

# A sustainability framework for mobile technology integration in schools: The case of resource-constrained environments in South Africa

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*The application of mobile technology integration in schools has been widely researched. However, the sustainability of mobile technology integration in resource-constrained environments has received less attention. Diverse contexts and devices complicate the construction of a consolidated view of how to sustain the pedagogical practice of learning with mobile devices in these environments. The purpose of this article is to indicate how feedback from teachers and district officials informed the development of a sustainability framework for mobile technology integration in schools (SFMTIS) in resource-constrained environments in South Africa. Employing design science research as methodology, an initial sustainability framework was synthesised from the existing literature. Teachers' views were obtained regarding the integration of mobile technology in their schools and were subsequently processed to inform the further development of the framework. Teachers, who were trained, and had*

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Mabila, J., van Biljon, J., Herselman, M. (2017). A sustainability framework for mobile technology integration in schools: The case of resource-constrained environments in South Africa. *The Journal of Community Informatics*, 13(2), 59–86.

Date submitted: 2017-03-31. Date accepted: 2017-08-21.

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*previously participated in an initiative that introduced mobile tablet use, and where information and communication technology infrastructure was provided to their schools, were purposively selected for the study. The Department of Basic Education officials based at district offices were also interviewed for their views on the sustainable integration of mobile technology. The findings were used to refine the initial SFMTIS. Besides the refined sustainability framework, the research contributes novel insights into the different perspectives of the teachers and the district officials, and how those can impact the sustainability of mobile technology integration in resource-constrained environments.*

## **Introduction**

Mobile learning projects are often funded through short-term sponsorships for technical support and training, consequently leaving sustainability beyond their funding period unclear (Ng & Nicholas, 2013). Although initiatives are being undertaken to provide information and communication technology (ICT) infrastructure and e-resources, and for the ICT-related training of teachers in public schools in South Africa, long-term sustainability remains a risk in many of these initiatives (Meyer & Marais, 2014). Sustainability is not an attainable end state, but rather a fundamental characteristic of a dynamically evolving system, where long-term sustainability results from continuous adaptation to changing conditions (Fullan, 2004). Frameworks are therefore required as a guide for projects, so as to avoid sustainability pitfalls.

The shortage of suitable frameworks to guide the long-term sustainability of information and communication technology for development (ICT4D) projects is a major problem, particularly in developing countries (Gichoya, Hepworth & Dawson, 2006; Mamba & Isabirye, 2015). The diversity of contexts and devices complicates a consolidated view of how to sustain the practices involved in teaching and learning with mobile devices (Ng, 2013). The implementation of mobile learning in educational environments has been investigated in many studies, however, few have comprehensively interrogated the dimensions that sustain mobile learning, or have developed frameworks to sustain mobile learning in schools (Ng & Nicholas, 2013). The categorisation and synthesis of mobile learning models and frameworks by Hsu and Ching (2015) supports Ng and Nicholas' argument on the lack of sustainability frameworks on the use of mobile learning in educational environments.

The "Framework for sustainable mobile learning in schools" that Ng and Nicholas (2013) developed, together with the "Person-centred sustainable model for mobile learning", was developed in the context of an Australian school. The school's efforts sought to introduce and sustain an mLearn programme using personal digital assistants (PDAs), and the school allocated resources to internally fund the programme. Sustainability of mobile technology integration in schools has thus been researched in other countries. However, a sustainability framework where teachers and district officials' perspectives were applied to refine a sustainability framework in the context of resource-constrained environments is novel. The literature review conducted in this

study identified sustainability dimensions based on frameworks of ICT4D projects in resource-constrained environments, but those frameworks are not specific to the education environment. The research question that this article seeks to answer is: *How does the feedback from teachers and district officials inform the development of a literature-based sustainability framework for mobile technology integration in schools (SFMTIS) in resource-constrained areas of South Africa?*

Design science research (DSR) offers a methodology for designing information-based artifacts in a strategic and holistic way, as is evident from the design of a mobile skills curriculum for teachers in resource-constrained environments (Botha & Verster, 2014; Van Biljon, Traxler, Van der Merwe & Van Heerden, 2015). DSR was selected as research methodology for this study due to its phased processes, which ensures the relevance and rigor of the findings (Hevner, 2007) and its focus on context (external and internal environments) (Drechsler & Hevner, 2016). The research is structured as a single case study with two units of analysis, namely, teachers at public schools in the Cofimvaba school district in the Eastern Cape Province of South Africa and district officials.

In the following section, the background to the study is outlined. The research is then presented according to the phases of the DSR methodology, as applied in developing the SFMTIS. In the first phase, the extant literature, reviewed for the main themes of the study, is presented. In the second phase, the DSR methodology, as applied in the research, is discussed. The findings of the case study in which teachers and district officials from the Cofimvaba school district participated, are provided, and those findings subsequently inform the development of the SFMTIS.

## **Background**

South Africa spends about five per cent of its gross domestic product (GDP) on basic education (DBE, 2016). The basic education system in this country caters for large numbers of learners: in 2014, the number of public schools was 24,060, and 12,117,015 learners were served by 390 608 teachers (DBE, 2016). The costs of purchasing large numbers of textbooks and transporting them from publishers to warehouses and eventually to schools – some of which are remote – are high. Crises in schools have, in the past, resulted from delays in the delivery and availability of textbooks (DBE, 2012; DBE, 2015). The South African National Planning Commission states that shortcomings in the basic education system include challenges in respect of management and school support (including the role of district offices), a lack of cooperation between key stakeholders (particularly unions and government), and a lack of accountability. The Metcalfe report identifies bureaucratic inefficiency, inadequate school leadership and management skills, ongoing changes to curricula, and the unavailability of learning and teaching materials, as some of the challenges facing the basic education system (DBE, 2012). Using mobile technology to address certain of these challenges, for example by providing teachers and learners with PC tablets has been proposed and piloted (Herselman, Botha & Ford, 2014), but little evidence-based research on the sustainability thereof – as informed by teachers and district officials – is available, and this provides the rationale for this study.

The views of teachers from resource-constrained environments on technology integration have been investigated (Van Biljon et al., 2015), but the perspectives of district officials provide a novel angle. The four main roles of school districts are to plan and support, and provide oversight and accountability to schools under their care in line with provincial plans (SASA, 1996). Districts are expected to provide an enabling teaching and learning environment, in line with the education policy, and interact with schools through school visits, classroom observations, consultations, cluster meetings, feedback reports, and related activities. Districts are charged with holding principals accountable for the performance of their schools and account to the provincial department. Districts' roles include facilitating ICT connectivity to schools, organising professional development for teachers, administrators and managers, and consulting and engaging with the public (DBE, 2013). However, unlike schools, education districts are not empowered to raise their own revenue (DBE, 2013).

This study builds on previous research on the sustainability of ICT projects in resource-constrained environments in South Africa and ICT4D sustainability frameworks to develop a conceptual sustainability framework for mobile technology integration. A conceptual framework is a graphic or narrated artifact that explains important factors, concepts or variables, and the relationships among them (Miles & Huberman, 1994), in addition to representing ways of thinking about a problem, its complexities, processes, variables and outcomes, and their inter-relatedness (Bordage, 2009). It allows researchers to build on each other's work in order to arrive at a deeper understanding of a problem and to guide the development of possible solutions (Bordage, 2009). The framework employed here was developed through the application of DSR methodology (Drechsler & Hevner, 2016), as discussed in the next section.

## **Research methodology**

The DSR methodology (Drechsler & Hevner, 2016), selected for this research, was applied as shown in Figure 1. DSR begins with an important opportunity, a challenging problem, and an insightful vision or a conjecture regarding something innovative in the application environment (Hevner et al., 2007), and iteratively builds the artifact by following the rigor, design, relevance, and change and impact cycles (Drechsler & Hevner, 2016). The relevance cycle defines the context, problem or opportunity, and input requirements from the contextual environment, and introduces the artifact into the environment. The rigor cycle provides grounding through extant foundation knowledge, theories, domain experience, and expertise into the research, and affords new knowledge generated by the research to the knowledge base. The design cycle that iterates between the rigor and relevance cycles, supports research activity for the actual iterative artifact design and redesign, and corresponding artifact evaluation (Venable, Pries-Heje, Baskerville, 2016). The change and impact (CI) cycle captures the dynamic nature of IS artifact design and enables DSR to cope with dynamic application contexts and follow-up design efforts, which may result from introducing the artifact to the environment (Drechsler & Hevner, 2016). The CI cycle encompasses the artifact's immediate application, that is, direct users of the artifact and the wider context – the socio-technical system within which the immediate application context is a subsystem

(Drechsler & Hevner, 2016). The immediate application context for the SFMTIS (artifact developed in this research) includes the school systems and infrastructure, the teachers, learners and principal as well as the district office and the officials. The wider context is the education system and society within which the immediate application context is a subsystem. Figure 1 shows how the DSR methodology was applied in this research.

In the CI cycle, the need to examine the sustainability of mobile technology integration in schools in resource-constrained environments was identified, which resulted in the objective of developing an SFMTIS. In the relevance cycle, the context of the problem was defined as the teachers in schools in Cofimvaba, who were provided with tablets, ICT infrastructure, and teacher training, through the ICT for rural education and development (ICT4RED) initiative. The single case study employed in the design cycle was schools in the Cofimvaba school district located in the Eastern Cape province in South Africa. The two units of analysis in the case were the teachers and district officials. The literature review of sustainability frameworks and the Department of Basic Education and government documents provided the initial knowledge base in the rigor cycle.

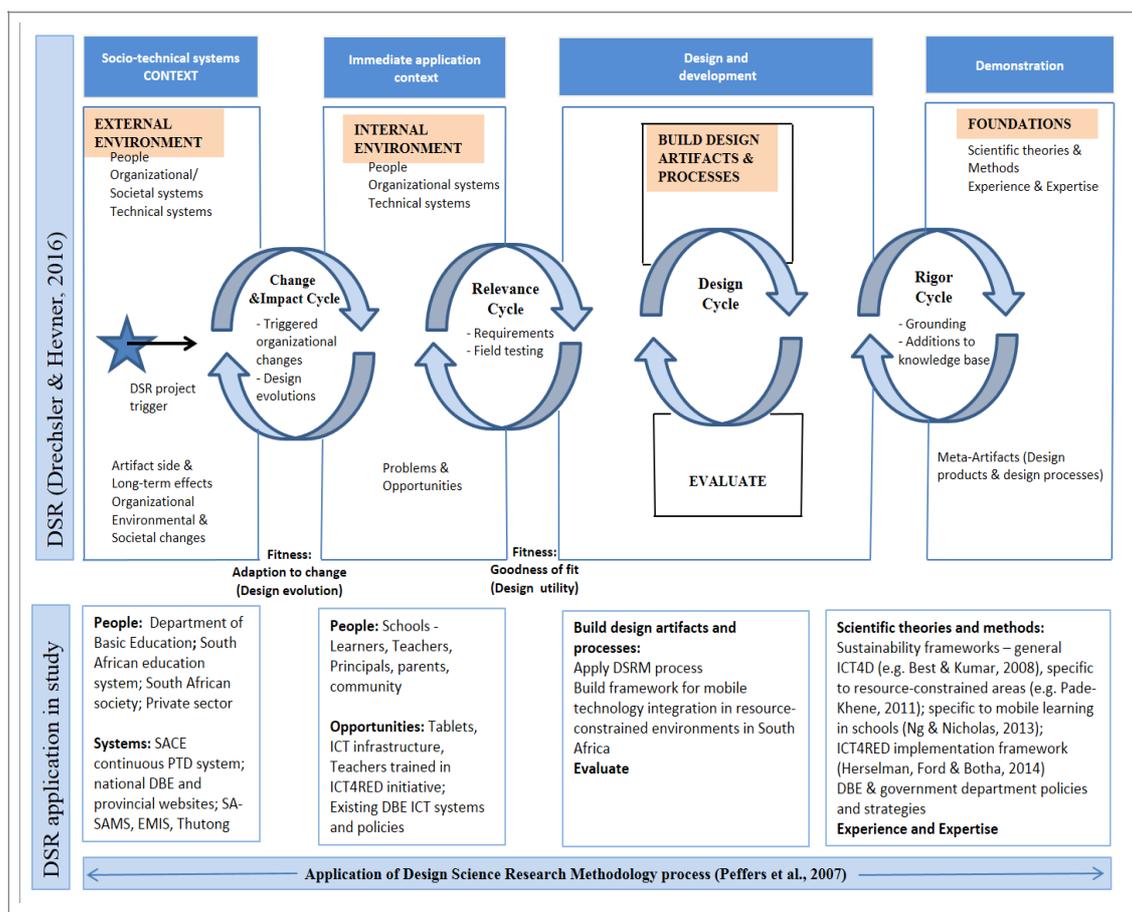


Figure 1: DSR methodology (Adapted: Drechsler & Hevner, 2016)

Peffers, Tuunanen, Rothenberger, and Chatterjee’s (2007) DSRM process provides a mental model and process of how to conduct DSR in information systems and consists

of six phases as depicted in Figure 2, where “rce” means resource-constrained environments and “mti” means mobile technology integration. Application of Peffers et al.’s (2007) DSRM process in developing the artifact incorporates practices and procedures required to carry out such research, including iterative design and development. There were three phases in this research. In the first phase, literature was reviewed to identify sustainability dimensions that were used in developing the initial SFMTIS. In the second phase, the views of teachers and district officials on mobile technology integration were investigated. Their feedback helped to refine and further develop the initial SFMTIS into the SFMTIS presented in this paper. In the third phase, the SFMTIS will be evaluated through expert reviews. Given the requirement of peer review as a measure of relevance and rigor in DSR, it was considered advisable to submit the framework for review and publication before embarking on Phase 3.

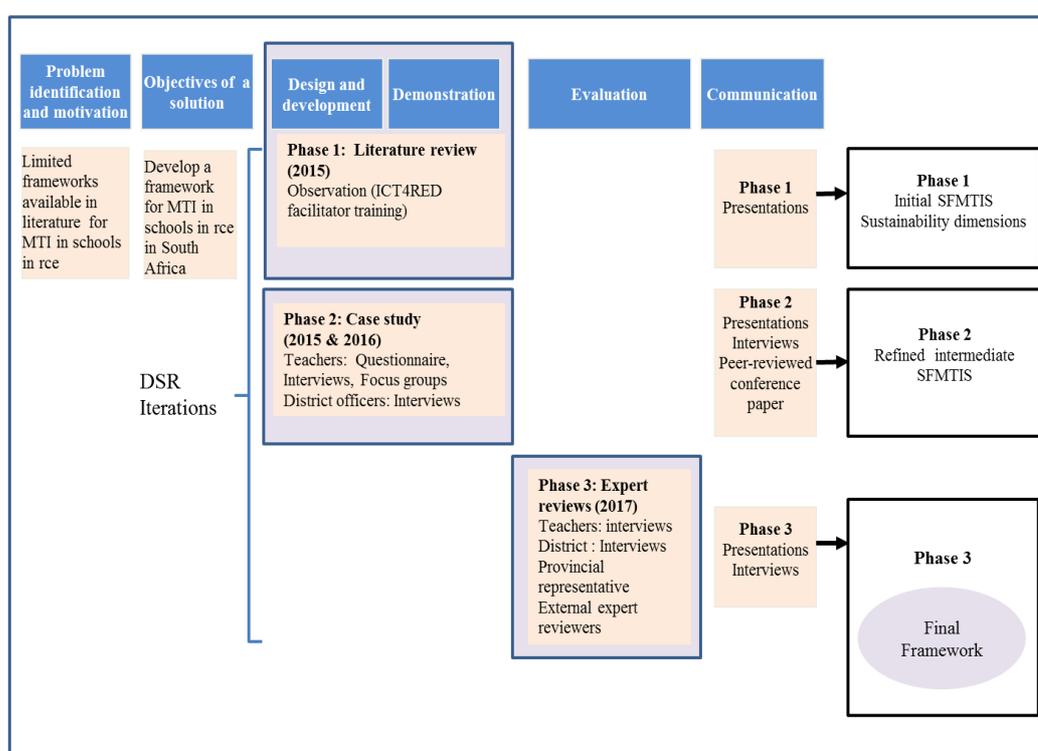


Figure 2: Application of DSR process in the study (Adapted: Peffers et al., 2007)

## Phase 1

Extant literature was reviewed for the main themes of the study, focusing on sustainability frameworks in general, frameworks for ICT4D implementation in resource-constrained environments specifically, and frameworks for sustainable mobile learning in schools. This research builds on these frameworks. The findings from these different types of sustainability frameworks will now be discussed.

### Sustainability frameworks in general

Researchers have proposed theoretical frameworks to explain the long-term sustainability of ICT4D projects. These include the Critical Success Factors (CSF) and

Critical Failure Factors (CFF) models by Heeks and Bhatnagar (1999), Stakeholder Theory (Bailur, 2006), and the Sustainability Failure Model (SFM) (Best & Kumar, 2008). Best and Kumar’s (2008) SFM provides an analytical framework comprising the five key factors that endanger the long-term sustainability of programmes namely: Financial/economic, cultural/social, technological, political/institutional, and environmental sustainability failures, which should be addressed for a project to be sustainable (Best & Kumar, 2008). The National Health System (NHS) sustainability model, which functions within the healthcare environment, identifies three main dimensions: organisation (infrastructure and fit with goals and culture), people (training involvement, behaviours and senior leaders), and process (monitoring progress, adaptability, the credibility of evidence and benefits) (Maher, Gustafson & Evans, 2010). Considering these frameworks, the common dimensions: Financial/economic, cultural/social, technological, political, and environmental sustainability – are extracted as shown in Table 1.

Table 1: Sustainability dimensions identified in general sustainability frameworks

Sustainability dimension	CSF Model (Heeks & Bhatnagar, 1999)	SFM (Best & Kumar, 2008)	Sustainability Model (Maher, Gustafson & Evans, 2010)
Financial/economic	Management	Financial/economic	
Social/cultural	Culture; people	Cultural/social	Organisation: infrastructure; fit with goals and culture
Political	Politics; structure; strategy	Political/institutional  (Power shift)	Organisation: infrastructure; fit with goals.  Staff: behaviours; senior leaders
Technological	Technical	Technological	
Environmental	Environmental	Environmental	
Institutional	Structure;  Strategy		Organisation: infrastructure; fit with goals
<i>Monitoring and evaluation (M&amp;E)</i>	Process;  Management	Evaluation and monitoring	Process: monitoring progress, adaptability, credibility of evidence
<i>Training</i>	People	Training	People: training and involvement; behaviours; senior leaders
<i>Sustained leadership</i>	Management	Sustained leadership and institutionalisation	
<i>Institutionalisation</i>		Institutionalisation	
<i>Identify benefits</i>			Process: benefits
<i>Process</i>	Process		Process: adaptability; credibility of evidence

<i>Information and knowledge management</i>	Information	Publicity activities to generate awareness of services	
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The CSF and SFM both include the environmental dimension. However, SFM presents political and institutional sustainability as one dimension. In the political dimension, power relations within a government hierarchy can affect long-term sustainability, and individuals who are in positions of authority/influence/control in local bureaucracies, affect sustainability by their effectiveness in their positions (Best & Kumar, 2008). Leadership, training, monitoring and evaluation, coordination, communication, control and management, identifying benefits, processes, and information and knowledge management, affect sustainability as shown in Table 1. The sustainability dimensions discussed in the preceding section are based on general ICT4D sustainability frameworks; the following section examines frameworks specific to resource-constrained environments in South Africa.

**Specific sustainability frameworks for ICT4D implementation in resource-constrained environments**

Resource-constrained environments (as used in this context) are characterised by limiting economic circumstances and inadequate infrastructure and basic amenities (Anderson, Anderson, Borriello & Kolko, 2012). Consequently, teachers who operate within the limits of these constraints implement changes in less than favorable circumstances, they contend with challenges related to electrical power and network connectivity, and deal with economic conditions that are characteristic of low-income communities (Anderson, et al., 2012; Herselman & Botha, 2014). Public schools in South Africa are classified into five groups: Quantile 1 to Quantile 5, from most to least poor. Quantile 1 encompasses a group of schools in each province, which caters for the poorest 20 per cent of schools, followed by the next poorest 20 per cent (Quantile 2), with the least poor schools in Quantile 5 (DoE, 2016). The schools in this study are in the lower quantiles, 1 and 2, and are considered to be located in resource-constrained environments.

Frameworks which have been developed based on the findings of ICT4D projects conducted in resource-constrained environments in South Africa which highlight sustainability dimensions include: The “Critical success factors of rural ICT project sustainability” (Pade-Khene, Mallinson & Sewry, 2011), and the “Rural ICT project development framework” (Mamba & Isabirye, 2015). The “Critical success factors of rural ICT project sustainability,” identifies 19 critical success factors for rural ICT project sustainability, which have (for the purpose of this study) been grouped within economic, political, social, technological and institutional sustainability dimensions (see Table 2). Building on existing public facilities, a holistic approach to the project, institutional partnerships, and values such as trust, sound ethics, and transparency, are also included in the CSFs. The “Rural ICT project development framework” found that

sustainability of projects requires local participation, local technical support, and skills development. Mamba and Isabirye (2015, p. 11) highlight the need for infrastructure and skills development resources, stating: “It is critical to have financial support from the government and the private sector.” This point is important for resource-constrained environments. The aforementioned frameworks are, however, not specific to the education environment.

In contrast, the detailed “Evidence-based ICT for rural education and development (ICT4RED) implementation framework” (herein referred to as ICT4RED framework) (Herselman, Botha & Ford, 2014) is *specific* to the education environment and incorporates sustainability factors. The ICT4RED framework is an implementation framework and emphasises the importance of the teacher professional development (TPD) component. The TPD is “the center around which everything else happens and supports or influences or enables the TPD component” (Herselman, Botha & Ford, 2014, p. 67). The ICT4RED framework underscores the need for the following: changes in classroom interaction in line with the introduction of appropriate ICTs; the selection of appropriate school ICT hardware and software; and relevant decisions on infrastructure and connectivity – 3G/satellites, local area network (LAN) and Wi-Fi selection (Herselman, Botha & Ford, 2014).

Analysis of these frameworks shows the interconnectedness of the sustainability dimensions. Finances are required in order to support aspects in the institutional dimension such as, monitoring and evaluation, training, and communication, and for technological sustainability, the maintenance of tablets and ICT infrastructure, and the provision of technical support. The sustainability dimensions identified in these frameworks are summarised in Table 2.

Table 2: Sustainability dimensions identified in sustainability frameworks for ICT4D implementation in resource-constrained environments

<b>Sustainability dimension</b>	<b>CSFs of rural ICT project sustainability (Pade-Khene et al., 2011)</b>	<b>Evidence-based ICT4RED implementation framework (Herselman et al., 2014)</b>	<b>Framework to guide development through ICTs in rural areas of South Africa (Mamba &amp; Isabirye, 2015)</b>
Financial/ economic	Economic self-sustainability;  Motivating and incentivising for community ICT job placement;  Using ICT to enhance existing rural development activities	Programme management (budget allocation)  Cost-utility model (Meyer & Marais, 2014:217)	Financial support (private sector and government)
Political	Understanding of local political context; Cultivating an influential project champion	Programme management (managing stakeholders)	Change management

Social / cultural	Community participation (target groups); Local/demand-driven needs; Encouraging local ownership; Building local partnerships; Incorporating socially excluded groups	Programme management (managing stakeholders, community);  Community (people, organisations internal to specific context)	Local participation;  Long-term private and public sector partnerships
Technological	Choosing appropriate technology	School ICT (hardware and software selection, infrastructure, connectivity – decisions and issues); School ICT committee; Communication	Plan for long-term presence of skilled personnel;  Technical support by local, skilled personnel
Institutional			
<i>Monitoring and Evaluation</i>	Doing ongoing monitoring and evaluation of the project	Monitoring and evaluation (measures success/failure and impact); Overarching to include programme management	
<i>Training</i>	Undergoing appropriate training and capacity building	Teacher professional development programme; Change management	Skills development;  ICT training
<i>Leadership and management</i>	Cultivating an influential project champion	Programme management; Operations management: content, infrastructure, project, devices, support, maintenance;  Change management	
<i>Identify Benefits</i>	Stating simple, clear project objectives	Benefits identified	Goal determination;  Identify role of technology
<i>Policy</i>	Creating awareness of specific ICT policy influencing the project	Programme management: evidence-based policy	Sound policies
<i>Communication, Information and Knowledge Management</i>	Building on local information and knowledge systems;  Facilitating local content development	Programme management: communication	Coordination and communication are critical

The financial dimension is significant in the context of resource-constrained environments. The framework presented by Mamba & Isabirye (2015) explains the role of private sector involvement and government funding in financially supporting ICT infrastructure and skills development. Analysis of these frameworks further shows how a number of factors such as leadership, management, monitoring and evaluation, and communication can be considered to be within the institutional sustainability dimension.

### Frameworks that address sustainable mobile learning in schools

The “Framework for sustainable mobile learning in schools,” the “Person-centred sustainable model for mobile learning,” (Ng & Nicholas, 2013) and the “framework for sustainable mobile learning in schools in resource-constrained environments,” (Mabila, Herselman & Van Biljon, 2017) are discussed in this section. The context of Ng and

Nicholas's (2013) framework and the "Person-centred sustainable model for mobile learning" is secondary education in Australia and is based on data collected at an Australian school. The framework is based on the more general "Framework for sustainability of ICT in education," (Cisler, 2011) which comprises economic, political, social and technological sustainability. Ng & Nicholas add a fifth dimension, pedagogical sustainability (see Table 3), while the environmental dimension is excluded. The school principal at the Australian school was technologically "savvy," enthusiastic, and actively participated in the mLearn programme. Funding for the mLearn programme was provided internally by the school. The context of Ng and Nicholas's framework differs from the context of the present study, where funding for the initiative to introduce tablets to the schools was external, and provided by government departments. In addition, the schools participating in the present study are in a resource-constrained environment. The "Person-centred sustainable model for mobile learning" (Ng & Nicholas, 2013) recognises the complex relationships between technical aspects and people-related factors, the interpersonal relationships between leadership and management (principal and programme coordinator), teachers, students, technicians and the wider community (parents, suppliers, policy makers, software developers and researchers).

Mabila, Herselman and Van Biljon (2017) argue that a framework for sustainable mobile learning in the context of schools in resource-constrained environments should take institutional structures into account, and proposed the addition of the dimension "institutional sustainability." This is in line with earlier findings of an analysis of frameworks in resource-constrained environments. The financial dimension is highlighted since the availability of financial resources was identified as one of the sustainability risk factors when ICT4RED was implemented. The ICT4RED funding was allocated at a strategic, national level, with a short-term, three-year implementation focus, rather than a long-term sustainability focus (Meyer & Marais, 2014). Additionally, the educational system is funded via predefined budgets, in which the flexibility of reallocation is limited, while schools in resource-constrained environments have limited financial resources.

These frameworks confirm four of the five sustainability dimensions identified when analysing general frameworks, namely financial/economic, cultural/social, technological and political sustainability. The environmental dimension is added to the SFMTIS since it pertains to making plans for the eventual disposal or reuse of the large number of servers and tablets in different schools when these reach the end of their effective life.

Best and Kumar (2008), as well as Heeks and Bhatnagar (1999), include the environmental dimension in their frameworks. For the SFMTIS, the institutional dimension is also considered in addition to the dimensions in Ng and Nicholas's (2013) framework. The pedagogical dimension in the "Framework for sustainable mobile learning in schools" (Ng & Nicholas, 2013) is an essential part of the SFMTIS. The pedagogical dimension refers to "teaching or learning practices that support the long-term goals of the mobile learning programs" (Ng & Nicholas, 2013, p. 4). The SFMTIS sustainability dimensions synthesised from an interrogation of the literature include

financial/economic, political, social/cultural, environmental, technological, pedagogical and institutional sustainability as shown in Table 3.

Table 3: Framework for sustainable mobile learning in the context of resource-constrained public schools in South Africa (Source: Mabila et al., 2017 adapted from Cisler (2011), Ng and Nicholas (2013))

C i s l e r (2011)	1. Economic	The financial capability of the educational institution to support the ICT technology in the long term
	2. Political	The role of leadership and the institutional policies required to adopt, maintain and monitor the success of mobile learning programmes; Consultation and feedback between different levels of the institution
	3. Social	Community involvement (parents, political leaders and business partners such as computer companies)
	4. Technological	Informed technology selection based on institutional needs and mid-to-longer-term strategic goals; Need to consider technology, access and maintenance costs, access to infrastructure and technical support; Consultation and feedback between service providers regarding content, technical support and users (teachers)
Ng & Nicholas (2013)	5. Pedagogical	Teaching and learning practices to support the goals of mobile learning programmes; The roles of teachers (and learners) in facilitating learning with mobile devices; Prepare and practice to facilitate learning with mobile devices; Peer collegiality required to ensure best pedagogical practices; Formal and informal learning facilitated by mobile learning
Mabila et al. (2017)	6. Institutional	Alignment between processes, leadership support and policy implementation. In context, this is at school (micro), district (meso), and provincial and national (macro) levels
	7. Environmental	Making plans for the maintenance of tablets (replacing damaged mobile devices). Making plans for the eventual disposal or reuse of the equipment (large numbers of servers and tablets) when they reach the end of their effective life (Best & Kumar, 2008; Heeks & Bhatnagar, 1999). Impact of these decisions on teaching, such as how quickly tablets are repaired.

The sustainability dimensions across the different frameworks are summarised and presented as a basis for the SFMTIS in Table 4.

Table 4: Comparison of the sustainability dimensions across frameworks as a basis of the intermediate SFMTIS dimensions

	SUSTAINABILITY frameworks			FRAMEWORKS: ICT4D implementation – resource-constrained environments			Mobile
<b>Sustainability dimension</b>	<b>CSF Model (Heeks &amp; Bhatnagar, 1999)</b>	<b>SFM (Best &amp; Kumar, 2008)</b>	<b>Sustainability Model (Maher, Gustafson &amp; Evans, 2010)</b>	<b>Critical success factors of rural ICT project sustainability (Pade-Khene et al., 2011)</b>	<b>Evidence-based ICT4RED implementation framework (Herselman, Botha &amp; Ford, 2014)</b>	<b>Framework to guide development through ICTs in rural areas in South Africa (Mamba &amp; Isabirye, 2015)</b>	<b>Ng &amp; Nicholas (2013); Mabila et al. (2017) adapted from Cisler (2011)</b>
<b>Economic</b>	Management	Financial / economic	Use cost benefit analysis framework for ongoing resource needs (staff and equipment)	Economic self-sustainability; Motivate/ incentivise community ICT job placement; Use ICTs to enhance existing rural development activities	Programme management (budget allocation); Risk identification; Monitoring and evaluation; Change management; Cost-utility model (Meyer & Marais, 2014:217)	Financial support (private sector and government) for infrastructure and skills development	Economic
<b>Social /cultural</b>	Culture; People	Cultural/ social	Organisation: fit with goals and culture; Staff: training and involvement, behaviours, senior leaders	Community participation (target groups), local/ demand-driven needs; Encourage local ownership; Build local partnerships	Programme management (managing stakeholders, community); Community (people, organisations internal to specific context)	Local participation; Long-term private and public sector partnerships	Social
<b>Political</b>	Politics; Structure; Strategy	Political institutional	Organisation: fit with goals; Staff: behaviours, senior leaders	Understanding local political context; Cultivating an influential project champion	Programme management (managing stakeholders and partners); Change management	Change management	Political
<b>Technological</b>	Technical	Technological		Choose appropriate technology	School ICT (hardware and software selection, infrastructure, connectivity – decisions and issues); School ICT committee; Communication	Plan for long-term presence of skilled personnel; Local, skilled personnel should provide technical support	Technological
<b>Environmental</b>	Environment	Environmental					
<b>Pedagogical</b>					Teacher professional development; Curriculum content; Content management, change management		Pedagogical (Ng & Nicholas, 2013)

<b>Institutional</b>		(Institutional-isation)	Organisation: infrastructure, fit with goals	Simple clear objectives; Awareness of ICT policies; Holistic approach; Monitoring and evaluation	Evidence-based policy; School ICT policy; Sustainability plan (district and provincial level); Programme and change management	Goal determination; Identify role of technology; Sound policies; ICT training	Institutional (Mabila et al., 2017)
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## Phase 2

To add value to the SFMTIS developed from the reviewed literature, Phase 2 of the study utilised a case study to demonstrate and refine the SFMTIS developed in Phase 1. A case study approach can be applied to understand complex social phenomena (Yin, 2013) and requires that the case be defined (Creswell, 2014; Yin, 2013). The case study for this research was selected schools in the Cofimvaba district in the Eastern Cape province of South Africa, which were part of the ICT4RED initiative. The philosophical position taken in this article is that of pragmatism. Pragmatic thinking acknowledges “knowledge is consequential, generated after action and reflection on action, even if we can use what we know already to guide our actions” (Hammond, 2013). Pragmatism considers the choices about the goals to be pursued (“why to”), and the means to meet those goals (“how to”) (Morgan, 2014). Cultural, values, and personal perspectives can affect how the researcher observes, interprets and reports findings (Berger, 2015; Clancy, 2013). Interpretivism was only applied in data collection in the case study as the results were interpreted within the DSRM process model, in Phase 2 as shown in Figure 2.

## Sample

The study is set in a real-life situation, involving public schools, teachers and district officials in the Nciba school district of Cofimvaba in the Eastern Cape Province, South Africa, who had participated in the ICT4RED initiative. The ICT4RED initiative was selected as a case and deemed appropriate due to the environment in which it was implemented and the need to sustain the initiative. This phase of the research was conducted about six months after the implementation of the ICT4RED programme. The study involved ten of the 26 schools participating in ICT4RED, the large-scale pilot South African government research, development and implementation initiative carried out by the Meraka Institute of the Council for Scientific and Industrial Research (CSIR) with the goal of improving the quality of teaching and learning, especially in mathematics and science subjects (Herselman & Botha, 2014). ICT4RED was implemented in phases between 2012 and 2015 in the Nciba circuit in Cofimvaba school district with 26 schools, 6,500 learners, 350 teachers, and 16 district officials involved in the initiative (ICT4RED, 2015). The project entailed deploying tablets to schools, supported by educator training, the provision of technology hardware and software to boost schools’ infrastructure, and network connectivity including, Wi-Fi equipment, safekeeping and charging facilities, and technical support. In total, 4,233 tablets were supplied to teachers and learners (ICT4RED, 2015). Digital content such as workbooks, lesson plans and e-books were loaded onto the tablets and the content

servers supplied to schools (ICT4RED, 2015). Teachers and facilitators were trained through the TPD programme on how to teach with technology and integrate mobile tablets in their classrooms. The teachers who participated in this study were selected through purposive sampling.

A questionnaire was distributed to 100 teachers in the ten purposively sampled schools, which constituted the case study. The questionnaire was used to obtain their views on mobile technology integration and the sustained use of tablets at their schools. Both closed and open-ended questions were used. The questionnaire was printed and disseminated to teachers who manually completed it, after which, 58 responses were received from eight schools. (For a profile of the participants, see Table 5.)

Table 5: Classification of participating teachers by gender and age

	Age (years)				Total
	21–30	31–40	41–50	51–60	
Male	3% (n=2)	5% (n=3)	10% (n=6)	9% (n=5)	28% (n=16)
Female	5% (n=3)	5% (n=3)	40% (n=23)	22% (n=13)	72% (n=42)
<b>Total</b>	9% (n=5)	10% (n=6)	50% (n=29)	31% (n=18)	100% (n=58)

Most participants, 81%, were above 40 years of age, and 62% of those were females.

The data of the teachers were supplemented by including the views of four district officials from Cofimvaba school district. The officials' perspectives about mobile technology integration in the schools participating in the ICT4RED initiative were investigated. Semi-structured interviews were seen as important for capturing the views of the officials (all senior personnel based in the district and part of the district management team) on sustainability aspects and for informing the development of the SFMTIS.

## Findings and discussion

The study found that teachers were mostly positive about the integration of tablets in their classrooms, citing positive impacts for both learners and teachers. Teachers indicated that the use of tablets increased their knowledge and skills in 21<sup>st</sup>-century learner-centered teaching strategies, and reduced technophobia among them. It also made it easy to access, store, retrieve and manage information. Some teachers were, however, concerned about the future use of tablets at their schools and indicated that they require maintenance of infrastructure (Internet access and Wi-Fi connectivity), more tablets, technical support, electricity, and quality tablets, in addition to tablets being secured against theft. The teachers also stated that they need continuous ICT professional training and that issues pertaining to access to digital content on servers should be addressed. The teachers also identified the need for district officials' involvement in monitoring and support.

Figure 3 shows percentages of teachers’ top ten recommendations from the results of an ATLAS.ti computer-based qualitative data analysis. ATLAS.ti is a computer-based qualitative data analysis (CAQDAS) tool. Teachers’ responses to the open-ended questions in the questionnaire regarding what was going well in terms of teachers using tablets for teaching at their school, and their concerns, were compiled into a primary document in the hermeneutic unit for the ATLAS.ti analysis. In Figure 3, technical support, digital content, and security are flagged as the three main issues teachers highlighted during site visits. District officials concurred with the teachers’ concerns regarding security and the need for technical support.

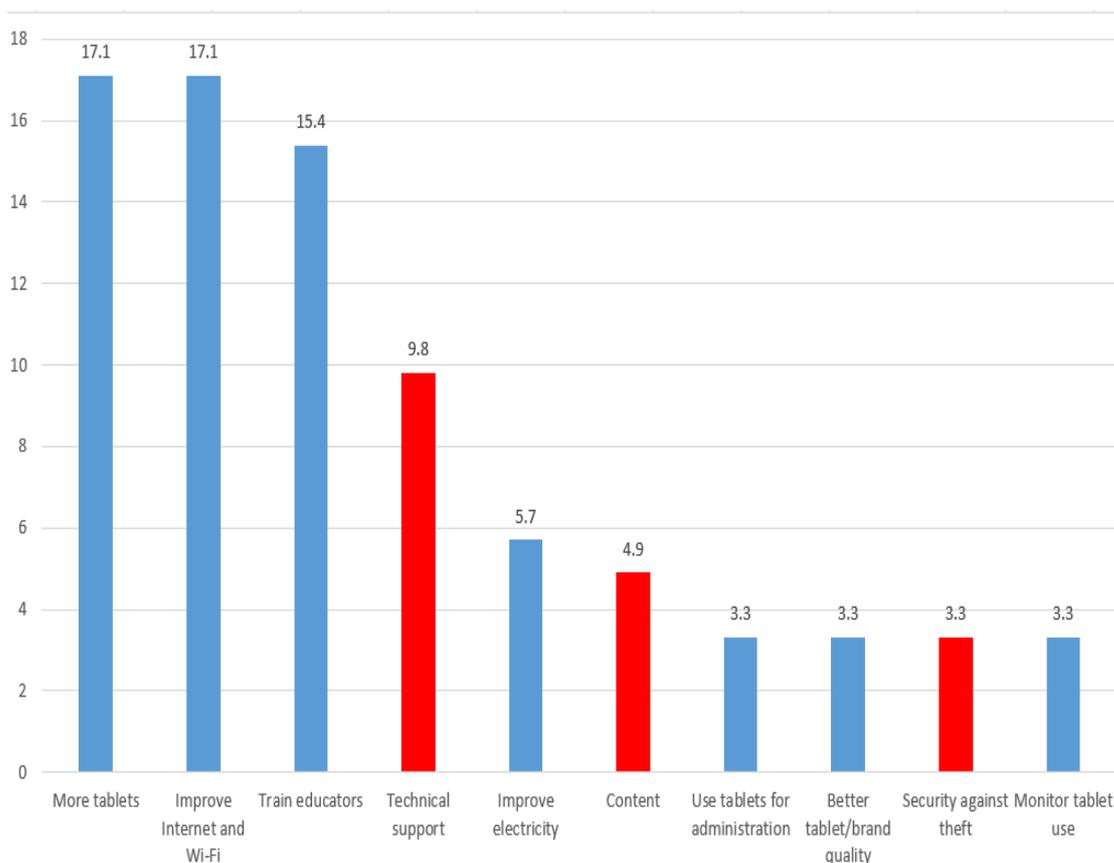


Figure 3: Teachers’ top ten recommendations for improving sustainability

A detailed view of teachers and district officials’ perspectives is presented in Table 6 (<https://goo.gl/9WDxwr>)

The following section discusses the views of teachers and district officials, using the seven sustainability dimensions identified in Table 4. These dimensions are: economic, technological, political, cultural, pedagogical, institutional and environmental.

- Economic: Teachers and district officials’ responses supported the need for schools’ financial budgets to cater for costs of tablets, maintenance, technicians and technical support, security for tablets and ICT infrastructure against theft, and ICT training for teachers. District officials indicated the need to apply economies of scale in the

education system in order to reduce costs such as Internet and Wi-Fi costs. District officials also pointed out that the schools are “section 21” schools and consequently could raise funds.

- **Technological:** Teachers pointed out the need for more high-quality tablets in the schools, improvement of Internet and Wi-Fi connectivity, technical support to teachers, and ICT infrastructure maintenance. District officials noted that planning is required to facilitate future supply of tablets to schools. District officials also expressed the need for well-trained, qualified technicians, who can provide technical support to teachers, and perform network administration functions. As one of the district officials stated, “Teachers are not technicians. A teacher’s job is to teach.”
- **Political:** Teachers and district officials were not explicit in expressing views that can be considered to be political. These views were implicit in statements made. Teachers contended that more school visits by district officials would be welcomed. Teachers also expressed the need for increased district support to schools in solving Internet and Wi-Fi connectivity, technical support, and security issues. District officials asserted that the DBE provincial should fund schools’ ICT related requirements such as technicians, and ICT maintenance.
- **Cultural:** District officers indicated that there is a need for parental support and involvement.
- **Pedagogical:** Teachers maintained that more digital content available should cover the whole syllabus, cater for more subjects, and be align to the DBE requirements. Teachers suggested that ICT training be provided to enable teachers to have “knowledge of how and when to use tablets.” In contrast, other teachers suggested minimisation of usage of tablets citing that students’ writing skills, English language grammar, and mental calculations should be developed, and students’ overreliance on computers for performing basic calculations should be minimised. Teachers argued that tablets may be misused for cyberbullying, accessing inappropriate content available online, social networks and games during classes. There were teachers who stated that “Learners video record teachers and take photos while they are teaching.” District officers indicated that schools with tablets can make more use of e-books, and that the DBE should develop strategies for reducing textbook publishing and print textbooks costs, which currently involve several book publishers.
- **Institutional:** Major aspects within institutional sustainability include leadership, communication and coordination, and security. Teachers noted that leadership and support by the DBE at national, provincial, and district level is critical. One of the teachers remarked that “DBE has to organise permanent employees (at meso and macro levels), to focus specifically on ICT-related programmes, who will always be there.” District officials explained that district officials facilitate communication and coordination between teachers and the district through regular subject committee and cluster meetings, which respectively occur monthly and quarterly. With regard to school security, teachers and district officials agreed that securing school premises is crucial. Teachers remarked that schools need to tighten up security. District officials agreed that security at some schools is inadequate, and that thieves

target the tablets. Schools reported the burglaries that have occurred to district management.

- Environmental: The complex and resource-constrained context that schools and districts in resource-constrained environments contend with, results in many challenges as evident in remarks such as:

“There are many needs – water, sanitation...”; “There are other barriers to learning, for example issues related to nutrition, scholar transport, remedial lessons, basic conditions of schools, and teachers’ motivation.”; “There is also too much workload on teachers.”, and “More personnel are required at the district.”

Teachers and district officials deal with mobile technology integration amidst these challenges, which span different dimensions.

### **The communication divide between teachers and district officers**

Teachers expected more leadership from the district in relation to the use of tablets at the schools, expressing the need for “regular monitoring by the office of education in the district checking the usage and condition of the tablets.” However, district officials seem to consider leadership at school level, by principals, school management teams (SMTs) and school governing bodies (SGBs) to be essential for sustainable mobile technology integration, stating, “Functional school leadership is essential (principal, school management team, school governing body), that is responsible for school management and leadership.” District officials also expressed the teachers’ responsibility of using the tablets for teaching and the school management’s responsibility for maintaining the tablets and providing security. Some of the district officials indicated that since the schools are “section 21 schools,” they manage the schools’ financial resources and can raise funds.

“Section 20” and “section 21” school descriptors refer to sections in the South African Schools Act (SASA), which describe the various functions exercised by the school governing bodies (SGBs) on behalf of the public schools at which they have been elected. All public schools are effectively “section 20” schools, while additional financial responsibilities are allocated to “section 21” schools’ SGBs that are seen to have the capacity to perform them (Roos, 2009). The perception given by some district officials was that the “section 21 schools” can raise funds. This perception is, however, not reflected in teachers’ responses as reflected in the statements: “We need more funding...”, and “A budget is required....” Considering the fact that the teachers’ responses on those topics are within the purview of the district officials, this may indicate a disconnect between the perceptions and expectations of those two groups, namely, teachers and district officials. Such a communication gap could impact the sustainability of the mobile technology integration, and is therefore an important contribution to this article. Thus, there is a need for institutional structures and processes that will facilitate communication and coordination of ICT specific issues between schools and the district.

## **Recommendations to address the sustainability dimensions of the SFMTIS**

The value that the case study adds is to demonstrate the applicability of sustainability dimensions identified in the reviewed literature. Detailed teachers and district officials' views are presented in Table 6 (<https://goo.gl/9WDxwr>). In this section, the SFMTIS sustainability dimensions, summarised in Table 4, are discussed and recommendations are made in the context of the study on aspects that need to be addressed.

### **Financial**

The DBE is advised to promote application of economies of scale, and frugal innovation in schools. Systems and processes for building on the ICT infrastructure and digital content that have been established through the ICT4RED project need to be established to combat the high costs of textbooks. The education budget needs to cater for financial support required for new responsibilities such as, maintaining digital content in school servers, and maintaining ICT infrastructure to support Internet access and Wi-Fi connectivity. Application of financial models such as the Total Cost of Ownership (Meyer & Marais, 2014) can assist schools, district, and DBE management to plan for sustainable mobile technology integration.

The DBE's planning and budgeting for the LTSM needs to consider ICT related costs in its structure. Schools expressed a lack of funds as a major reason for schools not affording to maintain tablets, and for inadequate security at schools. Schools need to cultivate a culture in which planning is prioritised, and become proactive in influencing the DBE's approach regarding school ICT requirements. For example, as one of the school ICT champions indicated, schools' annual planning and budgeting submitted to the Department of Education can include ICT maintenance costs, technical support, and content management costs. School can also raise funds in line with their "section 21" school's status, and the intention and implications of the "section 21" policy should be better communicated between schools and the Department. Increased focus needs to be given to providing appropriate training and capacity building of school managements' (principals, school management teams (SMTs) and school governing bodies (SGBs)) planning, resource management, and entrepreneurial skills.

### **Political**

At macro level, the role and responsibilities of the provincial ICT Forum in the Eastern Cape Department of Education (ECDoE) needs to be clarified. At meso level, the district's roles and responsibilities, particularly the district's ICT4RED Champion, the e-learning coordinator, and subject education specialists (or subject advisors) in mobile technology integration in schools, and safety and security official's role, must be well-communicated between schools and the district offices. At micro level, the roles of principals, SMTs, SGBs, and school ICT champions' roles and responsibilities need to be well defined. Clearly defined roles and responsibilities must be accompanied by appropriate planning, communication, coordination, implementation, monitoring and evaluation of ICT activities. The effectiveness of current structures and processes needs

to be assessed. Questions such as who should maintain the digital content on servers, and how this will be carried out needs to be asked, and appropriate planning, communication and coordination between the DBE and schools effected. A culture in which individuals at all levels, macro, meso and micro levels are held accountable for assigned roles and responsibilities needs to be established.

### **Cultural**

Strategies for increasing the involvement of parents, SGBs, and SMTs, and teachers in planning for, and actively participating in, activities to strengthen the integration of mobile technology into teaching, need to be established. Involving parents in finding solutions to security issues, and finding innovative ways to raise funds, is influenced by the school culture. The school culture also influences the SGBs approach and the extent to which the SGB hold teachers and principals accountable in their roles.

### **Technological**

Models such as the technology selection model (Meyer & Marais, 2014), which are relevant for this environment, can be applied when tablet selection choices need to be made. It is critical that schools identify and utilise existing facilities that the department of education, the government, private sector, and other agencies, developed to support teachers' ICT skills, and promote ICT use in schools. Examples of these facilities are the special e-Rate for Internet access for schools, online digital resources available for teachers, and digital resources already loaded on the school servers and tablets. Districts can assist schools to leverage and maximise on the ICT infrastructure that is in place through improved communication, coordination and support.

### **Pedagogical**

The role of subject education specialists (subject advisors), who are based at the district offices, in training teachers how and when to use mobile technology when teaching specific subjects, needs to be clearly defined and communicated. Checks and mechanisms to identify inefficiencies in existing reporting and monitoring structures and processes, need to be put in place. As Best and Kumar (2008) suggest, institutional structures and effective leadership at macro (provincial/national) level and micro level, need to be in place. Services should be "institutionalised" instead of allowing the services to be dependent on individual initiatives (Best & Kumar, 2008). In this case study, these would include: Continuous updating of digital content on school servers, continuous technical monitoring and maintenance of ICT infrastructure, maintenance of tablets, and the employment of qualified technicians to support schools. "Institutionalising" these activities would require that planning and budgeting processes in the Department of Education systems and structures integrate and align to these new needs and requirements.

## **Environmental**

Besides the broader environmental issues already covered in other dimensions, the increase in the quantities of ICT equipment, including tablets that are supplied to schools, requires that the long-term effects of these devices on the environment be closely examined. Close attention needs to be given to how schools handle, maintain and dispose of ICT equipment.

## **Institutional**

The school system is a component of the education system and interacts with socio-economic factors in its environment. The school system functions as an institution, and in the context of mobile technology integration in this research the school is the interface that links the different stakeholders. Teachers and district officials specified institutional processes, requirements, challenges, and governance issues that affect mobile technology integration. This explains why the institutional sustainability dimension is prominent in this research. Leadership, communication, and the ability to identify and utilise existing facilities to enhance mobile technology use in teaching are four of the critical aspects in the institutional sustainability dimension.

The dimensions listed in Table 4 will now be applied to the security aspect of mobile technology integration to demonstrate the usefulness of the SFMTIS framework.

## **Applying the SFMTIS to the security aspect of mobile devices**

Security of mobile devices, servers and other ICT equipment in schools is a challenge, mainly because of burglaries, but also because the devices could be used by learners and teachers to access inappropriate digital content, and may become susceptible to cybercrimes through the Internet. Figure 4 shows the application of the DSR cycles to this specific issue and how the design cycles are used to identify the stakeholders and actions in each cycle.

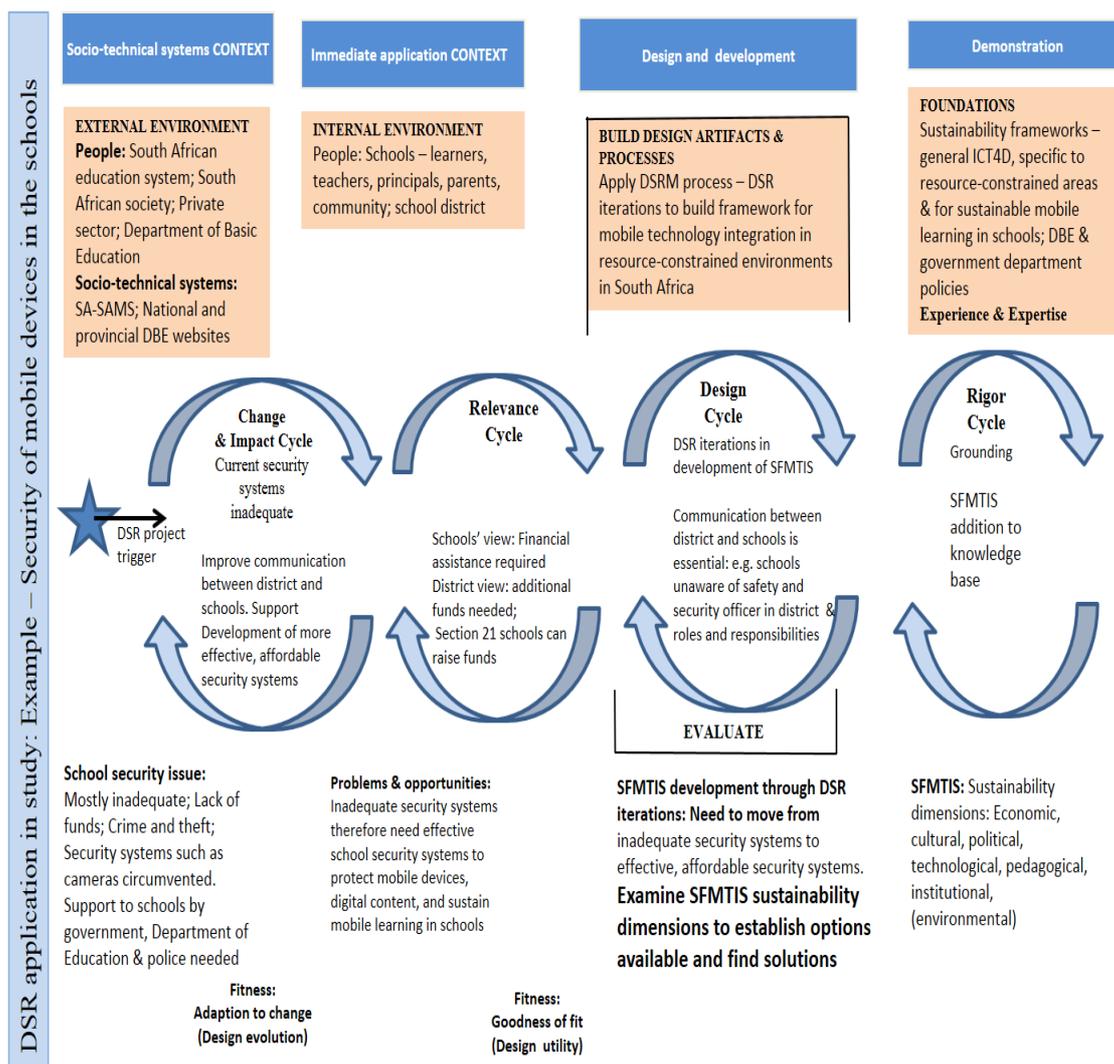


Figure 4: DSR application in the study - Example of security of mobile devices

The security issue was raised in the internal environment where teachers and district officials indicated that criminals target schools in order to steal tablets. Schools and the Department of Education were advised to prioritise securing the tablets and ICT infrastructure. Based on teachers and district officials’ observations regarding inadequate security in schools, more efforts need to be made to provide rigorous school security. Increased coordination and cooperation at different levels of the Department of Basic Education, research institutions and the private sector, are proposed to investigate and implement cost-effective and stringent security measures in schools. Districts need to develop policies and procedures to govern and monitor the securing of school ICT equipment, communicate same, and hold school management accountable so they take appropriate action.

Communication includes means by which schools interact with the district, and interaction within the schools, and encompasses systems and reporting procedures that enable monitoring. Analysis and communication of this information is essential for effective management. Mobile technology introduces new activities in which teachers

and students utilise mobile devices, and access digital content. Consequently, procedures for reporting day-to-day operations within the schools should cater for these activities, and should align to district reporting procedures. Districts have overall responsibility for schools in their jurisdiction, and relevant communication and reporting mechanisms that provide credible evidence of effective mobile technology integration should be developed in line with new ways of teaching. Teachers' remarks regarding security were, "Although the school tries to make tablets to be secured, criminals persist to take tablets at schools," and this necessitates "Tightening up security by installing good security systems like surveillance cameras," and "Beefing up other alternative measures for security - spray security, mesh wire with spikes."

Some teachers and principals, for example, were unaware that the district has an official that is specifically concerned with school safety and security. Some of these schools experienced burglaries, sometimes multiple times, where mobile devices were stolen. District officials' views regarding security were that the districts are aware of the situation and expressed, "Security at some schools is inadequate and tablets are targeted by thieves." However, "schools are expected to secure and insure school property, this includes ICT equipment".

Presentations to district officials and teachers of results from questionnaires, and interviews, revealed that communication, information and knowledge management between district and schools, and communities regarding these crimes, do not seem to be collated. If the impact and extent of the thefts could be highlighted, and the information collated and analysed, it could be used to motivate action by schools, district, communities, and safety and security officials.

Table 7 presents a summary of considerations for each dimension of the SFMTIS in terms of security. The SFMTIS dimensions can be examined to ascertain options and decide on the best plan of action. In this case, all the dimensions are relevant, with the exception of the environmental dimension, which is actually covered by overlapping with the technical, political, institutional and social dimensions. Communication is essential and has implications in all dimensions. When mobile technologies are implemented to support teaching in schools, all the different sustainability dimensions of the SFMTIS need to be considered. The dimensions are interrelated, and communication is essential since communication and information gaps have been found to exist between schools and districts.

Table 7: Applying the SFMTIS to a specific issue – security of mobile devices

Communication	Dimensions	Aspects to consider
	Institutional	Define roles and responsibilities of different stakeholders for school security.  Identify relevant departmental policies and school policies.  The procedures and practices described in the policies may have financial implications. Schools’ role in securing mobile devices.
	Financial	Security installation: hardware and software cost.  Security personnel costs.  Devices and infrastructure – loss and damage, and the need to be replaced has cost implications.  Determine how security installations can be implemented in an effective and affordable way.
	Culture	Values – Levels of crime, and attitudes towards guarding mobile technology integration and mobile devices and ICT infrastructure at the schools. This is influenced by the values, level of importance that is placed by the community, teachers, students on mobile technology integration in school, and crime levels in the specific environment.  School’s level of ownership and responsibility for guarding devices and ICT infrastructure, and department, school, teachers, and learners’ attitudes.
	Political	Communicate roles and responsibilities of the safety and security officer at the district to schools.  Enhance the effectiveness of the safety and security officer at the district, and their relationship with the schools.
	Technological	Ensuring secure use through installation of appropriate software such as antiviruses, and monitoring systems
	Pedagogical	Creating awareness of ethical use of mobile technology among teachers and students.  Protecting digital content from being illegally accessed, damaged, or deleted.
	Environmental	Not relevant in this example.

Financial resources are required for connectivity, for maintaining digital content, securing infrastructure, and the continuous training of teachers. This was confirmed in the reviewed literature and in the teachers and district officials’ views reported in the case study. In resource-constrained environments in South Africa, the districts’ interaction with schools is critical, as it affects the deployment of resources, finances and technicians. However, financial resources do not guarantee sustainability (Ng & Nicholas, 2013), and a programme can fail if it is politically and institutionally unsustainable, and this could be caused by people, management, cultural and structural factors (Best & Kumar, 2008).

## Conclusion

Despite the acknowledged importance of sustainability, there is a lack of theoretical frameworks for guiding the sustainable implementation of developmental projects. Therefore, this study set out to investigate a sustainability framework for mobile technology integration in schools in resource-constrained environments in South Africa. The SFMTIS sustainability dimensions abstracted from the literature include financial, political, social/cultural, technological, environmental, and pedagogical sustainability. The findings from the interviews with teachers and district officials provided evidence to confirm the value of the sustainability dimensions identified in literature. Much less expected was the institutional challenges identified, which motivated the addition of the *institutional dimension* to represent the policies, procedures and practices on macro, meso and micro levels. The study highlighted financial and technical support mechanisms required for the sustainable deployment of ICTs. Based on the responses of the teachers and district officials who participated in this study, financial resources are required to ensure that there is continuous educator training, monitoring, security of infrastructure, the provision of digital content and technical support. Long-term partnerships with the private and public sectors were suggested to aid financial sustainability, as different stakeholders have varying competencies and capacities. Institutional systems and processes have to be made explicit and communicated to ensure continuous cooperation and coordination. The nature of digital content and ICT infrastructure is such that it requires continuous support and maintenance. Institutional structures tasked with monitoring and support functions have to be strengthened and provided with resources in order to function effectively. The SFMTIS provides a point of departure for improving sustainability, by identifying aspects that need to be addressed to support sustainable mobile technology integration. A recommendation that can be made on the basis of utilising the SFMTIS sustainability dimensions is that communication and coordination at all levels of the education system, micro (school), meso (school circuit and district), and macro (province and national) levels, is essential in ensuring sustainability.

Future research is intended to present the framework to those teachers and district officials formerly interviewed for their expert evaluations. The generalisation of the framework is limited by the fact that the findings are based on a single case study. To improve the generalisability of this study, further research is needed to apply, evaluate and verify the framework in similar contexts.

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