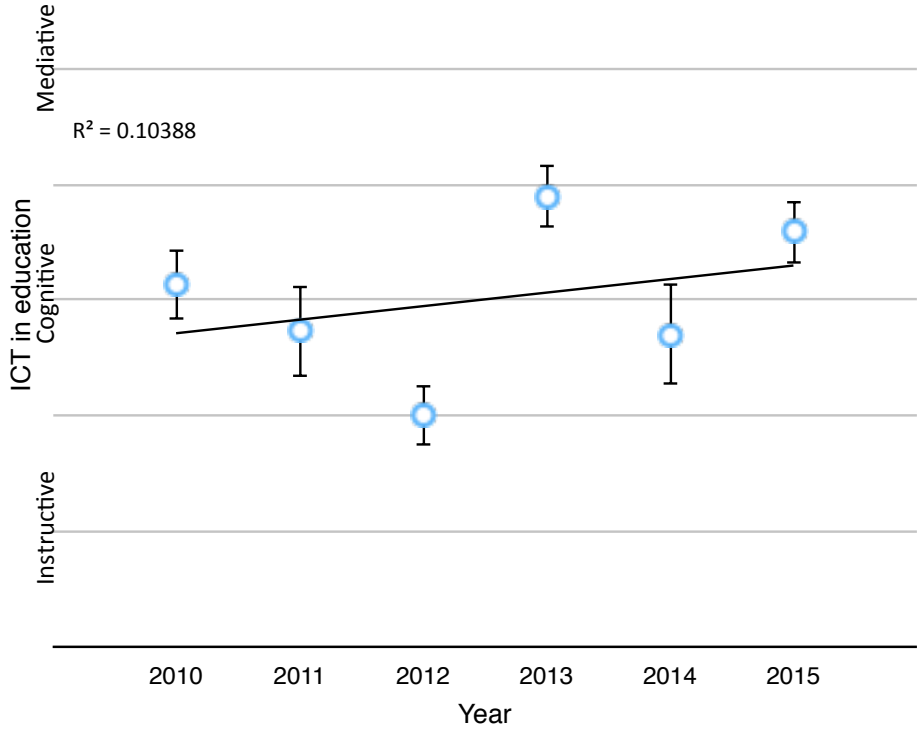

Figure 11. **Evaluation the use of ICT in education associated with research of the use of ICT to support teaching and learning (*n*=56; bar=standard error of the mean).**

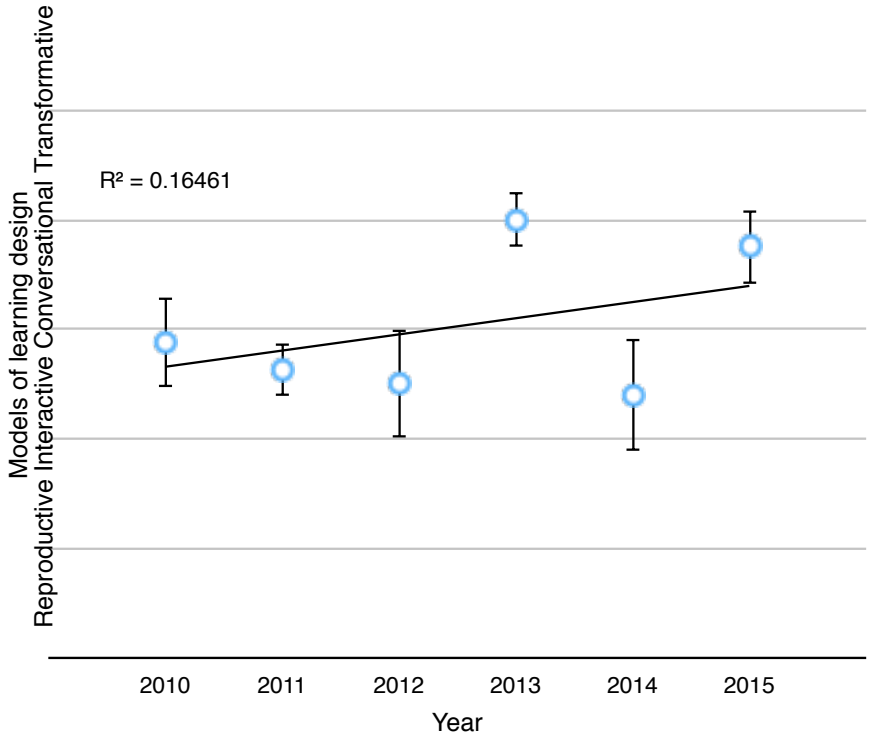

Figure 12. Evaluation the use of the models of learning design associated with research of the use of ICT to support teaching and learning (n=56; bar=standard error of the mean).

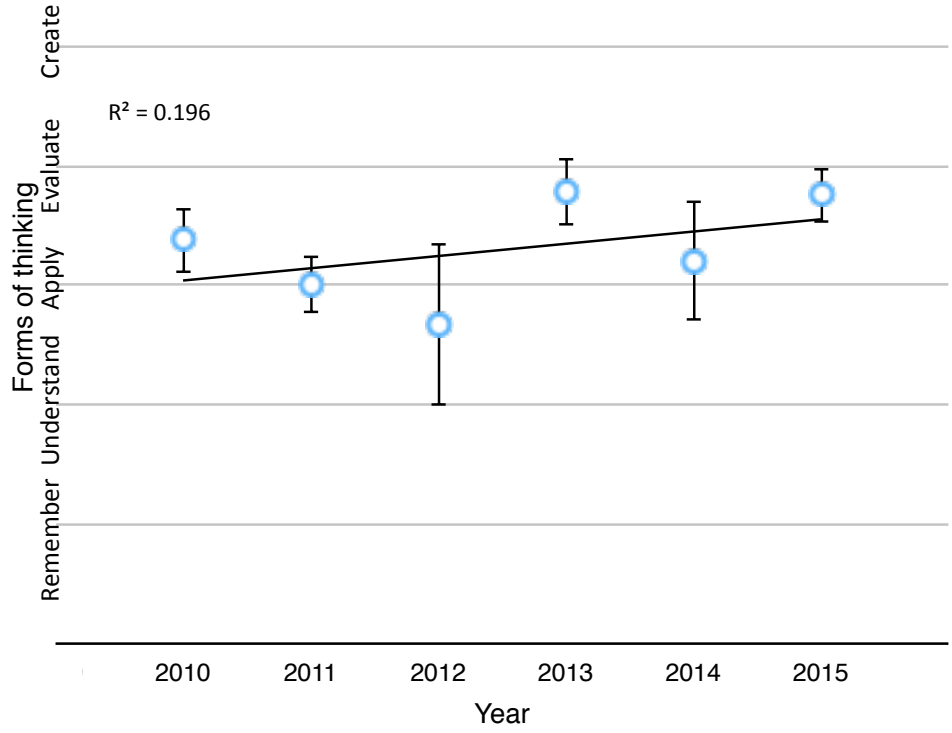

Figure 13. Evaluation the use of forms of thinking associated with research of the use of ICT to support teaching and learning (*n*=56; bar=standard error of the mean).

Fifty-six research articles that reported on the design of learning and associated outcomes were subjectively evaluated using the NIMB framework and analysed over time (Fig. 10-13). Mean values and associated standard errors are reported for each of the four vectors of the model: notions of learning (Fig. 10), use of ICT in education (Fig. 11), models of learning design (Fig. 12), and forms of thinking (Fig. 13). The analyses are similar for all the vectors. While there is a slight upward trend for each vector, these relationships are not statistically significant. This means that from 2010 to 2015 all form of teaching, learning designs, use of ICT and model to design earning are used internationally. However, ICT is mainly used as a cognitive tool to support the participation notions of learning. In addition, actions required by participants in ICT mediated learning design are about application and evaluation of information.

These analyses give rise to a number of reusable design principles:

3.1. The NIMB framework is able to evaluate teaching and learning outcomes (modes of thinking) using three independent variables including:
   a. Notions of learning (acquisition, participation and contribution);
   b. ICT in education (instructive, cognitive, mediative); and
   c. Models for learning design (reproductive, interactive, conversational and transformative.

3.2. The independent variable ICT in education mediated the contribution of the models for learning design variable and is therefore an important factor contributing to the development of higher order thinking objectives, such as creativity.

3.3. Reviews of international practice predominantly use a participatory approach.

3.4. Reviews of international practices associated with the use of ICT in education to foster all forms of thinking skills and objectives ranging from remembering to creation are clustered around the notions of using technology as a cognitive tool.

3.5. Reviews of international practices associated with the use of ICT in education make use of learning design models that support interactive and conversational approaches.

3.6. Use of drill-and-practice ICT tools in education support memorisation of information and development of skills.

3.7. The use of ICT tools to mediate learning fosters the development of higher order skills required to be creative.

Successes

ICT use has become an important aspect of teaching and learning in primary schools across the world because of the potential it has to improve the quality of learning (Vanderline, Aesaert & Braak, 2015).

The success of using ICT in teaching and learning varies from context to context, as do the success factors. Bhuasiri, Xaymoungkhoun, Zo, Rho and Ciganek (2012) identified critical success factors that influence the acceptance of e-learning systems in developing countries. These factors include technology awareness, attitude towards e-learning, enhancing basic technology knowledge and skills, improving learning content, motivating users to use e-learning systems, and high level support from the university. A study conducted in Saudi Arabian schools also confirms that ICT training and having a clear ICT policy in a school will go a long way in enhancing integration of ICT in the curriculum (Albugarni & Ahmed, 2015). Success factors highlighted above are pertinent in the developing context where there is limited exposure to technology on the part of both learners and teachers. Formal and systematic training programmes to familiarise people with the technology and to equip them with basic technological skills are key motivating factors for use of ICT in education.

Whether or not technology itself can teach remains a moot point, especially in the developing world. However, research in both the developing and developed world suggests that using ICT in teaching and learning makes a difference in terms learner performance. In a study conducted in Ecuador on the impact of using ICT in educational attainment, Carrillo, Onofa and Ponce (2011) found that

computer-aided instruction had a positive impact on the mathematics scores of learners in primary schools. Similarly, the MoMath Project that was started in South Africa in 2007 where Grade 10 learners accessed mathematics content using mobile phones showed that by 2011, there was a 14 per cent increase in mathematics skills, with substantial increase in time-on-task on the part of the learners (UNESCO EFA, 2015). In a big study that evaluated the impact of replacing the traditional algebra curriculum with integrated dynamic software and wireless networks in the USA, students demonstrated better mastery of core algebra concepts as well as procedural and conceptual problems as a result of the change to a technology enhanced curriculum (Hegedus, Dalton & Tapper, 2015).

ICT-integrated learning enhances understanding of difficult and abstract concepts in Chemistry. As Su (2011) argued from studies conducted in Taiwan, ICT integrated chemistry texts not only increased students' motivation to learn, but also improved learner performance and promoted the study attitudes of students. In more developed contexts where ICT have been well integrated in the curriculum, teachers have used technology as a strategy for enriching curriculum delivery by using open education resources. In a study of the impact of Curriculum Customisation Service (CCS), a software tool that was designed to support teachers in the digital era, results showed that there was significant increase in teachers' awareness of other teachers' practices and in their frequency of using interactive resources in their instruction (Ye, Recker, Walker, Leary & Yuan, 2015). In addition to this, students who were taught by teachers who showed the most variety in their use of the CCS had significantly higher learning gains.

Today's complex and fast-evolving world calls for young people who are creative and have problem solving skills. Ackaoglu reports on a study which shows that children can be taught problem solving through the use of computer programming (Akcaoglu, 2014). In this study, a group of middle school students with an average age of 12.6 was exposed to a game design programme for a period of 10 days. Students were assessed in their problem-solving skills at the beginning and at the end of the programme. The results showed that there was a significant improvement in students' problem-solving skills after participating in the programme. This study demonstrates that game-design activities (which make use of technology) can be used to enhance children's problem-solving skills.

The first examples illustrate that time-on-task approaches to teaching mathematics improved skills and motivation (remembering-acquisition-instruction); enriching the curriculum through engagement supported the development of understanding of chemistry (understanding-participatory-instruction); and the use of game development supported the development of problem-solving skills (create-participatory-mediative). These examples support the design principles associated with the NIMB framework:

3.3. Practices predominantly use participatory approaches.

3.4. The use of ICT in education fostered thinking skills and objectives that range from remembering to creation are clustered around the notions of using technology as a cognitive tool.

3.6. Use of drill-and-practice ICT tools in education support memorisation of information and development of skills.

3.7. The use of ICT tools to mediate learning fosters the development of higher order skills required to be creative.

ICT and teacher professional development

Saide (2010) made a strong case for the need for a more comprehensive suite of ICT professional development activities given that study's findings of the negligible impact that the current introductory ICT short course offering had in building teacher confidence and optimal use of ICT in teaching, learning and management. This finding was further corroborated by Amory (2012) reviewing the use of electronic learning resources in Gauteng schools that found current ICT

professional development opportunities were inadequate for teachers, citing the in situ training model approaches as a causal factor and recommending rather a developmental approach built on appropriate theoretical constructs. The latter study also ascribed the resistance of teachers to using ICT to the limited notional time allocated to workshops.

The NIMB framework advocates that to uplift educational practices with ICT a social constructivist model of learning needs to be part of practice. This supports Mikre (2011), who argued "regardless of all the limitations characterising it, ICT benefits education systems to provide quality education in alignment with constructivism, which is a contemporary paradigm of learning" and recommended that integration of ICT into the curriculum should be parallel to teacher professional development. However, Intel (2012) research indicated that inexperienced teachers lack subject and pedagogical knowledge to support the use technology in teaching, professional development often focuses on ICT skills rather that the integration of ICT into teaching practice, and institutional support systems are limited. Furthermore, top down approaches to transform teaching that include the uses of technology rarely work - supplying equipment and wiring school do not transform teacher practices (Vrasidas, 2015). Other barriers to the integration of technology into the classroom include: timetabling pressures (Bower, Highfield, Furney & Mowbray, 2013; Oye, Iahad & Rahim, 2014); lack of confidence (Wikan & Molster, 2011; Dwayi, 2015); lack of technical support (Oye, Iahad & Rahim, 2014); the perceived status of technologies (Hadfield, Joplin, 2014); insufficient funds and lack of leadership in schools in terms of funding, vision, and implementation plans (Khan, Hossain, Hasan & Clement, 2012).

To overcome such barriers local (Hennessy, Harrison & Wamakote, 2010) and international (Desimone, 2009; Romeo, Lloyd & Downes, 2012; Colpaert, 2013; Laurillard, Charlton, Craft, Dimakopoulos, Ljubojevic, Mogoulas, … & Whittlestone, 2013; Mabunda, 2013) authors advocated that teacher professional development requires a common conceptual framework for the use of ICT as well as teaching strategies based on contemporary pedagogic theory and approaches. In addition, teaching and computer self-efficacy and constructivist teaching beliefs (Sang, Valcke, van Braak & Tondeur, 2010) significantly improve teachers' integration of ICT into teaching. Successful initiatives that improved the use of ICT in teaching included: modelling of online collaborative group work (Ernest, Guitert Catasús, Hampel, Heiser, Hopkins, Murphy & Stickler, 2013); a 12-week collaborative, inquiry based learning practices (Valtonen, Kukkonen, Kontkanen, Sormunen, Dillon & Sointu, 2015); and time spent on professional development activities (Gunn & Hollingsworth, 2013). Dwayi (2015) demonstrated that when lecturers in technology from a vocational education and technology college were engaged in critical reflection on the use of technology embedded in a socio-cultural world, they developed a better understanding of the context, as well as ontological and epistemological approaches to the use of ICT in professional development and teaching. Furthermore, learning tasks for teachers need to be authentic (Teräs & Herrington, 2014; Rodriguez & Shaw, 2015). The most significant outcome of professional development is the transfer of skill and pedagogical knowledge development during development session into the classroom (ref).

Previously, the role of ICT in education vector of the NIMB framework was identified as an independent variable that mediates the relationship between the models of the learning design and the learning outcomes. The use of ICT in learning design ranges from instructive through cognitive to mediative. An exemplar study by Wang, Hsu, Reeves and Coster (2014), which used ICT as a cognitive tool to mediate learning, highlighted a number of important points pertinent to teacher professional development. This four-year design based research study involved 25 teachers from 24 K-12 science classrooms that made use of technology as cognitive tools with their students. Results showed teachers' positive changes in teaching and interaction with their students, who gradually took control of their own learning. This in turn led to a positive impact on students' understanding of science and ICT skills.

More importantly, this research identified a number of reusable design principles related to the integration of ICT into teaching and learning, including:

4.1. Teachers need time to master skills required to learn technology integration strategies and make learn to support their students;

4.2. Sharing among teachers allow teachers to take ownership of the technology and develop confidence;

4.3. Choices of technology needs to be affordable, free, and easy to access;

4.4. Use of technology literacy programme can support the development of technical skills;

4.5. Support from more knowledgeable colleagues and leaders is helpful;

4.6. Understanding the alignment between classroom activities and standards is vital;

4.7. An appropriate technology integration framework should include technology skill development and the pedagogical use of technology;

4.8. A virtual learning community where teachers can share their successes and challenges provides good support;

4.9. Scaffolded professional development opportunities should be provided for using technology as a cognitive tool; and

4.10. Templates should be provided to help teachers organise their use and development of cognitive ICT tools.

These principles aligned to the NIMB framework should, therefore, also influence the design of Initial Professional Education of Teachers (IPET) and Continuing Professional Teacher Development (CPTD) programmes. Yet, teachers also need to understand the role of ICT in: education policy; curriculum and assessment; and organization and administration (UNESCO, 2011). This UNESCO Competency Framework for Teachers (ICT-CFT) described each of these framework dimensions of a teacher's work at three levels: technological literacy, knowledge deepening (use of technology to solve complex problems) and knowledge creation (tools that support knowledge creation). The NIMB framework and Phakisa Lab streams can be aligned to the ICT-CFT framework. Therefore, the dimensions of the framework are labelled policy, professional development, pedagogy, curriculum and content, assessment, ICT and connectivity, and management and systems. Furthermore, the pedagogy dimension includes acquisition, participation and contribution, and the ICT dimension instructive, cognitive and mediative approaches. The integrated representation of the ICT-CFT and NIMB frameworks, and the Phakisa Lab streams (Fig. 14) was used to describe the context of the study, and can act as a developmental, planning and evaluation tool.

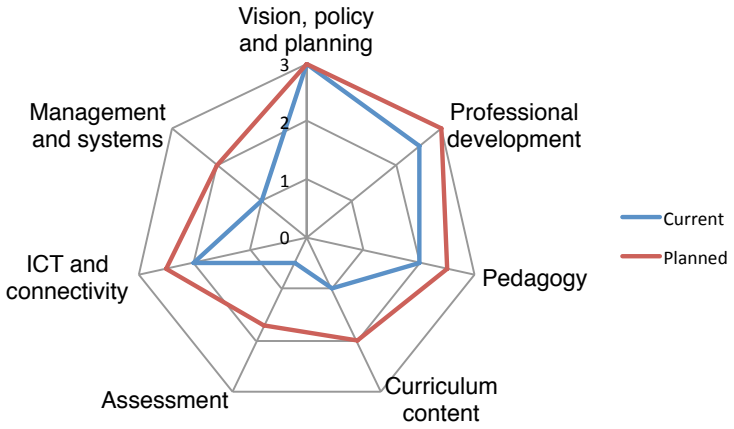

Figure 14. Model representing the integration of the NIMB and ICT-CFT framework with Phakisa Lab streams.

Elements associated with each of the components of this model are described in the next section in order integrate the principles developed thus far and to take into account current developments in the basic education sector.

Strategic Objectives and Recommendations

Introduction

The alignment of the Operation Phakisa streams, the ICT-CFT (UNESCO) and the NIMB framework creates a comprehensive model to structure a strategic objectives discussion. Furthermore, the principles previously identified are used to highlight important concepts and findings of the research. Objectives for the macro-, meso- and micro-levels of the education system are given for each element of the ICT-CFT-NIMB, namely: vision, policy and planning; professional development; curriculum content; assessment; ICT and connectivity; and management and systems.

Vision, policy and planning

Macro-level

The national department is responsible, in consultation with stakeholders, for the development of a coherent vision of ICT use in the South African school education[2.2], and for policy development, planning[2.1] and deployment to support the vision. In addition, national officials need to develop guidelines to support and capacitate the implementation of the vision at the meso-level. These policies need to highlight the important role of teachers[1.1] and pedagogy[1.2] in teaching and learning and the development of ICT-literate citizens[1.3].

Meso-level

Provincial and district officials need to have the knowledge and skills to support school management teams in the development of their individual policies, visions and plans for the use of ICT in their schools.

Micro-level

Each school should have a comprehensive vision for the use of ICT that is aligned to national policy priorities. The vision should: support the curriculum and promote the accountability of the school; be designed with all staff members, school governing board members, parents and students; identify the necessary policies to support the use of ICT in learning, teaching, assessment, management and administration. The vision should be revised in terms of new technological developments and pedagogical approaches.

Professional development

ICT skills development is required for all officials, managers, administrators, ICT technicians and teachers. Officials, managers, teachers, school board members and trainers require professional development in the pedagogical use of ICT in teaching and learning[2.3].

Macro-level

Existing providers can support ICT skills development using existing curricula. However, to further strengthen professional development, national officials should design a curriculum for officials and in-service educators aligned with the NIMB framework[3.1] and endorsed through the South African Council of Educators (SACE) CPTD system. The design of the intervention needs to be in based on the principles previously described[4-1-4.10]. Providers, such as Higher Education Institutions and NGOs, should implement and deliver short learning programmes aligned to this curriculum. National officials responsible for teaching and learning should be required to be competent learning with technology practitioners.

In addition, the pre-service teacher Minimum Requirements for Teacher Education Qualifications needs to include the NIMB framework to ensure the future teachers will understand the *learning with technology* paradigm.

The lack of implementation of an ICT platform to support in-service teacher professinal development needs to be addressed.

Meso-level

Provincial and district officials responsible for teaching and learning are required to be competent learning with technology practitioners. They support and guide the micro-level professional development opportunities and feed to the national department suggested improvements to the design of the programmes.

Micro-level

Schools need to develop plans for individual members and whole school development to regularly and systematically review the ICT skills of staff and identify individual and whole-school needs in accordance with the vision of the school.

Pedagogy

It is essential that pedagogical approaches associated with the use of ICT in teaching and learning shift away from acquisition-instructive-reproductive-remembering to contribution-mediative-transformative-creative modes[3.1, 3.4, 3.5, 3.7]. Vision, policy and planning and professional development strategic objectives, as discussed above, should incorporate these pedagogical approaches.

Officials at the macro-level, in consultation with meso-level (provincial and district) officials and school management and teachers, should develop an instrument for self-evaluation of the pedagogic use of ICT in teaching and learning for the micro-level.

Curriculum content

Macro-level

It is acknowledged that there has been substantial development of learning resources in South Africa to support teaching and learning; for example the literacy, numeracy and life skills workbooks developed at a national level, and the materials developed for provincial initiatives such as the Gauteng Primary Literacy and Mathematics Strategy. In continuing this process, emphasis needs to be placed on educational resources that encourage learners to actively participate in the learning process, rather than being passive recipients of content. The future development of curriculum content needs to consider the notions of learning, use of ICT in education and models of learning[3.1]. In addition, material designs need to include creative outputs[3.2], collaboration[3.5], and ICT mediation[3.7]. Use of Creative Commons licencing needs to be prioritised.

Meso-level

Officials need to understand the requirements for future curriculum content development and be able to support teachers to use and adapt materials.

Micro-level

The schools create environments to support teachers to use and adapt content appropriately and creatively for their learners and contexts that are shared, not only in the school, but also in national teaching portals.

Assessment

The education system should provide appropriate ways to support both formative and summative assessment. There are a number of different stakeholders who require information on student performance, including: national government, national and provincial entities, schools, pupils and parents. Each group requires specific information.

Macro-level

A number of systems are currently in use to support the Annual National Assessments and the Matric results. Little data is available in the public domain, or was supplied by DPME, to make an evaluation of these systems. However, ICT systems for formative and summative evaluation at the school level need attention. Furthermore, the use of mobile device and other approaches to connect learners, teachers, schools and parents need to be considered.

Meso-level

Provincial and district officials need to support school management teams in support the use ICT for formative and summative assessment.

Micro-level

Development, implementation and use of reliable systems to support the use of ICT in formative and summative assessment should form part of the management objectives of the school. The use of self- and peer-assessment is known to improve performance.

ICT, connectivity, management and systems

Macro-level

This element is concerned with the physical environment for ICT, the impact of the physical environment on the quality of learning, teaching, assessment, management and administration. Also to be considered is the sufficiency of the ICT resources. Areas to be considered include: networked access for staff and students within a school and Internet access in relation to the needs of the school. To support the development of ICT-literate citizens for participation in the knowledge economy[1.3], it is required that all learners are skilled in the use of technology to find, understand, apply and evaluate information in order to create new knowledge. Therefore, even in the most rural areas of South Africa, teachers and students need to learn and work in a networked environment.

This does not mean that they are necessarily connected to the Internet, but they should have access to some form of local-area network. For school management purposes, at least one office needs to be connected to the Internet. The HSRC Policy Dialogue on ICT in education posits "[s]low speeds and low levels of bandwidth have resulted in failure to integrate ICTs in education, and have contributed to the concomitant lack of use of available technology in schools. The assumption that schools require lower levels of bandwidth should be challenged" (p. 5). The argument that availability of connectivity has limited the integration of technology into teaching and learning is spurious as the use of ICT as a cognitive development tool is not predicated on connectivity. However, it is necessary that in those schools without connectivity, teachers and learners have access to a local area network. In addition, South Africa requires that local area networks at schools are connected to a wide area network to support the development and use of the school management and examination system. Developments in this area include the Data Driven Districts Approach (Michael & Susan Dell Foundation), improvement to the South African School Administration and Management System (Zenex Foundation, 2015), and the UkuFUNda Mxit Reach application. More specifically, the plans for a national ICT school network (KPMG, 2009), the e-education Plan and Norms and Standards (DBE, 2014) and the study of existing e-education initiatives for the National Education Collaboration Trust (Ostrowick, 2015) articulate ways in which ICT can provide the infrastructure required to support the education system. Principles that should be use in designing the system, include:

- Every school needs at least a single connection to the educational wide area network.
- Different school contexts necessitate different models of connectivity to the educational wide area network.
- All teachers and learners should make use of technology in order to be ICT literate and to use technology as a cognitive tool to support learning.

- Security of the system must be considered from a number of perspectives. Some 'clients' require read and write privileges, while others only require read privileges.
- The design, implementation and management of the education wide area network should make use of the most recent architecture to support future development but should be built according to internationally agreed standards.
- Interfaces used by meso- and micro-levels should not require additional licencing, specific software or hardware.
- Bi-directional flow of data to support national objectives and local initiatives and management should be part of the specification.
- Use should be made of a change management system to implement the local and national management systems.

Meso-level

Provincial and district officials support the use of the national developed system at the meso- and micro-levels. They also foster communication between the marco- and micro- levels.

Micro-level

The ICT infrastructure and connectivity requires technical support at the local level and therefore requires in-house capacity to support local and national systems. Data needs to be available to support planning and the teaching agenda.

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