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Research Article

A developing realist model of the pedagogical affordances of ICTs

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ABSTRACT
This article sets out the eWits model of the pedagogical affordances of ICTs. These are inherent properties of computer technology that constitute possibilities for teachers to act to enable learning in classroom contexts. The model is informed by Gibson's realist theory of the psychological affordances of objects. We challenge interpretivist notions of affordance: while teachers recognise ICT affordances and activate them in pedagogical practices, these acts of recognition do not constitute them. Affordances are powers and potentials in the technology, and exist whether or not they are recognised and actualised by a teacher. On this understanding, we put forward a typology of ICT affordances that can be read in contrasting directions. First, it models a hierarchy of technological potentials, sourced initially in the capability of tools themselves, which afford a succession of action possibilities for teachers, from technological literacy, to the representation and recontextualisation of knowledge, to pedagogical engagement with learners. Second, it reveals how recognition of these affordances by teachers is manifest in pedagogical decision-making in the ongoing knowledge construction that characterises classroom activities. Our consolidation of the model is described, as we have developed it in the course of our own research work.

Keywords: affordances, e-learning, ICT pedagogical affordances, ICT integration, pedagogical decision-making, technological reductionism

Categories: • **Applied computing** ∼ **Education, E-learning** • *Human-centered computing* ∼ *Ubiquitous and mobile devices*

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1 INTRODUCTION

Over the past decade, the academic team – comprising researchers, teaching staff and postgraduate students – concerned with educational technology in the Wits School of Education has developed a focal conceptual and theoretical framework to guide our research endeavours. In this article, we try to set out that framework. It brings into concert two theoretical notions,

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the *pedagogical integration* and the *affordances* of information and communication technologies (ICTs), which together avoid the consequences of a reductionist technological rationality in the classroom. Computers can help enable remarkable learning; they can also stifle or trivialise it. Generally, the academic view of educational technology is that "the provisioning of ICT infrastructure must not be construed as automatically affording learners attainment, because there is intrinsically nothing in the provisioning of ICT tools that automatically guarantees cognitive development" (Dlamini & Nkambule, 2019, p. 5). Unfortunately, politicians and the IT industry often ruthlessly pump out the opposite message, in campaigns that seem to trump (no pun intended) academic knowledge on computers in education every time. One only has to google "computer solutions in education" to see the extent of claims that educational technology *will* solve all our educational problems. It is like the old IQ cop-out[1]– the education problem is defined as that which the computer can solve. We wanted to figure out how ICTs can indeed provide teachers with some of the tools they need to advance and deepen classroom learning.

We call our model the *eWits model of pedagogical affordances* for three reasons: "Wits" is the colloquial name for our university, in the isiZulu and Siswati languages, "eWits" means "at, to or from the place called Wits", and eWits connotes engagement with e-learning.

Our argument proceeds as follows: first, we sketch the history of how we arrived at the concept of ICT affordances in education. Second, we set out the importance of avoiding technological reductionism in teaching and learning, especially in this current era in which there is so much pressure on universities (and other educational institutions) to betray the pursuit of knowledge for the narrow transfer and processing of information about our society and economy. This leads to an account of Gibson's affordance theory, the major framework that underlies the complex conception of pedagogical affordances that we build up here. From there, the article moves through a narrative of how different members of our academic community contributed different dimensions of this model, along the way to defining what we suggest is a generative understanding of the pedagogical integration of the pedagogical affordances of ICTs that we can work with in our research and teacher education activities, and continue to develop in future.

2 A BRIEF HISTORY

The process we describe here started in our participation in the *Pan-African Research Agenda on the Pedagogical Integration of ICTs*[2] from 2007 to 2011 (Karsenti, 2009). We had just set up a Division of Educational Technology, and our "PanAf" engagements generated important, formative debates amongst us. The project introduced us to the notion of the pedagogical integration of ICTs in Africa, and that concept has been a central organising principle in our

[1]Boring (1923) posited a notorious operational definition in psychology: "Intelligence as a measurable capacity must at the start be defined as the capacity to do well in an intelligence test. Intelligence is what the tests test".

[2]We thank the project leader, Thierry Karsenti, and the Canadian funders CRDI-IDRC, for this opportunity.

academic work since. Our imperative became to ensure that ICTs are integrated according to primary pedagogical principles, and not that pedagogy is integrated according to technological principles, as so many IT companies, governments and funders seem to want to do.

One theoretical framework we explored before we came to affordance theory was TPCK (technological pedagogical content knowledge) (Mishra & Koehler, 2006). This model, which elaborates Shulman's account of the specialist knowledge of a teacher – pedagogical content knowledge, or PCK (Shulman, 2017) – helped us realise that there is TPK, specific knowledge of the capabilities of technologies in pedagogy, and conversely, "knowing how teaching might change as the result of using particular technologies" (Mishra & Koehler, 2006, p. 1028). It helped us understand that where there is no viable pedagogy – the 'chalk and talk' scenario, in which a teacher "mostly stands in front of the class lecturing, expecting that learners will learn simply by being told something … [or] writes things up on the board or overheads, believing that by copying them, learners will come to new understandings" (Moll, 2002b, p. 2) – then ICT as such presents the possibility of innovative pedagogy. But in the end TPCK is an empty shell; it tells us that it must be the case that technologies work in concert with pedagogy, but unless the reference point is an existing, engaged pedagogical practice at work in a classroom, it tells us little about how or why. TPCK demarcates the terrain of know-how (procedural knowledge), but it does not specify that know-how. It seems particularly incapable of helping us understand the integration of different tools for teaching specific subjects (Kim et al., 2013).

This led us to the *pedagogical integration of the pedagogical affordances of ICTs*. This formulation appears to be clumsy, but the theoretical salience of the repetition of the term 'pedagogical' is crucial to releasing the conceptual power of affordance theory in education. 'Pedagogical integration' focuses on teachers recognising real affordances in the object (computer hardware, software), and mobilising them to achieve their teaching aims in different ways at different points in time. 'Pedagogical affordance' elucidates the powers and potentials inherent in the technology itself, which are actualised only when the teachers use them strategically in realising their pedagogical ends.

In this article, and in the conceptual framework that we develop in it, we are concerned with both of these concepts: (i) the real powers and potentials of ICTs which constitute action possibilities in teaching; and (ii) the recognition by teachers of those powers and potentials as they practise in the classroom.

3 AVOIDING TECHNOLOGICAL REDUCTIONISM IN E-LEARNING

A compelling metaphor tells us, "we should not let the technological tail wag the pedagogical dog" (Moll, 2002b, p. 17). The academic imperative in any context in which ICTs are introduced into classroom teaching and learning practices, is to investigate and clarify how such technologies can be integrated so that they do not dictate engagement with learners in schools, but rather enhance or enrich prevailing disciplinary pedagogies. This is not to say that there are no schools or other educational institutions which could well do with a change in their teaching and learning practices, but simply that the source of these changes is unlikely to be

the introduction of ICTs.

The issue is simple. If we start with a generalised belief that the introduction of technology into classrooms, or of 'blended learning', will solve learning problems in education, then we are likely to focus on ICTs as the source of change. As researchers, we will probably conduct quantitative studies that treat digital hardware or software as an independent, causal variable, or qualitative studies that ask a question something like, "how do computers improve learning in a Grade 6 mathematics classroom?" If, however, our starting point is that teachers can use the powers of technology in thoughtful ways, with clear educational aims in mind, to enhance pedagogy in their classrooms, then we are likely to focus on those teachers as the source of change. Our research studies will examine their understandings of ICTs in the classroom, the way they mobilise the many exciting potentials of technology to enhance their practices, their preparation and training in relation to the pedagogical integration of ICTs, and so forth.

These contrasting starting points have dramatic implications for teaching and learning. The former position is what we call *technological reductionism*. When ICTs become the focus, then learning can be undermined. Learners and teachers tend to concentrate more on how to work the technology than on acquiring depth in understanding knowledge systems. For example, research suggests when they work with PowerPoint, students spend more time jazzing up their presentations than they do thinking about the knowledge content of the courses they study (Oppenheimer, 2004). Similarly, increasing Internet usage in school and university learning is associated with the decline of systematic thought and ability to concentrate on complex tasks (Carr, 2010). In the South African context, Fataar (2020) puts the problem of technological reductionism in education trenchantly, highlighting the deepening socioeconomic inequality that goes with it:

> … emerging educational architectures [of the ICT revolution] and a critical consideration of [its] curriculum and pedagogical dimensions … are informed by an orientation that prioritises the acquisition of generic skills. Sidelining knowledge and concepts as central to the structuring of the curriculum, a generic skills approach succumbs to what might be called a knowledge blindness that holds pernicious consequences for epistemic access in South Africa.

Chugh (2010, p. 62) expresses a strong version of this technological reductionism: "*Subjecting students to technologies* in the educational environment will make them better prepared for the future by providing them with the requisite digital literacy skills" *[our emphasis]*. He argues:

1. ICTs in science and technology are pervasive in society.
2. Today's diverse students want education to prepare them for this society.
3. Therefore, e-learning tools are fundamental in meeting the needs of students (Chugh, 2010, p. 59).

The validity of the argument might be shaky, but it is akin to a view that is widely encountered in educational institutions. Klaus Schwab, the primary ideologue of the "fourth industrial revolution", claims that education systems must prioritise "competences" required by an emerging "global work force" (Schwab, 2018, p. xvi). He means the World Economic Forum (WEF) "skill sets" (WEF, 2020, p. 4) that formulate the expert know-how required to run the geographically dispersed, ICT-driven networks of the globalised economy. The WEF's *Schools of the Future* report (WEF, 2020), which sets out how schools are supposed to achieve these competences, mentions "skill" over 160 times. However, it is telling that it mentions "knowledge" only six times (four in the phrase "knowledge society"!). This is a strong indication of a creeping technicism in notions about what schools should be doing.

In the 2020s, Schwab's competences resonate, across the industrial revolutions, with BF Skinner's notion of behavioural repertoires (Moll, 2021, p. 108):

> … a teaching machine presents carefully programmed material "in which one problem can depend upon the answer to the preceding problem and where, therefore, the most efficient progress to an eventually complex repertoire can be made" (Skinner, 1954, p. 95). The echo of Skinner in Schwab (2018, p. xvi) is deafening: "technology makes it possible to synthesise and analyse data to tailor pedagogy to individual student needs and provide feedback in real time".

In education, the WEF's generic skill sets are the latest in a long line of technique- or performance-oriented conceptions that reduce knowledge to the ability to execute information processing skills. Fortunately, teachers tend not to do this, a situation notably demonstrated amongst teachers in Silicon Valley in late 1990s (Cuban, 2001). Our research suggests that teachers in South African schools are generally not taken in by such narrow views (Minty & Moll, 2020; Ndlovu & Moll, 2016). They tend not to regard ICTs as the centre of educational operations, but they do draw on their often remarkable pedagogical affordances to enhance the learning processes in their classrooms.

It is worth noting that the above formulations (Chugh, 2010; Schwab, 2018; WEF, 2020) were all prior to the Covid-19 pandemic, when most primary, secondary and tertiary education was driven online around the world. The often repeated claim that Covid-19 has accelerated and demonstrated the possibilities and reach of polysynchronous online learning does not allay concern about its creeping technicism. Sean-Michael Morris points out, "the pandemic has not been learning design's finest hour" – the mass movement into online teaching spaces by educators with little history in digital learning amplifies its technicism and stifles its critical pedagogical possibilities (Morris, 2020).

Seymour Papert warned us about such technological reductionism some 50 years ago. In developing his LOGO software, he demonstrated that most developments of ICTs for the classroom are no more than the invention of "new gadgets to teach the same old stuff in a thinly disguised version of the same old way" (Papert, 1972). He criticised three traditional applications of computers in schools:

The computer as automated teacher: learning is programmed as a sequence of correct responses to questions about "a fixed body of discrete facts", as the attainment of strictly specified, predetermined behavioural objectives (Papert, 1979, p. 74).

The computer as simulated world: there is an illusion that the learners discover knowledge freely for themselves; in practice, the pre-defined boundaries of a computer programme constrain them (Papert, 1979, p. 76).

The computer as toy: restrictive computer languages allow only the "transmission of specific programming commands at specified times in the learning process" (Papert, 1979, p. 77).

Against these, Papert urges computer-enabled learning programmes based on a "grander vision" of learning, and of children. For him, technology-enabled teaching and learning must be situated in a microworld, "a subset of reality or a constructed reality whose structure matches that of a given cognitive mechanism so as to provide an environment where the latter can operate effectively" (Papert, 1980, p. 204).

This brings us to the second starting point mentioned earlier – that teachers take the lead in integrating technology in thoughtful ways into their pedagogical practices. There are numerous examples of this in the literature on the pedagogical integration of ICTs. For example, critical pedagogy envisages a teacher engaging learners actively in "post-typographic forms of textual practice" (Lankshear & Knobel, 2003, p. 17). In the 1990s, Anderson and his colleagues developed a successful intelligent tutoring system, based on a computational model replicating human reasoning and learning, that teachers could deploy to teach algebra to Pittsburgh high school students. Its crucial design feature, developed with teachers ("domain experts"), was that it presented itself as a nonhuman tool to assist learning rather than as a virtual human tutor (Anderson et al., 1995). When we prioritise the potential of teachers to mobilise digital technologies, "formal education can be so much more, and make far better, more direct, and more enabling connections between what students learn now and what they will do and be later" (Lankshear & Knobel, 2003, p. 206). It seems clear that a focus on the pedagogical affordances of ICTs offers a principled way of ensuring that teaching and learning does not become subjugated to the technological rationality of machine culture.

4 AFFORDANCE THEORY

The theoretical notion of affordance was first formulated in 1977 by the ecological psychologist James Gibson (Gibson, 1977, 1979). It describes the properties of an object that allow a person to use it to realise an action. More technically, it refers to action potentials or possibilities that exist in the environment. While they obviously have a relation to the action capabilities of an actor, these potentials are independent of the actor's perceptual abilities, experience or consciousness. When Gibson argues this case, he is not reducing psychological experience or interpretation to physics. For example, he states: "continual substantial surfaces are not real for physics, but they are primary realities for ecology and for the kind of psychology

founded on it" (Gibson, 1979, pp. 111–112). But neither does he suggest that interpretation by the actor constitutes ecological reality, or that it is merely a way of looking or thinking. Gibson describes his realist theory of affordances as follows: "physical reality does not consist of meaningful things. [However, in] the world of ecological reality … their meanings can be discovered" (Gibson, 1979, p. 33).

It seems unfortunate then that Norman (1988) adopted a radical interpretivist stance when he sought to popularise the idea of affordances in theorising human-computer interaction. He insisted that an affordance was in the first instance a mental representation, the perceived possibility of an action, even though such a power or potential may not actually exist in the object in question. However, the absurdity of Norman's position becomes clear after a moment's reflection.

Consider the murder weapon in Roald Dahl's (1970) short story, *Lamb to the Slaughter*: an angry wife brains her cheating husband with a heavy, frozen leg of lamb. She then thaws it out, roasts it to perfection, and serves it to the police officers investigating the killing. They are baffled that they cannot find the murder weapon. "It's probably right under our noses", says one, as he munches away. The leg of lamb is a weapon that can seriously crack open a skull only when it is frozen; it is a culinary delight when it is roasted. No amount of mental representation can change one of the affordances of the leg of lamb to the other in each of its different states. The aggrieved woman recognises its affordances, but she does not construct those affordances.

Nonetheless, seemingly intractable theoretical disputes regarding the perceived, intended and actual use of objects dominated research on affordances for decades after Norman's intervention (McGrenere & Ho, 2000). In more recent times, though, there has been an emerging realist consensus, opposed to the idea that affordances are simply mental (or merely 'discursive') constructions. Norman (1998, pp. 123–124) himself backs away from a strong interpretivist account in his later work, when he acknowledges his mistake:

> It's very important to distinguish real from perceived affordances. … the perceived affordances are [only] what determine usability. I didn't make this point sufficiently clear in my book and I have spent much time trying to clarify the now widespread misuse of the term.

Norman's (1988) early position suggests that perception creates affordances, whether or not they are actual properties of the object. In its context, his view was consistent with the 'constructionist' challenge to positivist psychology that gained ground in the seventies (Moll, 2002a), but ultimately it falters in an extreme relativism. This tension between the 'naïve realism' of positivism and radical relativist versions of interpretivism brought about the seemingly empty debates on affordances of the eighties and nineties, which assume a subject/object dualism (Oliver, 2005; Reed, 1997; Turvey, 1992).

Gibson's (1982, pp. 407–408) own formulation of these debates seems not to get trapped in this dualism:

> There has been a great gulf in psychological thought between the perception of space and objects on the one hand and the perception of meaning on the other. The meaning or value of a thing consists of what it affords. Note the implications of this proposed definition. What a thing affords a particular observer … points to the organism, the subject. The shape and size and composition and rigidity of a thing, however, point to its physical existence, the object. But these determine what it affords the observer. The affordance points both ways. What a thing is and what it means are not separate, the former being physical and the latter mental.

Gibson works with crucial distinction between *what a thing affords* and the *affordances of things* (Natsoulas, 2004, p. 327). The former refers to the powers and potentials of an object (often an artifact), whether or not these are recognized or realised by a human actor. This is a version of the critical realist distinction between the real and the actual domains (Bhaskar & Hartwig, 2016, p. 7). The real is whatever exists, whether it be natural, social or psychological. It consists of generative mechanisms that inhere within beings or objects, in their properties, structures and causal powers. The actual refers to what happens if and when these generative mechanisms are activated, and what they bring about as a consequence of their activation. A number of authors have identified the critical realist underpinnings of ecological psychology, and Gibson in particular (Jessop, 2015; Michaels, 2003; Mingers et al., 2013; Njihia & Merali, 2014; Volkoff & Strong, 2013).

These authors all suggest there is increasingly a "united front to oppose those who defined affordances as mental representations, arguing that such views directly contradicted Gibson's intention" (Volkoff & Strong, 2013, p. 819). The following definition by Michaels (2003, p. 146) is close to the consensus reached by theorists in this terrain in recent times:

> Affordances are the actions permitted an animal by environmental objects, events, places, surfaces, people, and so forth. An action is understood as a goal-directed movement (or non-movement) that entails intention, the detection of information, and a lawful relation between that information and the control of movement … an affordance entails an effectivity for its actualisation but not for its existence.

Norman's mistake is an idealist conflation of *what a thing affords* and the *affordances of things*. While the actual use of an affordance involves intentional, goal-directed movement, it is important to affirm Gibson's original sense of "possibilities of action afforded, or offered by, a given material object or social network" (Jessop, 2015, p. 240). In summary, the affordances of an object or being have three fundamental properties (McGrenere & Ho, 2000):

- They exist relative to the action capabilities of a particular actor.
- Their existence is independent of the actor's ability to perceive them.
- They do not change as the needs and goals of the actor change.

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These recognitions become crucial when we seek to understand how teachers realise the pedagogical affordances of ICTs in their classrooms (Phakathi & Moll, 2022). We must avoid the absurd implication of radical relativism at work in the classroom, that what teachers use the technology for "is not only restricted to the real affordances it has" (Ndlovu, 2015, p. 30). The crucial point is that even though a teacher might be able to recognise out-of-the-ordinary affordances associated with ICTs, these affordances are, ontologically speaking, in the technology, not in the teacher.

In the work we have done in educational technology at Wits, we have sought on the one hand to identify and understand the real pedagogical affordances of ICTs, and on the other to understand how teachers recognise those affordances and elect to use them in various ways that enhance the pedagogical practices of their classrooms (Dlamini & Nkambule, 2019, p. 92):

> We consider ICT affordances as process concepts; thus this work is an effort to operationalise and bring meaningful linkage between pedagogical choices and technology affordances. There is value in having deeper understanding of digital technologies categories and the link to digital technologies affordances in order to develop a systematic approach to integration in education. This has the potential to enable educators to adopt and use technology in teaching and encourage a different perception toward digital technologies.

If we do not seek to specify pedagogical affordances in this careful way, then the concept "has marginal value because it lacks specific meaning" (McGrenere & Ho, 2000, p. 8).

5 THE FALSE PROMISE OF CONOLE AND DYKE

At this point in our argument, we bring into focus a well-known, germinal article by Conole and Dyke that has been prominent in discussions about ICT affordances in education (Conole & Dyke, 2004). It sets out a "taxonomy of ICT affordances". The article has played a significant role in bringing the concept of affordances into the terrain of educational technology, and influenced the thinking of most people (including ourselves) located in the e-learning terrain. In particular, it posited a vision of how we might escape reductionist technological rationality that dominated discussions of computers in classrooms. In the end though, the article flatters only to deceive.

Conole and Dyke aim to produce a "clear articulation of [ICT] affordances … to understand how these technologies can be most effectively used to support learning and teaching" (Conole & Dyke, 2004, p. 113). They seek "to draw out these *inherent properties* building on Gibson's concept of affordances" (Conole & Dyke, 2004, p. 224) (our emphasis). However, having declared allegiance to Gibson, they show little evidence of his realist principles at work in their analysis. Instead, they locate themselves within "relevant current social theory and critique" associated with "late modernity" (Conole & Dyke, 2004, p. 116) – effectively the anti-realist

terrain of social constructivism[3] – and head off down the Normian slippery slope towards radical relativism. There is no evident concern in their taxonomy with the inherent properties of objects that constitute affordances. The grounds on which they identify an affordance tend to be purely discursive: anything that appears to be an affordance, by some interpretation or another, becomes an affordance. They do precisely what Ndlovu warns us not to do, imagining the use of ICT in education as "not only restricted to the real affordances it has" (Ndlovu, 2015, p. 36).

We briefly analyse seven categories[4] in the Conole and Dyke (2004) taxonomy to justify our claims:

Accessibility: ICTs afford access to vast information sources through technical means and user networks. Conole and Dyke (2004, p. 116) spin the notion of 'access' here as the 'critical selection' of information, rather than 'searching' for it. However, this is misleading. ICTs do not afford the selection of information; they provide search engines and similar affordances that enable people (like teachers) to select information critically according to their operative knowledge criteria.

Diversity: ICTs afford a "vast range of diverse and different experiences that can inform learning" (Conole & Dyke, 2004, p. 117). Yes, but Conole and Dyke do not sufficiently comprehend that such experiences are always mediated, represented by people using online learning environments. Strictly speaking, they should be writing about how ICTs afford the representation of diversity (and of a vast range of unfamiliar experiences), rather than the 'affordance of diversity'.

Communication and collaboration: ICTs afford new forms of communication, "enriched by [dialogic] engagement with the 'other' " (Conole & Dyke, 2004, p. 117). However, it seems obvious that it is not ICTs as such that afford such principled engagement with diversity – white supremacists (unfortunately) use them too. They do provide communicative, collaborative and easily transmittable representational affordances to allow people to engage in dialogue with the 'other'.

Reflection: ICTs afford reflection and critique which is not time-pressured. True, asynchronous technologies and quickly-accessible materials enable such discussions. However, Conole and Dyke (2004, p. 118) caricature conventional courses of study when they claim that online learning affords more systematisation than face-to-face learning. Both

[3]This is the broad theoretical terrain occupied by "(social) constructionists, constructivists, pragmatists, postmodernists, epistemological (cognitive, epistemic) relativists, objectivists, sceptics, interpretivists, deconstructionists [and] reflexivists" (Edwards et al., 1995, p. 43). It is not the kind of constructivism that assists us very much in education (Moll, 2002a).

[4]We have concentrated on these seven identified affordances because they clearly lie within the domain of a classroom or a virtual learning environment, with direct implications for pedagogy and teachers' work. The remaining three (speed of change, monopolization and surveillance) seem to be in the domain of institutional change, although they are by no means insignificant.

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delivery modes can provide systematic developmental frames for critical reflection over long time periods if the right representational and pedagogical affordances are mobilised. It requires a good teacher to recognise and mobilise the appropriate, inherent ICT (or other) affordances to do so (Dlamini & Nkambule, 2019).

Multimodal and non-linear: "The non-linearity of the web (epitomised by hypertext and powerful search engines)" affords individualised learning pathways and strategies (Conole & Dyke, 2004, pp. 118–119). This claim seems to rest upon a prevailing fallacy, that people have different (individual) learning styles that manifest in preferred learning strategies. Neuropsychology has thoroughly falsified this notion (Beere et al., 2005; Geake, 2008; Goswami, 2004). A 'learning style', if this is the correct term, is a characteristic of the material being learnt, not of the learner. It follows that ICTs cannot afford individualised learning; what they do afford are different modes of representation that in turn afford a teacher different ways to teach different knowledge content.

Risk, fragility and uncertainty: This claim seems to be that late modern ICTs afford high-risk choices to humans, often based on unintended consequences. However, the term 'affordance' has little coherence here. Did the frozen leg of lamb afford the risk of dying? Can a machine embody unintended consequences? In education, there are indeed risky actions or states of mind associated with "the increase in the volume of [instantaneous] information available on the web" (Conole & Dyke, 2004, p. 119) – plagiarism, skimming and scanning rather than focused reading, and "the permanent state of distractedness that defines the online life" (Carr, 2010, p. 112), to name but a few. But to consider these to be 'affordances' of ICTs stretches the point too far.

Immediacy: We agree that ICTs afford very rapid, real time, exchanges of information via the Web and email. This does lead to "a shift in user (student) expectations in terms of response times" (Conole & Dyke, 2004, p. 120).

There is little clarity here about how the supposed affordances are "inherent properties building on Gibson's concept of affordances" (Conole & Dyke, 2004, p. 114). This conceptual confusion means that any sense that these "affordances" could be relevant to a teacher or learner is accidental, rather than based on rigorous affordance theory.

6 TECHNOLOGY, TECHNOLOGICAL AFFORDANCES AND PEDAGOGY

Members of our academic team started working, often loosely, with concepts of the pedagogical affordances of ICTs over 10 years ago, as reflected in a number of publications (Dlamini, 2018a; Dlamini & Coleman, 2017; Dlamini et al., 2018; Dlamini, 2018b; Moll, 2002b; Ndlovu, 2009; Ndlovu, 2014). We owe our late-onset academic colleague, Tom Waspe, a special debt of gratitude for the work he did circa 2013 in bringing a more rigorous concept of ICT

affordances to the fore. He designed and taught our first fully online course,with a substantial module on affordances. The model that we present here emerged from these engagements.

The initial organising principle for this theoretical framework came from the work of Drennan on coaching teachers in iPad usage (Drennan, 2018; Drennan & Moll, 2018). As indicated earlier, we had been consumed in futile debate about whether PCK or TCK took precedence in understanding teaching and learning with computers. The TPCK model did not help us at all, and it soon became clear that the relationship between pedagogy and technology needed to be conceived in some other way. The concept of affordances stepped into the breach.

Drennan's important theoretical move was to draw a distinction between the capabilities and the affordances of digital technologies (Table 1).

So very simply, the small size, robust screen and long battery life (technological capabilities, or technical features) of the iPad afford easy portability and the possibility of extended work without access to electricity – there being no need for a power cable (technological affordance), and so on. Both are inherent properties of technology, but previous accounts of them tended to conflate the two categories. Drennan and Moll's (2018, p. 122) distinction is a crucial insight into affordance theory:

> Technological capabilities can be defined as the hardware and software elements of the physical iPad and its applications. An example … would be the physical camera and its operating software. Technological affordances can be defined as the use of technological capabilities, for example, using the camera to take a photo.

Another example relates to the direct manipulation interface of the iPad. Among its distinctive technical features are a touch screen and software that allow the user to control the device by touching buttons directly on the screen (technological capability). This affords continual actions that correspond to the manipulation of physical objects, e.g. spreading one's fingers to enlarge an onscreen object (technological affordance).

Two important, related theoretical principles need to be highlighted: the directionality of affordance, and the notion of affordances as emergent properties. Technological affordances emerge from the capabilities of technology. 'Emergence' describes how any qualitatively new phenomenon emanates from forms of organisation at a lower level (Drennan, 2018; Polanyi, 1967, p.36; Polanyi, 1968; Salthe, 1991; Bhaskar, 1993; Moll, 2004, p.59). The latter provide initiating conditions, or constitutive elements, of the former. Prigogine (1984) won his Nobel prize for demonstrating how 'self-organising systems' lead disorder at one level to emerge as order at a higher level. Popper and Eccles (1977, p. 21), in the same vein, examine the emergence of mind in these terms: "In a material universe, something can emerge. Dead matter seems to have more potentialities than merely to produce dead matter. In particular, it has produced minds … consciousness of self, and the human awareness of the universe". Note the principle that the materiality of lower levels are constitutive elements of higher levels of organisation – so technological affordances incorporate technological capabilities, but cannot be reduced to them.

Table 1: Drennan's model of the technological and pedagogical affordances of iPads

iPad Capability	**Technological Affordance**	**Pedagogical Affordance**
Size (physical capability) Long battery life (physical capability)	Portability Teacher carries little home Work for long hours without electricity	Polysynchronous learning, not time bound – learning is ubiquitous, asynchronous, flexible Teacher and learner mobility inside and outside the classroom
Touch screen (hardware capability) Direct interface (software capability)	Intuitive interface – tap and swipe Immediate access Quick and easy to learn	Teach with and through, not about, technology – procedural thinking Facilitate learner's control – deliberate tap and swipe ("the click option") Team teaching and materials development Teacher corrections/feedback
Multimodality (hardware capability) Integrated images, audio and video resources (software capability)	Multimodal convergence Make and play back audio and video recordings Access to worldwide resources	Multiple representations of knowledge Movie/audio recordings Written/spoken comments Authentic learning Virtual stage/performance Digital textbooks Facilitate learner construction of material -– research, produce, represent
Guided access (software capability)	Temporarily restrict to single app Choose app features Disable screen buttons	Stay on task Facilitate learner focus/"ownership" Disable task irrelevant screen areas Prevent accidental gesture distractions
Apps (software capability) Apple TV (connectivity capability) Apple classroom (connectivity capability)	Seamless integration Share screen of one iPad Monitor and manage iPads	Document and resource sharing makes collaborative work easier Whole class can see peers' or teacher's work – text, audio, shared to whole class or visual presentation or Only teacher can see learners' work. Teacher sends or receives work via any app to and from individuals

Drennan and Moll (2018) go on to build a model of how pedagogical affordances emerge from the nexus of technological affordances and capabilities. "Pedagogical affordances refer to the way teachers and students use technological affordances to meet educational goals. The camera … might be used (technological capability) to take a photo (technological affordance) of a flower to show leaf arrangement (pedagogical affordance). The purpose to which the technological affordance is put determines its categorisation as a pedagogical affordance" (Drennan & Moll, 2018, p. 125). Table 1 sets out this analysis of the technological and pedagogical affordances of the iPad.

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Nelisiwe Phakathi, in her study on young children using iPads to document their own learning (Phakathi & Moll, 2022), brought "the click option" (Battro, 2004) into the picture. Battro's idea highlights the most basic affordances of computers in learning, where the properties of a mouse, a keyboard, a cursor, selection buttons or a touch screen enable tapping, swiping, dragging, typing, font sizing, zooming, pinch-zooming, highlighting, viewing and clicking. Both pupils and teachers actualise these affordances constantly in a digitally-enabled classroom. These in turn afford deliberate acts by a teacher to articulate knowledge in the classroom. Battro's thesis is that the "global impact of digital technologies on human society, and particularly on education, is related to … the ability to decide to produce a simple change of state in a system" simply by clicking a mouse or tapping a screen (Battro, 2004, p. 79). There are two levels of affordance here that we can call technological and pedagogical affordances respectively (Drennan, 2018). We find the 'click option' idea particularly generative in understanding ICT affordances: it refers to a conscious, deliberate act to represent or act on the world in a particular way by actualising the powers and potentials of the computer. It is an idea that avoids completely the dangers of technological reductionism.

7 HUMAN COMPUTER INTERACTIONS

Parallel to these developments, Dlamini and Nkambule (2018a, 2019) were mapping 'affordances', as expressed in the broad educational technology literature, according to certain ethical principles regarding e-learning. In this, they employed the Human-Communication-Human-Interaction Model as an organising framework (Desjardins, 2005; Desjardins & Bullock, 2012). Desjardins categorises ICT usage into four sets of competences, by analysing the ability of people to carry out tasks with technology (Desjardins et al., 2001). Three stem from the complex cognitive tasks individuals can perform with a computer:

Informational competence: a set of theoretical and procedural knowledge comprising strategies used to search, select and produce documents. Cognitively, it refers to "mindtools" involved in the identification, selection, accumulation, organisation and interpretation of information (Jonassen, 1996);

Epistemological competence: a set of theoretical and procedural knowledge about the focal discipline or field of study. The 'paradigmatic' rules, methods and parameters of a discipline require particular cognitive operational methods or schemas to use any digital tool (e.g. photo, video, spreadsheet, database, authoring system) effectively;

Social competence: a procedural knowledge set related to the use of computer-mediated communication technology. This entails viable strategies of respecting and acting with others online, that are safe and ethical.

The fourth, *technical competency*, is basic procedural knowledge of hardware and software – 'how to work it'. The model assumes any user of digital technologies must have these competencies, learned by using ICT tools in collaboration with teachers and other users.

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Desjardins (2005) distinguishes these competences from more restricted views of ICT literacy (echoing Papert's "grander vision" of computer-enabled learning programmes for children), allying himself to the foundational principle of *digital literacy* that it "is about mastering ideas, not keystrokes" (Gilster, 1997, pp. 1–2).

Dlamini and Nkambule carry this "*relational approach* to how people interact with technology" into their analysis of affordances (Dlamini & Nkambule, 2019). They do so according to four *principles of learning* that they suggest are latent in the use of ICTs for pedagogical purposes:

Autonomy: a learner-centred approach can be supported by the ubiquitous learning made possible by online courses of study;

Connectedness: conceptual fluency and higher-order thinking can be fostered by interaction with digital "content, concepts and terminologies", simulations, etc.;

Diversity: educational access and collaboration can be enabled by online learning, although "pedagogical and technical expertise of the teacher is absolutely critical";

Openness: there is a reciprocal relationship between teaching and technology that encourages educators to use ICTs in the classroom *and* determines how these technologies take shape in on-the-ground implementation (Dlamini & Nkambule, 2019, pp. 922–923).

None of these are *action possibilities* for teachers as such, and so should not be thought of as affordances (as Conole and Dyke (2004) loosely do with respect to 'diversity'). They are, however, principles that should guide teachers to mobilise affordances in the classroom.

These principles, coupled with those of the directionality and emergence of affordances, produce a typology of ICT affordances that can be read in two, contrasting directions, as represented in Figure 1.

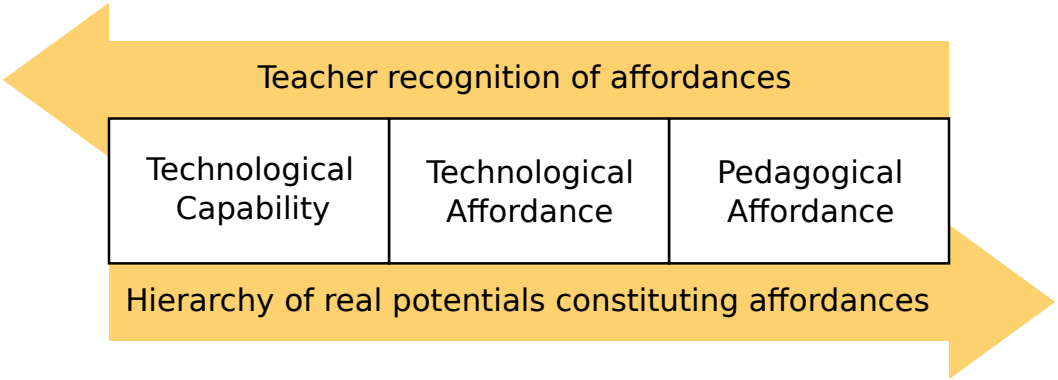

Figure 1: The emergence and recognition of pedagogical affordances

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The bottom arrow depicts the emergence of pedagogical affordances. It uncovers a hierarchy of ICT-related potentials, sourced initially in the capability of tools themselves, which then afford action possibilities for teachers, from manipulating technology to actual pedagogic practices. The top arrow reveals how their grasp of these affordances manifests in ongoing pedagogical judgements that actualise the technological possibilities of ICTs. Recognition of these affordances is often tacit in ongoing knowledge construction that characterises learning activities.

Two other important insights from Dlamini and Nkambule (2019) strengthen the vertical dimension of Drennan's (2018) model (see Table 4):

1. Desjardins's (2005) 'competencies' add conceptual cohesion to the contents of each row.
2. They add various insightful content to the Drennan model. However, bear in mind her caveat that "teachers and students are endlessly creative, so no exhaustive listing of affordances would be possible" (Drennan, 2018, p. 16).

8 MULTIMEDIA AFFORDANCES

Over time, we have understood that the ability to represent knowledge using multiple media types is perhaps the most important affordance of ICTs in the classroom (and any other learning space). Some theorists of e-learning suggest a focus on representation is "empiricist" or "objectivist" (Hodgkinson-Williams, 2006, p. 6). However, psychological acts of mental representation are more complex than that, in both its internalising and externalising strata (Clark, 2006). Think for example of trying to teach the idea of a waterfall to children in Dobsonville and Katlehong. Because the former township is close to the Walter Sisulu Botanical Gardens, local schools organise excursions for learners to see and directly experience a substantial waterfall; the learners in Katlehong, however, cannot easily have the same experience. Obviously, a direct encounter with a waterfall affords the best representation of the idea that children can have, but for Katlehong children, multiple, age-appropriate representations of a waterfall – the use of multimedia affordances by a teacher (see Figure 2) – can go a long way to helping them understand the idea.

Ndlovu (2015, 2016), in her research work on the affordances of digital media, carried out case studies on how teachers in Soweto classrooms actually mobilise ICT affordances. Its theoretical starting point was a critique of the linear use of digital technologies that makes them appear to be "mere vehicles that deliver instruction" (Ndlovu, 2015, p. 2). It presents an immediate challenge for the Drennan model: most South African schools are not equipped with iPads, nor any other kind of tablet technology. So we had to think more carefully about how this model of ICT affordances would apply to the classroom local area network (LAN) setups that schools do indeed have – some of these learning environments are connected to the Internet, others are not. The model also needs to take account of 'intermediate devices', like laptops. For this purpose, it seems plausible to treat iPads and standard school computer

Figure 2: Multimedia representations of a waterfall

laboratories as two ends of a continuum. We thus expanded the scope of applicability of the model, as represented in Table 2, without losing sight of advantages that tablet technology has over fixed, desktop technology.

Table 2: From iPads to classroom LANs

Technological Capability	**Technological Affordance**
Size	Portability
Long battery life	No power cable ↑
Tablets ↑	Teacher carries little home
	LAN-wide connections ↓
Desktops ↓	Central console
Classroom LAN	
Touch screen	Intuitive interface
Direct interface	Tap and swipe –- immediacy of access ↑
Tablets ↑	Easy to learn
	Click and drag ↓
Desktops ↓	Mouse-cursor interface
Mouse, external keyboard and trackpad	

Obviously, one huge advantage that tablet (and laptop) machines have is polysynchronous

learning that is not time bound – learning can be flexible, 'anytime, anywhere', and teachers and learners are mobile, inside and outside a classroom. However, if we accept this limitation, LAN-based school computer laboratories with Internet access still have, *in principle*, most of the pedagogical affordances of ICTs available for teachers. If teachers themselves use mobile computer technology, with connected presentation devices, the situation is even better.

To turn now to more significant implications of Ndlovu's research: she builds her account of affordances on the five ICT *media forms* identified by Laurillard (2002) – narrative, interactive, communicative, adaptive, productive – and on 'thick description' of the mobilisation of these to represent knowledge by the teachers in those Soweto classrooms. She also employs some of Conole and Dyke's (2004) descriptions of affordances to help her identify pedagogical value, "to understand how teachers go about engaging ICTs to enrich their teaching" (Ndlovu, 2015, p. 21). Table 3 represents Ndlovu's understanding of the relationship between digital multimedia and the pedagogical affordances of ICTs.

Table 3: Ndlovu's description of the pedagogical affordances of media forms

Media Form	**Affordances**	**Evidence**	**What pedagogical value does it add?**
narrative	non-linear	multimodality	apprehending structure and connections
interactive	immediate	immediate feedback	exploration – misconceptions amended
communicative	collaboration	discussion: class/group	re-description of concepts
adaptive	(de)familiarise[5]	reproduction, experiment	concretising theory in practice
productive	articulation[6]	product, animation, model	knowledge construction

Laurillard's crucial claim is that it is the entire learning environment that must afford learning (Laurillard, 2012, p. 105). She suggests that Papert's notion of a *microworld,* "an environment designed to afford the learning of some system or set of concepts and powerful ideas" (Laurillard, 2012, p. 54), might be the best way to think of the affordances of ICTs.

[5]Ndlovu's initial term here was 'diversity' (see Ndlovu and Moll (2016), p.126), after Conole and Dyke, by which she meant the affordance of ICTs to represent the unfamiliar to learners. In our post-publication discussions, on the problem of describing 'diversity' as an affordance, it was changed to '(de)familiarisation'.

[6]Similarly, Conole and Dyke's 'reflection' was the initial term here, but we realised that this applies anywhere and anytime in the learning activity. Instead, 'articulation' from Laurillard's (2002) description of the productive media form was adopted.

Media and modes can be mixed and matched in teaching – "the medium does not determine the form of learning. The teacher does that, by using it to convey what is to be done and what is to be learned" (Laurillard, 2012, p. 105). It is within this recognition that Ndlovu considered evidence of how teachers were using the affordances of ICTs in their classrooms. Evidence of *multimodality* was found (or not found) in the integration of different modes of communication, linked to narrative media used to deliver content "beyond linear pathways of learning". *Immediacy* was found in the use of ICTs by learners to solicit quick responses in the online learning environment. Laurillard (2002) associates this affordance with the ability to navigate with ease and control viewing of content. *Collaboration* was seen in easy communication with the teacher in online learning. *(De)familarisation* was found in the ability of ICTs to present learners with other people's experiences, "to make the strange familiar and the familiar strange" in exploring diversity and inequality!(Sikes, 2003). *Articulation* was evidenced in learners' ability to create their own models of the descriptions of the world. All of these affordances can be realised using both digital and non-digital media forms (Ndlovu, 2015, pp. 34–36). Laurillard (2012, p. 148) contends that, whatever the multimedia we use, the important thing is that we "understand the contrasting affordances of these different media, and their differential value for learning."

The notion of *representation* as an affordance has been apparent in the discussion up to now. In considering Ndlovu's research, we realised that there is a case to be made analytically to separate 'representational affordances' from 'pedagogical affordances'. The ability of digital multimedia to represent complex knowledge is a real, emergent affordance arising from the strata of technological capabilities and affordances. The ability of teachers to identify and use ICTs to represent knowledge is perhaps the salient feature of their use in education. In Figure 3, the notions previously classified together have been unbundled to further clarify the hierarchy of affordances that a teacher might recognise and mobilise. We have also worked Laurillard's media forms into the model in Table 4.

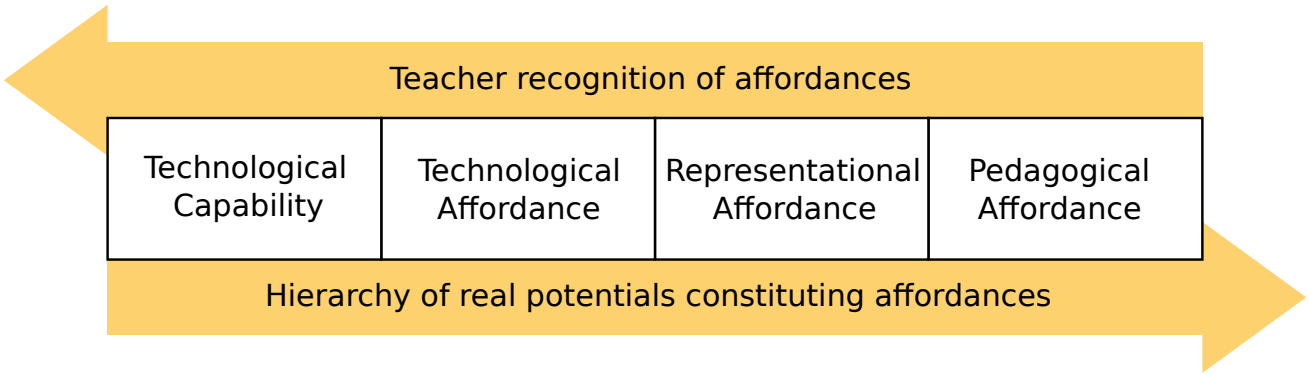

Figure 3: Working the stratum of representational affordances into the model

The understanding of the technological, representational and pedagogical affordances of ICTs in education arrived at in the preceding discussions is represented in Table 4.

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Table 4: The eWits model in all dimensions

	TECHNOLOGICAL CAPABILITY	TECHNOLOGICAL AFFORDANCES	REPRESENTATIONAL AFFORDANCES	PEDAGOGICAL AFFORDANCES
TECHNICAL INTERACTION	Touch screen Direct interface **Tablets ↑** **Desktops ↓** Mouse, external keyboard & trackpad	Intuitive interface Tap and swipe -– immediacy of access Portability No power cable ↑ Teacher carries little home LAN-wide connections ↓ Central Console Click and drag Mouse-cursor interface	***Interactive media*** Any time any place Direct manipulation interface ↑ ***"The Click option"*** –- deliberate representation (tap & swipe or click & drag)	Polysynchronous, ubiquitous, flexible learning Teacher & learner mobility inside/outside classroom ↑ Teach with & through, not about, technology –- procedural Teacher feedback Team teaching & materials development Facilitate learner control/ decision making ("click option")
INFORMATIONAL INTERACTION	Multimodal capability Integrated images, audio & video resources Texting Social media Web/ LAN access	Make and play back audio & video recordings Access worldwide resources Virtual learning environments	***Narrative & Productive media*** Multimedia presentations Movie/ audio recordings Virtual stage Digital textbooks Search for and exchange articles, video, music, books, etc.	Multiple representations of knowledge Strong teacher presentations -– synchronous and asynchronous Facilitate learner construction of material –- research, produce, represent Presentations/ performance by learners Written/ spoken comments Animation/ modelling Authentic learning
EPISTEMOLOGICAL INTERACTION	Guided access (software capability) Internet connectivity	Temporarily restrict to one app only Choose app features Disable screen/ hardware buttons Learning management systems Content management systems	***Adaptive media*** Guided access/ management of cognitive load Facilitate learning environment Create concept maps, plans, diagrams, pictorials, graphics Prevent accidental gesture distractions Disable task irrelevant screens	Stay on task Flipped classroom Facilitate learning centred tasks Diverse experiences beyond everyday Facilitate learner focus/ 'ownership' Complex calculations

Continued on next page

Table 4 – *continued from previous page*

	TECHNOLOGICAL CAPABILITY	TECHNOLOGICAL AFFORDANCES	REPRESENTATIONAL AFFORDANCES	PEDAGOGICAL AFFORDANCES
SOCIAL INTERACTION	Video, audio, texting Web-based connectivity (connectivity capabilities) Apps (software capability) Virtual environments (software/ connectivity capability)	Seamless integration Share screen Virtual learning environments/ Virtual classrooms Social media Monitor & manage ICTs	***Communicative media*** Networked collaboration Document and resource sharing Networked sharing of text, audio or visual Document sharing through any app to or from individuals Accessing others' screens Communicate via email, video, audio; social media	Whole class sees peers'/ teacher's work or Only teacher sees learner work. Teacher sends/receives work via any app Peer/teacher text, audio, visual to whole class Online collaboration Active participation

In viewing it, it is important to keep in mind the principled distinction between affordances and their actualisation. Affordances are the potentials in the networked iPad or LAN technology as such for pedagogical actions with respect to a teacher's or learners' goals. Actualisation, as the action itself, is the enacted configuration of pedagogical practices in any classroom (teaching/learning) episode. Thus, while affordances relate to potential actions and educational outcomes, actualisation relates to specific actions that a particular teacher or learners have taken.

9 CONCLUSION

Our research tells us that teachers seek to use ICTs to add pedagogic value to their existing teaching and learning practices. They tend to be sceptical about technology as the next 'big fix' in education, and resist injunctions to change entirely what they do to go digital – whether from education authorities, parents, or the general hype about digital technologies in our society. However, in an educational and social environment in which we now habitually use networked digital technologies to do our work and communicate, teachers do look for guidelines or ways of thinking about the pedagogic affordances of ICTs in their classrooms. As much as they need to know the subject matter they teach, they need to know how this knowledge can be expanded and elaborated by technology. As much as they have established pedagogical practices that allow them to recontextualise and represent knowledge, they need to think about how the integration of ICTs can enhance, deepen and widen access to these practices.

We understand that there is not one all-embracing theory that can grasp the complexity of teacher knowledge and practice. However, we put forward eWits as a framework which we believe teachers can use to understand and thoughtfully integrate ICT affordances in their classrooms. Reading Table 4 from left to right, they will be able to see the potentialities in

the technology that might enhance their teaching. Reading it from right to left will assist them to recognise what they should choose to integrate in their classroom activities. We also suggest that a similar reading of the eWits model can guide further research on successful (and unsuccessful) teaching with technology, and also curriculum development in teacher education related to *the pedagogical integration of the pedagogical affordances* of ICTs by teachers.

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