Landscape Review
Mobile Education for Numeracy

Evidence from interventions in low-income countries

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Table 1: Contributing individuals to the project descriptions

Organisation and individual	Project	Country
Alia Karim - Earth Institute, Columbia University	Millennium Villages	Kenya and Tanzania
American University of Sharjah – Imran Zualkerman	School Garee Program	UAE / Pakistan / Bangladesh
Anthony Harfield – Naresuan University	OLPC	Thailand
Carmen Strigel – RTI	Tangerine	Kenya
Christelle Scharff – Pace Uni	CibleCI (Senegal) & SenMobile	Senegal
Dylan Busa – MindSet	MindSet Learn	South Africa
Jo Besford – Green Shoots	Maths Curriculum Online	South Africa
Kathy McCabe – Radical Learning	TeachCAPS	South Africa
Khanyiwe Shawa – VSOInt	Unlocking Talent	Malawi
Laurie Butgereit – CSIR / Meraka Institute	Dr Maths	South Africa
Mark Bennett and Claire Stead - iSchool	iSchool Zambia	Zambia
Mike Dawson – Paiwastoon	Ustad Mobile	Afghanistan
Mohamed Matar – RAFAH		Palestine
Sashwati Banerjee and Anuragini Nagar - Sesame Workshop India	Play 'n Learn	India
Stephen Anzalone - EDC	IRI	Global

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Garth Spencer-Smith conducted much of the data gathering and analysis for this study. He pursued all three sources of data: human networks, online web searches and the searches for published research work. Lee Moodley provided some assistance in finding online sources of relevance. Nicky Roberts provided conceptual guidance, an analysis of lessons learnt, and completed much of the writing of the report.

This study was commissioned by the GIZ Education Section on behalf of the BMZ. The views expressed are those of the authors and do not necessarily reflect the position of the GIZ and BMZ.

Contents

Acronyms

BMZ:	German Federal Ministry for Economic Cooperation and Development
BYOD:	Bring Your Own Device
CAI:	Computer-Assisted Instruction
EFA:	Education For All
EGMA:	Early Grade Mathematics Assessment
EGRA	Early Grade Reading Assessment
GIZ:	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GPE:	Global Partnership for Education
ICT:	Information and Communication Technology
KfTM:	Knowledge for Teaching Mathematics
LMIC:	Low to Middle Income Countries
mLearning:	Mobile Learning
mNumeracy:	Mobile Education for Numeracy
MDG:	Millennium Development Goal
OECD:	Organisation for Economic Co-operation and Development
PCK:	Pedagogical Content Knowledge
SMK:	Subject Matter Knowledge

Executive summary

This GIZ-commissioned landscape review focuses on mNumeracy interventions in early grades in low income countries. A search of the internet and academic journals, and correspondence with contacts within the mNumeracy space, resulted in the unearthing of a total of only 24 projects (from 12 countries) that fit the above criteria. This illustrates the paucity of such projects (or, at the very least, the lack of documentation about such projects).

The projects found have been mapped to the four key areas of focus for the review: Mathematics instruction and teaching and learning materials; teacher professional development; learning outcomes assessment; and parents and community involvement. The vast majority of projects are mapped to the learner instruction and materials focus area. There are a few projects relevant to teacher education, and only one project mapped to each of the other key areas.
Six case studies have been chosen to outline in more detail; three for the key area Mathematics instruction, and teaching and learning materials; and one for each of the other key areas.

The 'lessons learnt' and 'identified gaps' are summarised by the aforementioned key focus areas and highlighted in the text of Chapter 3. Here we present a summary of our findings on the key questions.
The main findings relating to the "why mobile learning interventions?" question are:

- There is existing research on the affordances of mLearning in developed contexts, and this seems to be applied to low- to medium-income countries (LMIC) contexts.
- There is a need for more evidence on how mNumeracy interventions can enhance learning and teaching in the particular challenging contexts of low-income countries.
- We found no studies of mNumeracy interventions where a comparison is made to other technologies or to alternative pedagogical interventions.
- The low cost, rather than the mobility, of the mobile device seems to be a driving factor for choosing mobiles.
- Most of what we have found relates to formal learning settings (schools); there is far less documented on informal learning settings and how mNumeracy can support teachers and parents/caregivers of children.

The main findings relating to the 'what numeracy skills?' and the 'how is numeracy taught?' questions are:

- There is some evidence emerging that attends to the general pedagogic shifts evident from interventions, but this was only for a few of the (already limited) case studies.
- Pedagogic shifts reported pertain to the general form of the classroom interventions (such as more group work, less transmission or chalk and talk teaching, higher attendance) and not the approaches to the mathematics content of particular topics that is in focus during these interventions.
- There seems to be no evidence of mobiles being used to generate content (by teachers or learners).
- As such, we found no evidence of mobiles being used to help to address concerns about content relevance to local contexts.
- We have not found examples of interventions making use of diagnostic assessment or supporting the mathematics for teaching knowledge of early grade teachers.

The main findings relating to the question of "at what financial cost?" are:

- Consideration of costs of hardware are being taken into account in choosing mobile learning approaches.
- But the cost question remains thorny with some projects unable or unwilling to reveal costs; others only tracking overall project cost; and others tracking cost per user (which is seen to decline over time).
- Studies on cost effectiveness with comparisons to other technologies and or other possible pedagogic interventions seem rare.
- There is apparent silence on the broadband data cost implications for the use of online digital content on these devices.

CHAPTER 1: Background and context

1.1 Introduction

With the Education for All agenda, the international community has made a commitment to "improve all aspects of the quality of education and ensuring excellence of all so that recognized and measurable learning outcomes are achieved by all, especially in literacy, numeracy and essential life skills" (Goal 6). The goal has been defined more than ten years ago, but remains less than fully attained.

The German Government, represented by the Federal Ministry for Economic Cooperation and Development (BMZ), supports the Global Partnership for Education (GPE) in its vision of "a good quality education for all children, everywhere, so they fulfil their potential and contribute to their societies" and especially in its goal of developing numeracy skills in the pre-school and early grades in low-income countries worldwide. As targeted support to GPE's ambitions in numeracy education, the BMZ commissioned the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH with the implementation of a 'Sector Program Numeracy' for the promotion of numeracy competencies in pre-school and early grades. Mobile education and numeracy forms one of its four focal topics.

Mobile technologies and learning methods have long been experimented with in the field of literacy, and to some extent also in numeracy. However, most of these cases remain at a pilot phase with a rather narrow scope, lacking up-scaling, monitoring or sharing of lessons learnt. This leads to a limited availability of evidences on the impact of ICT and especially mobile technologies on learning in the formal education system.

Against this background, the 'Working Group mNumeracy' was launched by the GIZ Sector Programme Numeracy on behalf of BMZ and GPE at the mEducation Alliance Symposium in October 2013 to bring together NGOs, think tanks, donors, development partners and private sector stakeholders to exchange experiences and expertise on 'what worked' and 'what didn't' in the application of mobile learning to improve learning outcomes in numeracy education. This review is a further step in this direction.

The GIZ's approach to mobile learning adopts the definition put forward by the mEducation Alliance as being a "collective term for mobile devices… [which] includes mobile phones, e-Readers, tablet computers, flash memory, micro/pico projectors, audiovisual devices, and other similar technologies" (Raftree, 2013, viii). The review, therefore, follows the same broad definition of mobile learning.

1.2 Scope of the study

The chief goal of this review is to compile practices from early grade mNumeracy projects in low- and medium-income countries (LMICs) around the world, and summarise the lessons learnt and collate evidence of 'what worked' and 'what didn't'. This is in order to brief practitioners and policy makers worldwide on how to further improve the implementation of mNumeracy projects in such countries. The review serves a secondary purpose of defining existing gaps in our knowledge base about mNumeracy in early grades in LMICs. The key areas for consideration are:

1. Mathematics instruction, teaching and learning materials;
2. Teacher professional development;
3. Learning outcomes assessment[1]; and
4. Parents and community involvement.

These key areas were defined by the GIZ team and specified in the terms of reference for the study.[2]

[1] *This includes the use of mobile technologies for real-time data collection*

[2] *These areas are distinct, although overlapping, and related to the purposes of mLearning as identified in the m-Reading landscape review: Formal learning and instruction; Informal learning; Content; Training; Data collection; and Communication and dissemination*

There are several annexures which provide more detail on this study:
Annexure A: References;
Annexure B: Synopsis of Projects;
Annexure C: Persons and organisations contacted;
Annexure D: Detailed definitions of terms;
Annexure E: Detailed description of the data collection process;
Annexure F: Factors assumed to be particular to LMIC countries.

1.3 Definitions of terms[3]

In addition to the adopted definition of mobile technologies, presented above, there are several key terms which we have used:

- Mathematics refers to the formal school subject area as defined by the curriculum of most countries.
- Numeracy is "using mathematical skills and competencies efficiently to make sense of the world" (Strigel & Pouezevara, 2012, A1).
- mNumeracy refers to mobile education for numeracy. It therefore involves the use of mobile technologies to improve mathematics learning outcomes and numeracy skills.
- Early grades are defined as the as the first four years of formal schooling, which commonly takes place within a primary school setting. This includes the more informal kindergarten year (which may take place in a primary school or informal setting).
- Low and middle income countries are defined as per the World Bank[4].

[3] *A more detailed set of definitions of key terms is found in Appendix D*
[4] *See http://data.worldbank.org/about/country-and-lending-groups*

CHAPTER 2: Methodology

2.1 Framing the study

This landscape review has a particular focus that frames its attention in several ways. The technology options are constrained to mNumeracy; the education focus is on the early grades of schooling; the content domain is numeracy, and the context of implementation is LMICs. This narrow focus has both advantages and disadvantages. It has meant that a thorough search can be done to establish what is available (and, just as importantly, identify what is missing). At the same time, it has meant that there is little data available from which lessons could be drawn to inform the practitioners and policy makers.

There is some research which examines the potential of mNumeracy to enhance, improve or transform the education offerings. In this regard, attention is placed on questions like 'why a mobile learning intervention?' and 'how do mobile interventions impact on learning numeracy?'

There is small but growing body of research directed to considering the instructional benefits of mLearning, including mNumeracy. For example, several studies suggest that mLearning has the potential to extend education resources by opening access to disadvantaged peoples (e.g. women, homeless, offenders, disabled, sick, rural poor) and increase equity of access to education (Viljoen et al., 2005; Vosloo & Botha, 2009; Deloitte, G. S. M. A., 2012). There is also a growing body of literature on the instructional benefits of mobile phones (Daher, 2010; Johnson, Adams, & Cummins, 2012; Thomas & McGee, 2012; Thomas & Orthober, 2011). Two recent landscape reviews have added significantly to the body of knowledge around mLearning, albeit not in the mathematics/numeracy space, and not necessarily at early grade level: Raftree's landscape review of mobiles for youth workforce development (Raftree, 2013); and Wagner's landscape review of mobiles for reading (Wagner, 2014). The research directed to considering "why a mobile intervention?" in relation to other possible ICT options and other pedagogic interventions, is covered in the above reviews, as well as numerous other articles, such as those by Denk et al. (2007), and Mehdipour & Zerehkafi (2013) .

However, most of these studies (other than the landscape reviews cited) relate to developed world contexts. Koszalka & Ntloedibe-Kuswani (2010) report that research into the efficacy of mLearning in low income countries is in its infancy. They believe that evidence is lacking as to whether it is the mLearning that facilitates learning, or some other factor (e.g. a change in pedagogy), and that many of the case studies presented were methodologically poor and self-promoting rather than unbiased research.

Having mNumeracy as a starting point (and the resulting focus of the projects and studies), can be viewed as technology-led approach which backgrounds the mathematics and numeracy learning (Liu, Han and Li, 2010).

We have made use of Strigel & Pouezevara's (2012) affordances of mLearning, when focusing on mNumeracy:

- *accessibility* (access to learning opportunities, reference materials, experts/mentors, other learners);
- *immediacy* (on-demand learning, real-time communication and data sharing, situated learning)
- *individualization* (bite-size learning on familiar devices; promotion of active learning and a more personalized experience); and
- *intelligence* (advanced features making learning richer through context-aware features, data capture, multimedia).

We have also made use of Strigel & Pouezevara's (2012) framework on variations in mobile learning configurations:

- A *learning spectrum* which ranges from formal (in class in school) or informal (out-of-school but formal learning, and/or informal learning for pleasure or entertainment);
- A *kinetic spectrum* which ranges from the learners being stationery to being mobile; and
- A *collaborative spectrum* from individual to collaborative.

In the resource-constrained context of LMICs there is a particular focus on researching questions like: "at what financial cost?" An increasing number of studies on mobile learning in recent years have lent weight to the view that mobile phones open up new ways of extending the scope, scale and quality of education (Mishra, 2011). Why mobile learning is a viable technology option, is based on two main factors: the drop in the price of mobile devices (particularly mobile-phone handsets) and usage costs, which makes mobile devices increasingly common, even in poorer communities; and the highly flexible nature of mobile devices (Traxler, 2009). It seems that the apparent near-ubiquitous access to mobile devices is a key driver of some mNumeracy interventions which make use of Bring Your Own Device (BYOD) approaches. However, we conjecture that the requirements of access to suitable mobile devices and reliable access to cost-effective bandwidth are likely to be significant factors that hinder uptake of mNumeracy interventions using BYOD approaches in LMICs (particularly where the target end-users are young children and their primary caregivers, who are mostly women).

While focusing on mNumeracy it is also important to situate this study within the literature on mathematics education. Attention is paid to specialised teacher knowledge for teaching mathematics, including subject matter knowledge (SMK) and pedagogical content knowledge (PCK). Put simply, the research questions attend to: "what numeracy skills?" and "how is numeracy taught?" This helps to shift the considerations away from the technology-focused approach to a more learning-focused one where questions asked relate to the nature of mathematics, how children learn (and can therefore be supported to learn) particular mathematics concepts, and how the availability of the mobile learning tools shifts what is taught (and so what is made available to learn).

The mathematics education literature is a rich and contested research terrain with various debates on pedagogic approaches for mathematics of particular topics with particular age groups, and how best to learn (and so teach) mathematics. For example, Öllinger et al. (2012) advocate for a strongly cognitive model for learning mathematics, where evidence is drawn from neuro-scientific studies. Their proposed approach emphasises mathematical thinking and pays attention to diagnostic processes, including detailed error analysis, as well as social and cultural factors such as motivation. Wright et al. (2006) adopt a more problem-solving approach, paying attention to the means of developing children' skills and strategies in their Mathematics Recovery Programme. They have a similar emphasis on diagnostic processes (to inform teaching trajectories) and different kinds of interventions or remediation which is required for different children.

There is much mathematics education research within this realm on the teacher knowledge required for effective teaching of mathematics (Rowland & Ruthven, 2011; Ball et al., 2008). Many of these studies draw on the seminal work of Shulman (1986) who divides teachers' knowledge into seven categories, two of which are commonly in focus: subject matter knowledge (SMK) and pedagogical content knowledge (PCK). There are various contesting theories on how to work with teachers to better prepare them for, and later support them when, teaching mathematics. As an example of an LMIC, in South Africa much emphasis is placed on researching the specialised knowledge for teaching mathematics (KfTM), with particular focus on resource-constrained, multi-lingual and challenging school and community contexts (see, for example, Ensor et al., 2009, Adler & Davis, 2006, Venkat & Naidoo, 2012).

When considering "mathematics and ICTs", it is clear that with the advent of ICTs mathematics education has shifted away from accurate and efficient manual calculation (although procedural fluency is still recognised as an important skill), to an emphasis on mathematical thinking as sense making and problem solving, requiring the interpretation of information and appropriate use of mathematical tools (including calculators, dynamic geometry tools and related software) (Anghileri, 2007).

For both of these bodies of literature (mNumeracy and mathematics education) there seems to be:

- more documentation pertaining to technologies and mathematics which focuses on the secondary school and higher education ends of the education system.
- a paucity of research in mathematics and technology at the primary school level - and the early grades in particular.
- limited documented evidence and/or published research which pertains to LMICs.

2.2 Data collection[5]

This landscape review was undertaken as a desk study. Firstly, a brief scan of literature was undertaken to locate the landscape study in relation to the mNumeracy and mathematics education literature. In particular, this drew on three GIZ-commissioned reports[6].

Secondly, data was collected from human networks and online searches (including relevant academic journals). The review of published research and the project websites resulted in fewer than 20 articles or reports of relevance for the topics. Fairly commonly there was no published research on the projects to which the human network had referred or which had been found using web searches. In some cases there is documented record of what was done, but this remains at the level of internal project documentation and has not been published in the journals or submitted for peer-review scrutiny.

A total of 24 projects from 12 countries that met the four criteria of the study scope (mLearning, focused on mathematics/numeracy, and in early grades in LMICs) were obtained through the above process. These projects were then mapped against the four key areas for the study: instruction and materials; professional development; assessment; and parents and community. A synopsis of information on all of these projects is presented in Annexure B.

Six case study projects were then selected to develop in more detail. The selection of these cases was largely pragmatic: to include projects for which there was sufficient information (at the detailed level of 'lessons learnt'), that reflected a spread of countries, and to include at least one example from each key area. Once the case studies were selected, more detailed case study descriptions were developed using a project case study template developed in consultation with the GIZ team.

We then conducted our analysis across the different data sets (review of published research articles, project descriptions, case study write ups and). In so doing, we focused our attention on identifying lessons and recommendations which could be generically relevant to practitioners and policy makers in the early grades mNumeracy arena. We organised the lessons learnt by making use of the framework of the four key areas of the study, mentioned above. When describing lessons learnt for each key area we drew on the detailed case studies and lessons referred to in the literature we consulted.

[5] A detailed description of the data collection process and people consulted for this study is found in Appendix E

[6] Strigel, C & Pouezevara, S. (2012). Mobile Learning and Numeracy: Filling gaps and expanding opportunities for early grade learning; Öllinger, M., Ströhle, A. and von Müller, A. (2012). Early Grade Development and Numeracy: The academic state of knowledge and how it can be applied in project implementation in socio-economically less developed countries; Davis, J. & Sitabkhan, Y. (2012). Assessment of Learning Outcomes with Reference to Early Grade Numeracy in Socio-Economically Less Developed Countries

CHAPTER 3: Discussion of key areas

In this section we present our mapping of the projects against the key areas. We then discuss each of the key areas by means of the following scheme: an introduction, followed by a detailed description of one or more case study projects, with related lessons learnt.

We mapped the 24 projects from 12 countries (Egypt; India; Kenya; Malawi; Pakistan; Senegal; South Africa; Somalia; Tanzania; Thailand; Turkey; and Zambia) that met the four criteria of the study scope to the key areas, as shown in the table below:

Table 2: Mapping of projects to the key areas

Key area	Number of projects
Learner instruction and materials	17
Teacher professional development	4
Assessment	2
Parents and Community	1

The majority of projects were mapped to the learner instruction and materials focus area. There were a few projects relevant to teacher education (but only one for which there was detailed data), and only one or two projects mapped to each of the other key areas.
We selected the following six case studies (by the process described in the methodology) for detailed descriptions:

3.1 Mathematics instruction and learning materials

Most studies involving the impact of mobile learning on mathematics understanding and performance have been carried out in grades higher than Grade 3 and/or in high income countries. So one of the key questions of this review is to ask how mathematics instruction in the early grades in LMICs can be best supported through mobile technologies. In answering this, cognisance was meant be taken of some of the special challenges of low-middle income countries like teaching large groups; the need of a more learner-centered education; existing pedagogic practices and teacher knowledge; teaching multi-grade classes; teaching in multilingual and inter-cultural settings; as well as teaching in conflict-affected contexts. We have found very little in the literature which discussed directly how these challenges can be addressed, or learning in such contexts enhanced, through mNumeracy initiatives.

Advocates for mNumeracy claim that there is the potential to increase access to teaching and learning materials in classrooms that lack them (the accessibility affordance). This topic therefore also looks at how far this promise has been implemented to improve results in learning outcomes in selected projects in LMICs around the world. What follows are the three detailed case studies relevant to this topic: Sesame Workshop (India), iSchool (Zambia) and Unlocking Talent (Malawi).

Table 3: Summary of projects selected for detailed description mapped against the focus areas

Focus Area	Projects	Countries
1. Mathematics instruction and materials	iSchool Sesame Worksop (Play 'n Learn) Unlocking Talent	Zambia India Malawi
2. Teacher professional development	Mindset	South Africa
3. Assessment	Tangerine	Kenya (and now in over 20 other countries too)
4. Parents and community involvement	TeachCAPS	South Africa

Case study: Sesame Workshop India

Title of the project: Play 'n Learn

Implementing agency: Sesame Workshop India (SWI)

Funders and partners/stakeholders: Qualcomm (funder); South Delhi Municipal Corporation (partner)

Country/region: Delhi, North India

Target group(s): Children aged 6-8, teachers and caregivers

Project launch and end date: In-community – 1st June to 30th September 2013; in-school – 6th November 2013 to 31st March 2014 (includes school holidays)

Number of schools, learners, teachers served by the project: 40 families with children 6-8 years of age; 4 schools; 12 teachers; 300+ learners

Goals of the intervention: To test if exposure to technology and digital games bring about improved learning outcomes of the target group in Hindi literacy and numeracy.

How the intervention operated (i.e. what did the project do?)

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SWI developed 10 GGSS[5] games (5 on Hindi literacy and 5 on mathematics).

In-community Intervention: 40 low cost, 3G enabled handsets were provided to the participating communities with children aged 6-8 years in a slum community in Delhi.

In-school Intervention: Also deployed the games in 12 government run primary classes (Grades 1, 2, and 3) in four schools in Delhi through 3G enabled low cost android tablets (Micromax fun book).

In addition, teachers were trained in the Delhi schools to integrate the GGSS games in their class schedule, and all handsets and tablets were loaded with an application usage tracker to track the frequency of use of the games.

Monitoring and evaluation methodology

The study was conducted by two different research agencies: for the in-community intervention, Policy Innovations conducted the study and for the in-classroom it was done by New Concept.A quasi-experimental study using a non-randomized control group pre-test/post-test design in which participants of the study were chosen from areas recommended by the SWI team. The study applied a pre- and post-intervention design using control and intervention groups. Quantitative and qualitative methods were used for data collection at end line and baseline which included teacher's interviews, children's focus group discussions and measures of children's Hindi and Mathematics skills as well as classroom observations to document and track the impacts of teaching and learning practices. Monthly data from application usage tracker was used to understand which games were played the most (duration and frequency). Teams from SWI visited the schools and slum communities monthly to get feedback on the games, and help the teachers with any challenges/issues

Findings on impact (what changes the intervention has brought about)

The quantitative learning outcomes have not been impacted through the tablet but there have been qualitative improvements in the classroom environment and children's learning experience. Children enjoy the games thoroughly and look forward to the tablet sessions as has been consistently seen during this assessment study (resulting in improved school attendance).[6]

The tablet sessions are conducted through the group work method, which is a welcome change for the children from the normal chalk-and-blackboard method of learning. It also makes learning colorful and attractive to them with the use of characters and audio and video elements.

The intervention has also built the capacities of the teachers. Some unique learnings include how to integrate digital based learning in the classrooms, an improved understanding of using tablets, smartphones to access different types of content and in using multiple media to engage children in classrooms.

[5] *Galli Galli Sim Sim (the Indian adaptation of Sesame Street)*

[6] *However, there was no comparative research to determine whether one would have found the same results with the teachers being trained in and applying non-digital educational gaming opportunities within the classroom.*

Why a mobile learning intervention?

The in-community intervention made use of low cost, 3G enabled Karbonn handsets. The in-school intervention used low cost android tablets (Micromax fun book).

The rationale for choosing this technology (over other technology options) was explained by programme managers as focusing on game-based learning and using accessible, low cost technologies.

What numeracy skills?

The topic focus in terms of Numeracy was on Numbers, Number operations (multiplications, divisions, additions and subtractions), Shapes and spatial understanding. Numeracy experts were not involved in the instructional design of the content.

At what financial costs?

The project managers have tracked the costs of the intervention. However they "cannot share the figures since this is a funded project, and we would require approval from our donors to share the cost/and budget details."

The project managers report that they have conducted cost comparisons relating to choices made in the intervention in terms of technical and pedagogical options.

Sources of information

http://www.sesameworkshopindia.org/

Personal communication from Sashwati Banerjee, MD of SWI, and her colleague Anuragini Nagar

Case study: iSchool Zambia

Title of the project: iSchool Zambia

Funders and partners/stakeholders: Mark Bennett, Ian McFadyen (private investors)

Country/region: Zambia

Target group(s): Head teachers, teachers in schools, students, communities (anyone who wants to improve/complete their primary education).

Project launch and end date: 2010 to date (2010 = pilot study in 5 schools in Lusaka area)

Number of schools, learners, and teachers served/reached by the project: 8 000 devices in use; reaching 75 000+ students in 50+ schools

Goals of the intervention: To improve the learning outcomes for local children, and the teaching skills and standards of the local teachers, whether trained or not, in all subject areas.

How the intervention operates (i.e. what does the project do?):

Tablet based cross curricular learning for the whole primary age range with lesson plans and learning content for the children that is developmental and structured. iSchool has created multi-media interactive localised eLearning content across the entire Zambian primary school curriculum. This is available on the fully-preloaded ZEduPad tablet – designed by iSchool to be a low-cost low-power device (which can be charged off solar) that will work in any environment. Learning for all lower grades is in 8 of the main local languages[7], as well as in English. Teachers have lesson plans for all 5 000 lessons, moving them to interactive enquiry-based learning. A teacher professional development course is also available. The material is currently being adapted to use on low-cost smart phones.

Monitoring and evaluation

Monitoring and evaluation is conducted twice a year in 5 control schools and 5 pilot schools with over 3 000 students. USAID's EGRA (Early Grade Reading Assessment) and EGMA (Early Grade Maths Assessment) are used alongside a critical thinking tool that iSchool developed and tested with the help of the University of Zambia and Cambridge University. There is an internal M&E team with external evaluators from Universities of Alberta and Cambridge.

[7] This was in response to Zambia's Ministry of Education mandated material delivery in the 8 languages.

Findings on impact (i.e. what changes the intervention has brought about)

iSchool students are outperforming control students in four (number identification; quantity discrimination; addition; subtraction) of the six math skills identified by USAID and measured by the EGMA tool.

iSchool management have noted a number of positive spin-offs from their intervention: teachers now understand what they should be teaching, often for the first time; they are in school more as the lessons are planned for them and they just need to deliver them; they are better able to deal with the large class sizes as the lesson plans split the children into three groups; they are developing their professional skills and are excited by the impact that this is having on their classroom practice; and they are proud of their achievements and consequently keen to continue improving.

Similarly, the iSchool management has noted that learner engagement is very high, and therefore attendance at school is almost 100%; and the learners find the lessons are more enjoyable and consequently teachers no longer need to resort to shouting and violence to control the learners.

Why a mobile learning intervention?

This intervention initially used netbooks and a server at each school but subsequently changed to ZEduPad tablets. This shift is explained as a result of difficulties with the Internet server and reliable electricity supply, and the ability to use the tablets in classrooms (not in a computer lab). A 7 inch tablet was chosen as it was seen to be big enough to be useful, and a good size for primary school children to use, while still being cheaper than the 10 inch or more variant.

What numeracy skills?

This intervention is designed to cover the entire mathematics curriculum. Teachers were used to write the lesson plans, and were used to plan the curriculum content progression based on the Zambian National Curriculum. Teachers used the statements of attainment from the Zambian national curriculum and used their knowledge of other (perhaps more structured) curricula to inform the curriculum development process for the product.

At what financial cost?

The cost of the specific mathematics component has not been tracked, although the costs of the whole intervention are known. The costs were mostly incurred in product development rather than in the intervention itself. No cost comparison with other technical or pedagogical options was made.

Sources of information

http://ischool.zm/

Personal communication from the CEO of iSchool, Mark Bennett

Case study: Unlocking Talent

Title of the project: Unlocking Talent

Implementing agency: Voluntary Service Overseas (VSO) International - Malawi

Funders and partners/stakeholders: Eurotalk/onebillion[8], VSO (funders); Malawi Ministry of Education, Science and Technology (stakeholder)

Country/region: Malawi

Target group(s): The direct beneficiaries/target groups are the teachers and learners

Project launch and end date: September 2013 to date

Number of schools, learners, teachers served by the project: 1 school, 400 learners, 8 teachers

Goals of the intervention: The project aims to contribute to the attainment of core competencies in numeracy and literacy in primary school age children in Malawi.

How the intervention operates (i.e. what does the project do?)

This project uses digital educational technology (DET) – the Masamu tablet[9] – which has been loaded with Ministry of Education Science and Technology curriculum-aligned content. For the pilot, this content was used for 30 minutes daily for 8 weeks. For the future, it is planned to use it for 3 times a week, 30 minutes each session. It is used for Std 1 and 2 (equivalent to Grades 1 and 2) but for the 8 week pilot it was also used for Std 3 learners.

[8] Eurotalk is the for-profit company that develops the apps/software; onebillion is the charity arm of Eurotalk that enables Malawi to access the software for free.

[9] The Masamu tablet is a standard iPad with all other apps blocked and loaded with the Masamu apps provided by onebillion

A learning centre was built at the school and the tablets are housed here. It also serves as a hub where students, national and international volunteers, teachers and others can come and use the tablets and can also help and support each other through informal discussions and sharing.

Monitoring and evaluation

The University of Nottingham undertook an evaluation of the pilot project in 2013. It included a baseline study which aimed to provide an accurate measure of the status quo before project intervention for the targeted Standard 1 and Standard 2 children, and a final evaluation conducted using the same methodology as the one used for the baseline study. Four hundred learners were part of this study, and were divided as follows: 115 children were in the intervention group (who used the Masamu app[10]), 195 were in the control group that received normal classroom practice, and 90 learners used tablets but without the Masamu app.

Ongoing monitoring includes assessing the functionality of the DET and support systems and the effect of the DET training on teachers, school administrators and community members. Data on progress made in each topic, and time spent on each topic is available. These data is available by child, school, type of teacher, district / region, etc.

Findings on impact (what changes the intervention has brought about)

An evaluation of the pilot study carried out in 2013 by EuroTalk, the University of Nottingham and VSO Malawi showed that a tablet-based intervention, delivered over an 8 week period for 30 minutes per day, significantly improved mathematical ability compared to normal classroom practice.

Children using the Masamu tablet tripled their specific mathematics curriculum knowledge, with Standard 2 children raising attainment levels to a higher level than the average shown by Standard 4 children with normal pedagogical practice. The Unlocking Talent intervention was just as effective at supporting the development of mathematical skills in girls as it is for boys.

The intervention was effective in raising mathematical standards even in low achievers. Over the 8 week intervention period, 78% of low achievers who received the Masamu tablet improved their Maths ability to a level typical for their standard, whereas only 17% of children who received normal tuition raised their mathematics attainment to within the normal range.

Why a mobile learning intervention?

This intervention made use of the Masamu tablet, with the Masamu app. The project managers did not indicate why this technology was chosen over other technologies, but did indicate that the iPad was chosen over other tablets due to its superior performance.

What numeracy skills?

The numeracy skills covered are all those in the Malawi math curriculum for standard 1 and 2, so includes basic addition, subtraction, shapes, colours etc. The project managers did not indicate whether numeracy experts were involved in the instructional design of the content. The content is available in Chichewa (the local Malawian language).

At what financial cost?

According to the project manager, the building of the learning centre and the iPads cost about 10 GBP per child. onebillion is not charging for the cost of developing the software, as they have committed to providing the software to Malawi for free.

Sources of information

https://onebillion.org.uk/downloads/unlocking-talent-final-report.pdf (Pitchford, 2014)

Personal communication with Khanyiwe Shawa, Senior Program Manager at VSO Malawi

[10] The Masamu app includes numeracy content that is aligned to the Malawi standard 1 and 2 mathematics curriculum

Lessons learnt

For all three cases selected as being primarily focused on mathematics instruction and materials, there is implicit reference to the mLearning affordances of accessibility, immediacy and individualisation. However, these affordances are very similar to that of any online digital content. We found no examples of mobile content being available offline (or options for how this might be facilitated). We found no examples of, or research pertaining to, learner-generated content where the mobility of the device and its recording functions (voice and image) are used. mNumeracy tasks of this kind, could include, for example, 'take a photograph of triangle in your home, or 'tell a story about your family that includes the words "more than"'. It is also notable to us that none of the case studies made implicit mention of the intelligence affordance of mNumeracy. This seems to be an area where there is less focus (and marks a potential gap in the landscape).

All three cases reveal the tension along the learning environment spectrum, from targeting formal (school) to informal (after school and home) environments. All three interventions included a formal school integration component, but Sesame Workshop (India) directed its attention to both in-community early grade caregivers (informal) and in-school teachers (formal). In our view, the ability to view the learning context as a spectrum where movement between formal and informal contexts is facilitated (by the device and learners being mobile and present in both contexts) is a key benefit of mLearning. Yet, we note that most of the data we found for this review reflected a formal setting for early grade numeracy intervention. There was far less that attended to the informal setting (which we discuss as part of the key area focus on parent and community involvement).

In the formal settings, the importance of partnerships, and engaging the right stakeholders at all levels of the education system, is critical to an intervention's success. Piper & Kwayumba (2014), writing about an early-grades Kenyan mNumeracy intervention, note that "The intervention needs to be strongly supported by the local and national ministries or departments of education in order for it to work. This partnership is key". Scharff, Ahouansou, Bakhoum & Cheung (2013) advocate a formal introduction of all stakeholders. Unlocking Talent (Malawi) programme managers advised that "It is necessary to obtain government consent before implementation"; learnt that family consent for the involvement of early graders in programmes is an ethical requirement; and reported that "the primary school education advisor should be involved in all activities."

The importance of engaging teachers and attending to their mathematics pedagogy (and not just their technical skills) was commented on in all three cases. This will be discussed in more detail in the key area of teacher training (below).

In formal settings, the involvement of local teachers in the design and presentation of digital content for the local context is an important lesson. Sesame Workshop (India) noted this, commenting that "Working with the teachers is very important. Do not try to create content without consultation." That teacher involvement results in product design changes was also commented on by iSchool (Zambia):

> *"Be prepared to take time to develop the product: It took us 6 years to develop the product. This was done through trial and error; through testing, watching, talking and changing until we discovered what it was that was needed and the level of support that teachers would require to make the changes to the way that they are working, effectively."*

Related to this is the need for content to be nationally and locally relevant to teachers and learners, with particular attention paid to the alignment of content to the local mathematics curriculum. This lesson seemed to be learnt especially by the experience in Peru of the "One Laptop Per Child" initiative which did not pay sufficient attention to the design of curriculum related content (Strigel & Pouezevara, 2012). Curriculum alignment and relevance is a key feature of the iSchool (Zambia) project where the lessons have been designed against the local curriculum, and in local languages. As a Thailand mNumeracy intervention showed, "verify that the content and structure of the app is well-suited for [the grades in which it is to be used]" (Harfield and Viriyapong, 2014, p 18). In the case of open educational mathematics materials – such as those of the Khan Academy, that cover specific mathematical skills - it is important that these should be mapped to the national curriculum. The Sesame Workshop (India) case description noted that there should have been clearer links between the games and national curriculum framework, commenting that "The teachers are more used to linear teaching methods, and therefore they were generally unable to draw a parallel in the class lessons with the games".

Digital content means that it is possible to accommodate a wider range of language options within a school as the content can be made available in many languages, without the cost of printing, distribution and storage implicit with printed materials. This is an important consideration as most early grade mathematics learning in LMICs takes place in local languages. We are pleased to note that the Unlocking Talent (Malawi) and iSchool (Zambia) case descriptions includes reference to materials in local languages.

One of the added benefits of mNumeracy is the increased motivation and enjoyment from children when using digital content (on a mobile device). iSchool (Zambia) project coordinators described that the tablet they use “provides the students with their learning materials in an engaging and entertaining way”. The Sesame Workshop (India) case description refers to teacher comments relating to the children enjoying the tablet sessions, and creating a dynamic, multimedia learning environment. This was an explicit finding in the SenMobile project[11]: children love to learn with mobile technology (Scharff et al. 2013).

The choices to use tablets or smartphones was motivated by the low cost for Sesame workshop (India) and iSchool (Zambia), where the tablet size for easy handling by young children was a further motivation for the “why a mobile intervention?” question. iSchool (Zambia) also commented explicitly on the potential to use the tablets outside of classrooms. The portability of the mobile device means that motivational benefits can be leveraged in both formal and informal settings and available to children while they are moving (inside the classroom, the school, while travelling, or in their community environment). We found little that attended directly to the motivation and enjoyment as a result of the device being mobile.

Although the advent of mNumeracy has in some cases reduced the unit costs of purchase of devices, and removed consideration for where the devices will be located (as they are mobile), in formal contexts attention to the procurement, repair, maintenance and storage or mobile devices remains relevant. Piper & Kwayumba (2014) note that procedures need to be in place to ensure that the ICT hardware is safely stored, otherwise it is soon lost. In the case of iSchool (Zambia), tablets were provided to schools; and in the formal approach in the case of Sesame Workshop (India) tablets were provided to participating schools. It is surprising to note the Unlocking Talent (Malawi) approach of building a learning centre at a school to house tablets. This seems to mirror processes relating to school computer labs. The learning centre is obviously a secure space for storage, but may well have the unintended negative consequence of reducing the usage of the tablets due to their relative inaccessibility. The importance of budgeting for requisite infrastructure for the storage of equipment was noted in the lessons from the Unlocking Talent (Malawi).[12]

Related to this, and relevant for many mNumeracy interventions, are the equity issues implicit in the lack of affordable broadband data which impact on LMICs. We note that none of the projects we reviewed referred to e-rates[13]. Based on our experience in mNumeracy interventions we are aware that access to reliable and affordable broadband data is a key success factor for mNumeracy interventions which rely on Internet connectivity. We hypothesise that lack of access to dependable, affordable bandwidth in LMICs may have contributed to the paucity of examples which we found through this review.

In adopting a more informal approach there is potential for schools (and governments) to divert costs of ICT procurement, repair and maintenance to the end-users. This argument for Bring Your Own Device (BYOD) models is particularly attractive in the mNumeracy environment where personal ownership for mobile devices is near ubiquitous (even in developing country contexts for particular groups of adult and youth). However, this option is not yet viable for the target of early graders in LMIC contexts. These children are unlikely to already own suitable (or, indeed, any) devices. Their teachers, caregivers or parents may have access to a suitable device, and interventions could target these role players by encouraging them to loan their devices to their children (however, we found only one such initiative through this review). This is possible, but requires ongoing engagement with the parent community. Using the argument of mobile devices being familiar and available (as their rationale for “why a mobile learning intervention?”), low cost 3G-enabled handsets were provided to each participating family by Sesame Workshop (India). However, power dynamics within the family ensured that the children did not get sufficient access to the donated handset. We discuss this aspect of the intervention of Sesame Workshop (India) in more detail as a part of the key area: parent and community involvement.

In terms of the “what numeracy skills?” question, it is worth first identifying the common focal areas in early grade curricula (Strigel and Pouezevara, 2012): Numbers and operations (and their properties and relationship), shape and space, measurement (length, mass, capacity, time, money), and data handling. In addition, there are cross-cutting focal areas which relate to problem solving, and mathematical patterns and reasoning. Sesame Workshop (India) reported on selecting the key topics of numbers and operations, and shape and space. iSchool (Zambia) reported a focus on the entire curriculum. This review did not probe to the level of detail of reporting on “how is the numeracy taught?”, so the pedagogical approaches to mathematics teaching chosen by projects (such as sense making or problem solving or developing procedural fluency) is not known. This is a potential gap in the mNumeracy landscape.

3.2 Teacher professional development

This key area considers pre- and in-service mathematics teacher professional development in LMICs, and how mobile education can support improved teacher professional development in mathematics teaching. There are two main areas which were meant to be addressed:

- Using mobile technologies in teacher professional development for mathematics, regarding subject matter knowledge, and pedagogic content knowledge of the teachers;
- Support of mobile technology skills of teachers for implementation in their mathematics classes.

The iSchool (Zambia), Sesame Workshop (India) and Unlocking Talent (Malawi) cases all had mathematics instructions and materials as their primary focus. All three cases also simultaneously attended to teacher professional development, and their lessons related to this key area are discussed in this section. But we first present a further case study of Mindset (South Africa), which had teacher professional development as its primary focus.

[11] *The Senmobile ‘Mobile phones in primary school’ project was run for 5 months in 2013 in Senegal. Two mobile applications (one for numeracy and one for literacy) were developed and piloted in the Grade 2 classes of one school in Dakar. More information is available in the Scharff, Ahouansou, Bakhoum & Cheung, (2013).*

[12] *This was a lesson learnt reported by this project. We are not aware of evidence that storage at a static point is safer than allowing devices to be mobile.*

[13] *E-rates refer to preferential (reduced) data usage rates for educational services or use of data at educational sites.*

Case Study: MindSet

Title of the project: Flora Foundation Phase Mathematics Teacher Development

Implementing agency: MindSet

Funder: Flora Family Foundation

Country/region: South Africa

Target group(s): Classroom teachers teaching Grade 1 - 3 Mathematics as well as those involved in Teacher Professional Development (teacher mentors, HODs, NGOs, district officials etc.).

Project launch and end date: January 2013 – September 2013

Number of schools, learners, and teachers served/reached by the project: unknown; however, there were 27 921 views of videos in the 12 month period July 2013 to June 2014 (on YouTube)

Goals of the intervention: The goals of this small project were:

1. To test the application of some of the international models to the South African context
2. To start development of a strategy for this area of Mindset’s work
3. To experiment with different video production techniques
4. To experiment with different programme formats
5. To produce media that could serve as proof of concept for further funding

How the intervention operates (i.e. what does the project do?)

Thirteen videos were produced for Grade 1 - 3 Mathematics as defined by the SA CAPS (curriculum statement). Each video is called a Great Lesson Idea as it profiles one teacher’s great idea for how to teach a specific concept or topic. We tried to ensure that all the ideas were readily replicable by any teacher. In other words, they did not require any specific resources or technology that was expensive or difficult for the average teacher to obtain.

Each video is between 5 and 8 minutes long and was filmed in class during the lesson with as little disruption to the flow of the lesson as possible. Thus it shows the lesson as it was actually taught. Action from the classroom is intercut with footage and voice-over from the teacher explaining what they are doing and why. Each video is accompanied by a lesson plan of the lesson to assist other teachers in implementing the whole or part of the lesson.

Monitoring and evaluation methodology

None (however, videos produced on the Foundation Phase literacy curriculum were evaluated by means of focus group meetings)

Findings on impact (i.e. what changes the intervention has brought about)

None known at this stage, due to a lack of an evaluation.

Why a mobile learning intervention?

For this intervention no hardware was provided – only digital content via online videos that could be viewed on any ICT hardware.

As such the choice of video had nothing to do with mobile; mobile was simply a convenient delivery mechanism. Nevertheless, video as a medium was chosen as a result of the long and rich research basis for using video as a teacher professional development tool, drawing on Stigler & Hiebert (2004), Sherin (2004), Tripp and Rich (2012) and Powell (2005). The programme manager reported on the following three aims for their choice to use video: being a catalyst for individual and group reflection, documenting and sharing effective teaching practice, and challenging notions of transmission/reception approaches.

What numeracy skills?

This intervention did not focus on particular topics within the Mathematics curriculum. It aimed to stimulate reflection on practice and pedagogy that is unrelated to specific content. The focus was a lesson (teaching a particular concept/content), but everything else was directed to thinking more deeply about the practice being demonstrated, practice that can and should be translated into other areas of the curriculum.

The programme manager explained that the video was intended to focus on Pedagogic Content Knowledge (PCK), using the single video lessons as a means to an end of helping teachers generalise to other parts of the curriculum and starting to think more critically about how they were teaching generally. As such the video lesson selections were based more on what lessons the teachers wanted to teach rather than any explicit focus on a part of the curriculum.

Numeracy experts were involved in this process in that all the teachers we filmed with were practical "numeracy experts" in their own right. The project manager was also a teacher with 20 years classroom experience in this area.

At what financial cost?

The costs were tracked and and US$80 000 has been spent to date. About US$20 000 was on project team personnel costs and US$60 000 on content development costs. Mindset measures cost per user based on the number of teachers that have accessed the materials. As such this cost continues to fall. Currently it is approximately US$2.30 per user. Some cost comparisons have been made between this project and the cost of physically travelling around the country to engage with teachers face-to-face.

Sources of information

http://learn.mindset.co.za/resources/teacher-development/foundation-phase-mathematics/great-lesson-ideas

Personal e-mail communication from project manager (Dylan Busa, Mindset South Africa)

Lessons learnt

In the formal learning context the importance of teacher training was noted by Unlocking Talent (Malawi) as one of their key lessons: "Full training of teachers is essential. It is also important to provide them with necessary support so that they understand the technology since it is a new thing for most of them." iSchool (Zambia) reported that they had underestimated the training support needed: "It took us a while to find what support teachers needed; we originally assumed that they needed little."

One of the possible benefits of mNumeracy is that mobile phones, tablets, and other mobile devices are seen as easier to use and more intuitive than other technologies (such as computers). This seems to reduce somewhat the need for training teachers or caregivers in ICT skills, which was the case for PC-based interventions. This was commented on by iSchool (Zambia) where they changed technologies from computers to tablets.

While teacher training is known to be necessary in formal learning contexts, details on what training and for which pedagogic shifts are less evident. For mathematics learning, the attention to both the subject matter knowledge and pedagogical content knowledge for the grade level(s) at which each teacher teaches are critical. This was a lesson learnt in the mNumeracy context by the iSchool (Zambia) project as they initially (wrongly) assumed that teachers would require little support. They report that "working with the teachers is very important". Teachers need to buy-in to the product or material being introduced, and be supported to shift their pedagogical styles to use these effectively.

iSchool (Zambia) programme managers report that their product supports teachers on their journey of pedagogical change towards "enquiry-based models of instruction" (as well as considering improvements for learners).

In the formal learning context, without a quality teacher the mobile technology used in interventions is not particularly effective. Teacher 'buy-in' (or the lack thereof) influences the impact of the mNumeracy interventions. As stated in an article on a tablet project in Phitsanolok, Thailand, "we found that it was the teachers themselves that had the most influence on whether the tablets were successful in their schools…" (Harfield and Viriyapong, 2014, p. 18).

Like many computer-aided instruction offerings, mNumeracy provides opportunities for more differentiated offerings, with learners working at their own pace and level (the individualization affordance) and receiving immediate feedback on their mathematics responses (the immediacy affordance). The mathematics instructions and materials may be designed to encourage group work and class discussion (mathematics talk) amongst peers and with the teachers. What is new with mNumeracy is the flexibility created by the mobility of the device to integrate this into classroom sessions. For example, some learners can be kept engaged with entertaining mathematics games and applications (flexibly used at a desk, or in one part of a classroom, due to their mobility), while others can be working in a group with a teacher. These potentials can, however, only be reached if teachers are supported and they buy-in to their changed roles when integrating the mobile technologies into the classroom. Sesame Workshop (India) found that this was not always successfully done as some teachers seemed to use the intervention to escape their in-class teaching responsibilities.

The increased motivation of teachers and the potential to shift their pedagogy through mNumeracy interventions is noted in the case studies. The findings relating to the iSchool (Zambia) experience on the changed behaviour of teachers (which the programme managers' claim is a result of the mobile technologies) are particularly revealing: teachers attend school more; no longer resort to shouting and violence to control students; and they are enjoying their work more. These teachers are reportedly better able to manage large classes as they have lessons planned for them, which support their management of smaller group work within a large class. This project reported on a virtuous (positive) cycle of teachers improving their professional skills; being excited by the immediate impact which is evident to them; feeling proud of their achievements; and continuing along a positive path of improved pedagogy and increased learner performance. Similarly the transformative effect of the Sesame Workshop (India) intervention on teachers' pedagogy was noted in this project description. The main shift was moving away from the dominant context of "blackboard-and-chalk method" towards more group work methods. The specific changes in teaching pedagogy that Sesame Workshop (India) comments on are "allowing the children to take turns and discuss the work within their groups in order to arrive at an answer, [which] resulted in better group dynamics in the classroom." These projects are therefore not only attending to changes in learning outcomes, but are also exploring how these may be achieved (through focusing attention on changes in pedagogy). A notable gap is that while the case studies report on pedagogic changes in the form of the teaching (like group work versus whole class or transmission teaching), there was no indication of the pedagogic changes in the substance of the mathematics that was being taught. No evidence was provided as to how specific mathematics topics (for example, adding and subtracting) were approached differently, using which strategies and/or representations, when using an mNumeracy approach.

At the same time as recognising the potential motivating effect of mNumeracy on teachers, it is important to remain cognisant of the additional teacher time and effort that is required in transforming pedagogic practice in formal settings. In a context of low pay and overworked teachers, the extra time taken to learn new skills should not be overlooked. Some projects even recommend financial rewards for teachers who are involved in implementing the mobile applications (e.g. Scharff et al., 2013).

The Mindset (South Africa) case study reveals that video can be used to stimulate discussion on teaching pedagogy, and that this was informed by a strong research base relating to self-study and reflective teaching practice. However, the programme manager found that teachers were fearful of how this material would be interpreted and used by a wider audience. This nonetheless highlights the possibilities of using such video material in trusting and established sites of reflective practice (such as communities of practice for ongoing professional development) to share best practice or great lessons. Another lesson implicit from the Mindset (South Africa) experience is including some budget for video editing, to ensure that clips or critical incidents can be focused on in discussions; and that videos are short enough to remain engaging for teachers.

The Mindset (South Africa) example focused attention on teachers' pedagogy and reflective practice. As such the attention to "what numeracy skills?" was a bottom-up process with the teachers' lessons as drivers. We see this as contributing to the accessibility affordance where teachers have access to other teachers' practice, which then becomes a point of discussion. Here, the affordances of immediacy, individualization, and intelligence are less in focus.

It is possible to make greater use of the immediacy and individualization affordances in this teacher education context. However, this would require less emphasis on best practice, and greater emphasis on shared practice (where teachers see what other teacher have done or are doing, in their local community). In our experience, trust is more easily established if all participants subject themselves to voluntary recording and reflection; and no individual is held up as a role model. This shifts the teacher education content development away from designed content towards more teacher-generated content. In this situation the possibilities of utilizing the intelligence affordances by allowing teachers to find or present video clips on particular topics or within particular geographic regions (depending on their local context), may be possible.

Related to the above is use of mobile technologies for video-stimulated recall (VSR) which supports reflective practice and teacher professional development in a range of settings. Morgan (2007) provides an example of using VSR on early mathematics learning in a developed world context. The Wits Connect project provides an example of using VSR for teacher professional development in Grade 2 mathematics in a LMIC context (Abdulhamid & Venkat, 2014). Video recordings of early grade children's reasoning in mathematics, as well as teacher's pedagogical strategies in diagnostic assessments, classroom settings and small group interventions are used as key research and reflection tools in this research and development project. In this case – as for many mathematics education-focused interventions - the initiative is not framed as mNumeracy. The mobile electronic device (tablet or handheld video camera) is simply seen as fitting tool for reflective practice. Yet implicit in this use, is a potential affordance of mobile devices to cheaply create video clips to support reflective practice in early grade mathematics.

3.3 Learning outcomes assessment

This topic looks at how mobile learning can assist in improving assessment methods and understanding of assessment results in numeracy for improving learning outcomes.

A thorough check of journal articles and the internet has failed to provide even a single form of numeracy assessment in the early grades (in the LMIC context) where assessment is entirely online by means of mobile devices. All the standard forms of learner assessment at this level continue to either be by the pen-and-paper method or by oral testing. These include the following:

- Early Grades Math Assessment (EGMA) https://www.eddataglobal.org/math/
- Test of Early Mathematics Ability (TEMA)
- UWEZO http://www.uwezo.net/
- Numeracy Screener https://www.numeracyscreener.org/

However, there are a few examples where mobile devices have been used to record the answers provided by the learners during an oral assessment, or the results of the assessment. This is perhaps to be expected given that young learners are the target, and at this age they are not yet able to read and record responses independently.

One such example is that of Tangerine (see the case study), and another that of the Millennium Villages Project in parts of Kenya, Tanzania and Uganda, where the results of UWEZO numeracy tests that had been administered to learners are uploaded on Android phones and analysed by both local and international teams. The data is then shared back with communities, schools and local governments to enact changes. The mobile phones are also used to record learner and teacher attendance at school and various other data such as school materials and infrastructure.

Case Study: Tangerine®

Title of the project: Tangerine®

Implementing agency: RTI International

Funders: RTI International

Countries: The project began in Kenya, but Tangerine is now utilised in over 20 countries, including Kenya, Uganda, Ghana, Haiti, Dominican Republic, Macedonia, Sri Lanka, Indonesia, Pakistan, and the Philippines.

Target group(s): Researchers and organizations interested in early reading and mathematics student assessment.

Project launch and end date: The development of the initial Tangerine platform by RTI started in 2011. The first field trial of Tangerine was conducted in January 2012 in Kenya. As outlined above, currently Tangerine is used in more than 40 implementations and languages, 20 countries, and by more than 17 different organizations, with numbers steadily increasing. No "end date" is anticipated.

Number of schools, learners, and teachers served/reached by the project

To date, the Tangerine servers have registered more than 500,000 observations, that includes assessments with individual pupils, interviews with teachers, principals, or other survey activities for which Tangerine was used.

Goals of the intervention

To facilitate the field work and analysis for large-scale EGRA and EGMA data collections; to enhance the quality of data collected; to increase the immediacy at which data is available for decision making; and to increase the cost of large-scale, repeated data collections.

How the intervention operates (i.e. what does the project do?)

Tangerine is open-source data collection software optimized for mobile devices (such as tablets) to record student responses to the EGRA and EGMA, and to produce the questionnaires by which data from students, teachers, and principals is collected. The synchronization of data across a broad range of devices enables rapid and efficient large-scale assessments.

Flexible templates have been developed for Tangerine that allow digital data collection for the most common EGRA and EGMA subtests. For the latter these include: rational counting, number identification; number discrimination; missing number identification; addition; subtraction; word problem solving.

Monitoring and evaluation

The first field trial sample included 200 students across 10 schools in Kenya (English and Kiswahili speaking) to test the functionality and usability of EGRA assessments, as well as to determine whether the administration of the assessments electronically was better than by paper. (Pouezevara, 2012). Since then, Tangerine has been part of dozens of data collection efforts and monitoring and evaluation activities by RTI and other organizations.

Findings on impact (i.e. what changes the intervention has brought about)

Experience to date has confirmed the platform's value proposition of facilitating EGRA and EGMA field work, reducing the cost of larger scale, repeated EGRA and EGMA data collections, and enhancing the quality of data collected. Inter-rater reliability testing is significantly facilitated by Tangerine, as it allows immediate export and analysis of the data submitted and thus immediate enumerator reflection, feedback and coaching to address issues.

Why a mobile learning intervention?

Compatibility of Tangerine with mobile devices was critical given the usually low-resource and low-bandwidth context of implementation, and the nature of the EGRA/EGMA assessments where enumerators are travelling from school to school on a daily basis during an evaluation effort. Mobile devices like tablets also allow for minimal training time due to their intuitive, touch-enabled interface.

What numeracy skills?

The EGMA is an oral assessment designed to measure a student's foundation skills in numeracy and mathematics in the early grades. The Core EGMA has an emphasis on number and operations (including number identification, quantity discrimination, missing-number identification, word problem solving, addition and subtraction, shape recognition, and pattern extension).

At what financial cost?

No response was received relating to the costs of creating the software, or cost comparisons with other similar software. However, Tangerine is distributed as open source software (the code can be accessed freely via GitHub, thus any organization can install, host and manage its only Tangerine installation). Cost of use for data collections under such a scenario are then mainly for the maintenance of that installation, server hosting, procurement of the tablet devices and cases for the data collection, as well as potential cost for uploading the data to the central server. Use of Tangerine as a hosted service via RTI eliminates the cost of installation and server hosting and maintenance, but may incur a subscription fee, depending on actual use.

Sources of information

http://www.tangerinecentral.org/; http://www.rti.org/files/Tangerine_report_0112.pdf

https://www.eddataglobal.org/math/

Linda M. Platas, Leanne Ketterlin-Gellar, Aarnout Brombacher, and Yasmin Sitabkhan (2014) Early Grade Mathematics Assessment (EGMA) Toolkit RTI international. Personal communication from Carmen Strigel (RTI International)

Lessons learnt

There are several challenges inherent in assessing mathematical proficiency. Factors such what constitutes mathematical proficiency (what numeracy skills?); an understanding of how children learn; and the purpose and function of teaching (how is numeracy taught?) all come into play. All of these factors impact on the choice of approach to assessment (Dunne et al., 2012). This is made more complicated in early grades where written assessments cannot be used reliably as children are still learning to read and to record their responses. Regular oral and diagnostic assessment are an expensive and time consuming process, and reliable assessment in the early grades requires skilled facilitation with individual or small group interviews with children (Wright et al., 2006). This is an area where mobile devices could be used to make the administration and analysis of diagnostic mathematics tests more efficient.

The Tangerine project, which originated in Kenya and is now adopted in over 20 countries, makes use of mobile technologies to record and collate results from the EGMA. This is an example that reveals that a mobile device can be used effectively for the collation and dissemination of data pertaining to standardized mathematics testing in the early grades.

Video recordings of individual assessments (for diagnostic and analytical purposes) are commonly included as early grade mathematics research and intervention projects in developed contexts. The reason for this is recognition of the importance of the child's method, as well as the nature of their solution. What they answer; how long they take to arrive at an answer; as well as how they answer; are all seen as important pedagogically in mathematics. It would therefore seem logical that mobile devices (mobile phones, tablets or handheld video cameras) can be used to create video clips of teacher and learner interaction relating to mathematics. The only example we found of this kind of use in LMIC contexts was the Wits Connect project. However, as such research usually backgrounds the tool used (attending to the mathematics and pedagogy, rather than the technology) there are sure to be many other examples which we did not find through this review. The large class sizes typical in LMICs may mitigate against large scale adoption of such approaches, however.

3.4 Parents and community involvement

This topic looks at how mobile learning can support parents or community members in improving the numeracy education outcomes of their children. mNumeracy can enhance parents' participation in multiple ways: by involving parents in the relevance of education; helping them support the further education of the child at home; and encouraging them to participate in the school management and in the school accountability structures.

We found very little information, and only one case study project, that made use of mobile devices to involve parents and/or the community in supporting children's learning of mathematics in the early grades: TeachCAPS (South Africa). This case study attends to the informal end of the learning spectrum but was very limited in its scale, and its impact has not been measured.

A few other projects did have a parent or community element: the iSchool (Zambia) case study referred to community members (anyone interested in improving primary mathematics) as part of its targeted beneficiaries. They refer to the development of community learning platforms but this is not mathematics related, as the topics listed are farming, health, and skills training. The Sesame Workshop (India) project included a family or community focus, and reported that there was an evaluation conducted on this aspect of the intervention. However, most of what was reported to us on this project related to a children-focused intervention in a formal school setting.

Case Study: TeachCAPS

Title of the project: TeachCAPS

Implementing agency: Radical Learning

Funders: None

Country/region: South Africa

Target group(s): Teacher (primarily), but also parents

Project launch and end date: Early 2012 (it was in operation for approximately 2 months)

Number of schools, learners, and teachers served/reached by the project: Unknown (however, at the height of the project there were about 750 hits per day on the project website (a blog))

Goals of the intervention: To support Grade R-3 teachers and parents in the teaching of mathematics and literacy.

How the intervention operated (i.e. what did the project do?)

Teachers, via an internet-enabled cell phone, could access simple and effective daily lesson plans and a weekly homework activity schedule to use in numeracy and literacy from Grade R to Grade 3.

Similarly, via an internet-enabled cell phone, parents of Grade R-3 learners could access the weekly homework activity schedule was provided to so that they can be kept up to date with what they were learning, and assist them with their homework. This facilitated parental involvement in the learning process and ensured that the education of the children was a partnership between the teachers and the parents.

Monitoring and evaluation methodology: None

Findings on impact (i.e. what changes the intervention has brought about):

None (due to the lack of an evaluation)

Why a mobile learning intervention?

No hardware was provided; only material that could easily be accessed via a cell phone. The parent population aimed at was mainly rural and poorly educated. However, they did want to be involved in their childrens' education, and they often had their own internet-enabled cell phones for receipt of information

What numeracy skills?

The intervention aimed to cover the entire curriculum. However the project manager reported that lesson plans were developed week-by-week and the project was abandoned due to the extreme time demands before a full set could be developed. The author of the lesson plans had approximately 20 years of experience in early grade mathematics

At what financial cost?

No costs were recorded. All costs incurred were due to time spent on creating the lesson plans and blogs. No cost comparisons were undertaken.

Sources of information

http://www.e4africa.co.za/?p=4228

Personal communication with Kathy McCabe, ex-CEO of Radical Learning

Lessons learnt

There are several ways in which parents and communities can be engaged in their young children's learning of mathematics; for example: using text reminders of homework tasks; providing games and digital content for children to use while supervised at home (and monitoring this use and reporting on progress to parents); and providing tasks for home-based mathematics discussion (such as directing a parent/guardian to ask the child to count the bowls, plates or cutlery for a meal). Reporting on touchscreen technologies for early grade mathematics in South Africa, Graven (2011) identified applications falling into the following categories: math number recognition and writing, mathematically related games, spatial and number mathematics puzzles, maths illusions and games, maths jokes, maths fun facts, maths video clips, maths drills and maths tools.

We found very few projects that included parental and community involvement as their focus. In general, in fact, there is very little attention to the informal end of the mNumeracy spectrum for early grade mathematics in LMICs.

With the available data so thin in this key area, it is important to highlight that the TeachCAPS (South Africa) project made homework instructions accessible to parents (accessibility affordance). This could, of course, be done using a book which is taken home. However, for young children such information is frequently lost, and there are costs of duplicating instructions in printed format. Using mobile communication meant that parents received information directly and at a very low cost. This case did not seem to utilize the immediacy, individualization or intelligence affordances (although all three affordances could be leveraged for direct engagement with individual parents).

In relation to parental and community involvement the Sesame Workshop (India) case study noted a difficult power relationship in families as "adults took the [donated] smart phones for personal use" and siblings used the phones for their own content; which meant that "the children (target age group of 6-8 years), did not get as much exposure to the gaming digital content as was anticipated". If such family access methods are to be used, stronger monitoring of the appropriate use of the device has to be built into the project design, to ensure that the children get sufficient access. The consequences of children having inadequate access to the device must be agreed and communicated (for example, that inadequate access to the device by the child may result in the device being removed from the family). So it seems that providing access to mobile devices for children through the provision of one device to their family is only viable (in this context) with increased monitoring of usage.

The Unlocking Talent project in Malawi reported that "Community involvement is essential so that they understand the programme and give consent for their children to participate." This reveals a lesson in community involvement which relates to in-school interventions, where parental or guardian consent for the involvement of early graders in intervention studies is an ethical requirement.

CHAPTER 4: Conclusion

In this review we compiled practices from early grade mNumeracy projects in LMICs around the world, summarised the lessons learnt and collated evidence of 'what worked' and 'what didn't'.

With the narrow scope of the review (use of mLearning, focused on numeracy, in early grades, in LMICs), there was very little evidence on which we could draw. We found few articles or reports of relevance for the topics through our review of published research and the project websites. Typically there was only internal project documentation and no published work available. In total, we found only two dozen projects that met the four criteria of the study scope. The majority (about 70%) of projects were mapped to the learner instruction and materials focus area. There were four projects relevant to teacher education, two projects mapped to assessment, and only one related to community/parent involvement.

We note that there is existing research on the affordances of mLearning (responding to the "why mobile interventions?" question) in developed contexts, and this seems to be applied into LMIC contexts. We note that much of what we found pertains to digital content in general, and did not seem to build on the particular affordances of mobile access to digital content. The low cost rather than the mobility of the mobile device is a driving factor for choosing mobiles.

It is clear that there are several gaps in our knowledge base relating to mNumeracy in early grades in low-income countries. More evidence on how mNumeracy interventions can enhance learning and teaching in the challenging contexts of low-income countries is required. We found no comparative studies of mNumeracy interventions where comparison is made to other technologies or to alternative pedagogical interventions. Most of what we have found relates to formal learning settings (schools). There is far less documented on informal learning settings and how mNumeracy can support teachers and parents/carers of children in LMICs.

In relation to the 'what numeracy skills?' question, some case studies were able to provide indications of selections of topics. Integrally related to this is the 'how is numeracy taught?' question. This review did not find enough detail relating to underlying rationales for "what numeracy skills?" and "how is numeracy taught?" in LMICs. We note some evidence emerging that attends to the pedagogic shifts evident from interventions, but this was only for a few of the (already limited) case studies. The pedagogic shifts reported pertain to the general form of the classroom interventions such as increased group work, less chalk-and-talk teaching, and better attendance. The pedagogic shifts pertaining to particular mathematics topics and how these are approached are not in focus. We urge programme conceptualisers to reflect on and document the unique pedagogical and mathematical intentions of mNumeracy interventions. There seems to be no evidence of using mNumeracy to support teacher-generated or learner-generated mathematics content. The mobility of a mobile devices lend themselves to teachers and learners creating and sharing content. This may help to address difficulties of the content relevance to local contexts, yet we found not such examples. We also note that diagnostic assessment and knowledge for mathematics teaching are both key areas in the mathematics education arena, and may both potentially be cost-effectively supported using mobile devices. Again we found no projects focused on diagnostic assessment, and little about supporting the pedagogic content knowledge and subject matter knowledge of teachers that was specific to Numeracy. mNumeracy research should be situated squarely within the mathematics education literature, so that the research into how children learn (and can be better support to learn) specific mathematics skills and concepts can be brought to bare on mNumeracy interventions.

In relation to the "at what financial cost?" question, we note that consideration of costs of hardware are being taken into account in choosing mobile. The cost question remains thorny with some projects unable to reveal costs; others only tracking overall project cost; and others tracking cost per user (which is seen to decline over time as in the case of Mindset (South Africa)). We did not find studies on cost effectiveness with comparisons to other technologies and or other possible pedagogic interventions. In addition, there is apparent silence on the broadband data cost implications for the use of online digital content on these devices. We note this as another gap in the mNumeracy landscape where e-rates for reliable broadband data are required to facilitate most of the mNumeracy affordances in LMICs.

Research attention should be focused on the specific contexts of early grade numeracy in LMICs. This necessitates a focus on the factors which are likely to be particular to this resource constrained context.

We hope that this review provides a starting point for sharing lessons amongst practitioners and policy makers worldwide on how to further improve the implementation of early grade mNumeracy projects in LMICs. We urge those who are engaged in this arena to learn from the documented lessons presented in this review; and to include documenting lessons, researching impact, and dissemination of this research as part of their project scope. It is only through a collective effort to document and reflect on evidence of mNumeracy interventions that the limited pool of evidence will grow, and we will avoid repeating lessons already hard learnt.

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Annexure B: List of Projects

IMPLEMENTING AGENCY/IES	PROJECT TITLE	COUNTRY/ COUNTRIES	KEY AREA	URLs OF PROJECT WEBSITES AND/OR RELEVANT ARTICLES or REPORTS
American University of Sharjah	School Garee Program	Pakistan	Teacher professional development	
Bottom Up	Bottom Up Numeracy Project	South Africa	Instruction and materials	http://www.bottomup.org.za/bottomup-numeracy-project-update-june-2014
CSIR/Meraka Institute	Dr Maths	South Africa	Instruction and materials: online support	http://www.csir.co.za/meraka/Dr_Math.html
e-classrooms		South Africa	Instruction and materials: e-textbooks	http://e-classroom.co.za/
Earth Institute, Columbia University	Millenium Villages Project	Kenya and Tanzania	Assessment	http://millenniumvillages.org/the-villages/ http://cgsd.columbia.edu/files/2013/12/CIES-Abstract-What-drives-childrens-learning.pdf
EDC	SIRIP	Somalia	Instruction and materials: interactive radio instruction	http://idd.edc.org/sites/idd.edc.org/files/Somalia%20SIRIP%20EDC_print.pdf
EDC	Stepping Stone	Mali	Instruction and materials: lessons on basic mobile phones	http://sstone.edc.org/ http://www.edc.org/newsroom/articles/stepping_stone_success
Green Shoots	Mathematics Curriculum Online (MCO)	South Africa	Instruction and materials: online lessons	http://www.greenshootsedu.co.za/
HDF Pakistan	DiSH project	Pakistan	Instruction and materials: DVDs; interactive video lessons	http://www.educationinnovations.org/program/digital-study-hall-dish http://www.hdf.com/hdf-updates/hdf-digital-study-hall-dish-project-update/
iSchool Zambia		Zambia	Instruction and materials: tablets with lessons	http://ischool.zm/
Kytabu		Kenya	Instruction and materials: textbook subscription app	http://kytabu.org/ http://www.educationinnovations.org/program/kytabu

IMPLEMENTING AGENCY/IES	PROJECT TITLE	COUNTRY/ COUNTRIES	KEY AREA	URLs OF PROJECT WEBSITES AND/OR RELEVANT ARTICLES or REPORTS
MindSet	Flora Foundation Phase Mathematics Teacher Development	South Africa	Teacher professional development	http://learn.mindset.co.za/ http://learn.mindset.co.za/resources/teacher-development/foundation-phase-mathematics/great-lesson-ideas
Ministry of Education, Thailand	One Laptop per Child (OLPC)	Thailand	Instruction and materials: laptops	http://thesai.org/Downloads/Volume4No9/Paper_28-Facing_the_challenges_of_the_One-Tablet-Per-Child.pdf https://s3-ap-southeast-1.amazonaws.com/mobcomlab/uploads/abc-mobtechfored-report.pdf
Nafham		Egypt	Instruction and materials: online platform with educational video content	http://www.nafham.com/ http://www.educationinnovations.org/program/nafham
Pace University, Child Fund	SenMobile	Senegal	Instruction and materials: mobile apps	Apps: http://store.ovi.com/publisher/SenMobile (only available in a Nokia store in a francophone zone) Videos: https://www.youtube.com/watch?v=BHw9SOaOGCg. https://www.youtube.com/watch?v=gGMq2IzixnY&feature=youtu.be Slides: http://www.slideshare.net/senmobile/introducing-mobile-learning-in-kindergartens-in-senegal http://www.senmobile.com/officialsenmobile/index.php/en/elearning-en
Pace University. Mobile Senegal	CibleCI	Senegal	Instruction and materials: mobile apps	http://alturl.com/o3dd6 http://www.rupp.edu.kh/acis2012/ http://alturl.com/3u7yq
Pixatel	Math Whiz	India	Instruction and materials: online educational games	http://www.pixatel.com/mathwhiz
Radical Learning	TeachCAPS	South Africa	Parents and community	http://www.e4africa.co.za/?p=4228
Sesame Workshop	Play 'n Learn	India	Instruction and materials: tablets and online educational games	http://www.sesameworkshopindia.org/
Seward Incorporated International	Malawi Teacher Professional Development Support project	Malawi	Teacher professional development	http://alturl.com/2b72d
RTI International	Tangerine / Tangerine: Class	Kenya	Assessment	http://tangerinecentral.org/ http://www.tangerinecentral.org/sites/default/files/Field_trial_summary_v3_FINAL.pdf
The Communicators	Listen to Learn	Pakistan	Instruction and materials: interactive radio instruction	http://www.educationinnovations.org/program/broad-class-listen-learn
University of Witwatersrand	Wits Maths Connect Primary	South Africa	Teacher professional development	http://www.wits.ac.za/WitsMathsConnect
VSO International	Unlocking Talent	Malawi	Instruction and materials: tablets and lesson plans	https://onebillion.org.uk/downloads/unlocking-talent-final-report.pdf

Annexure C: Persons and organisations contacted for this review

Organisation / invidual	Project title	Country	Contribution
10 Monkeys – Simon Björklund		Global	Contacts
Aga Khan Academies – Karim Ismail, Joshua Muskin, Jonothon Marsh		Pakistan	Contacts
AIR - Matt Kam		USA	No response
Alison Druin – University of Maryland		USA	No response
American University of Sharjah – Imran Zualkerman	Numeracy Boost Program, & School Garee Program		Relevant content
AMESA – Gary Powell		South Africa	Contacts
Anthony Harfield – Naresuan University	OLPC	Thailand	Relevant content
Berner Lundstrom – Univ of Gutenborg	CoDAC	Denmark	No response
Bjoern Hassler – University of Cambridge		UK	Contacts
Bottom Up – Ashley Visagie	Bottom Up Numeracy Project	South Africa	Relevant content
Bridge International Academies – Marie Leznicki		Kenya	Responded but had no relevant contribution
British Council (Nigeria) – Lynda Ashaolu	Badiliko Digital Hubs	Nigeria	Responded but had no relevant contribution
Bugglegum – Dylan Green		South Africa	Responded but had no relevant contribution
Carol Carrier – University of Minnesota	Media players for pre-service teacher training	Malawi	Relevant content
Check My School		Philippines	No response
Christelle Scharff – Pace Uni	CibleCI (Senegal)		
SenMobile	Senegal	Relevant content	
Commonwealth of Learning – Vis Naidoo		Canada	Contacts
CoZa Cares – Fiona Wallace		South Africa	Contacts
CSIR / Meraka Institute – Laurie Butgereit, Anita Campbell, Adele Botha	Dr Maths	South Africa	Relevant content
Dan Wagner – University of Pennsylvania		USA	Contacts
Daniel Donohue – Brainpop		Haiti	Responded but had no relevant contribution
Deepa Srikantaiah – GPE	Numeracy Screener	Kenya and Cambodia	Responded but had no relevant contribution
Earth Institute, Columbia University – Radhika Iyengar and Alia Karim	Millenium Villages	Kenya, Tanzania and Uganda	Relevant content

Organisation / invidual	Project title	Country	Contribution
e-classroom – Natalie Wood		South Africa	Relevant content
EDC – Katharine Yasin	SIRIP	Somalia	Relevant content
EDC – Stephen Anzalone	IRI	Global	Relevant content
Elizabeth Henning – UJ		South Africa	Responded but had no relevant contribution
Eneza Education – Kago Kagichiri		Kenya	Responded but had no relevant contribution
Extra Marks		South Africa	No response
FHI360 – Seth Onguti	TEPD	Kenya	Responded but had no relevant contribution
Geoff Lautenbach – UJ		South Africa	Responded but had no relevant contribution
Green Shoots – Jo Besford	Maths Curriculum Online	South Africa	Relevant content
Hamza Venkat – Wits University		South Africa	Contacts
HDF Pakistan – Azhar Saleem	DiSH project	Pakistan	Unable to get an email that works
Helen Crompton – Old Dominion Uni		USA	Contacts
ICT4RED – Maggie Verster and Merryl Ford		South Africa	Responded but had no relevant contribution
IIM Calcutta – Dr Runa Sarkar	MOOC on M4D	India	No response
IITK – Dr Prabhakar	MOOC on M4D	India	Contacts
Innovations for Learning – Jackie Davis	TeacherMate	USA	Responded but had no relevant contribution
iSchool – Mark Bennett and Clare Stead		Zambia	Relevant content
IST Africa			No response
Johannes Cronje – Cape Peninsula University of Technology		South Africa	Responded but had no relevant contribution
John Traxler – Univ of Wolverhampton		UK	Contacts
Khan Academy – Salman Khan		USA	No response
Kobus van Wyk – ex WCED	Khanya Project	South Africa	Contacts
Kytabu – Tonee Ndungu		Kenya	No response
Malaysia MOE – Shamsuddin Hassan	PPSMI	Malaysia	Email rejected
Mark Kaplan	Masibambane	South Africa	No response
Mathletics		South Africa	No response
Mellony Graven – Rhodes University		South Africa	Responded but had no relevant contribution
Michael Matthews	Mpumalanga e-schools	South Africa	Responded but had no relevant contribution
Miguel Nussbaum – Pontificia Universidad Católica de Chile	Eduinnova	Chile	Relevant content
MindSet – Dylan Busa	MindSet Learn	South Africa	Relevant content
Mxit – Andrew Rudge		South Africa	Responded but had no relevant contribution

Organisation / invidual	Project title	Country	Contribution
Nafham – Mustafa Farahat		Egypt	No response (but info obtained off website)
Natoma – Edmond Gaible		USA	Contacts
Neil Butcher and Associates – Neil Butcher and Andrew Moore		South Africa	Responded but had no relevant contribution
Nokia – Sanna Eskelinen	Mobile Mathematics	Finland	Responded but had no relevant contribution
OLE – Richard Rowe and Kofi Essien		USA and Ghana	Responded but had no relevant contribution
OLICO – Lynn Bowie		South Africa	Responded but had no relevant contribution
OLPC		Global	No response
OWLA – Lorraine Burgess		South Africa	No response
Paiwastoon - Mike Dawson	Ustad Mobile	Afghanistan	Relevant content
Paul Kim – Stanford University		USA	No response
Pearson – Steve Vosloo		South Africa	Responded but had no relevant contribution
Pearson Foundation – Susan Tu	BridgeIT	USA	Responded but had no relevant contribution
Penryn Trust – Keren Gear		South Africa	Responded but had no relevant contribution
PILO – Afsaneh Tabrizi, Sue Cohen and Mary Metcalfe		South Africa	Responded but had no relevant contribution
Pratham/Aser – Ashok Mutum		India	Responded but had no relevant contribution
Radical Learning – Kathy McCabe		South Africa	Relevant content
RAFAH – Mohamed Matar		Palestine	Relevant content
Richard Larson – MIT	MIT Blossoms	global	Responded but had no relevant contribution
RTI – Carmen Strigel	Tangerine	Kenya	Relevant content
SAIDE – Jenny Louw		South Africa	Responded but had no relevant contribution
Sara Hennessy – Cambridge Uni		UK	Contacts
Save the Children Fund – Shirin Lutfeali		Global	Contacts
SchoolNet Nigeria – Wellington Oboh		Nigeria	No response
SchoolNet South Africa – Fiona Beal		South Africa	Contacts
Seeds of Empowerment – Lisa Griffin	SMILE	USA	No response
Sesame Workshop India – Sashwati Banerjee and Anuragini Nagar	Play n Learn	India	Relevant content
Sharon McAuliffe – Cape Peninsula University of Technology		South Africa	Contacts
South Africa DBE – Claude Tshimanika		South Africa	No response
South Africa DBE – Shafika Isaacs		South Africa	Contacts
STATSSA – Desiree Timmett		South Africa	No response

Organisation / invidual	Project title	Country	Contribution
Teletaleem – Asad Kareem		Pakistan	Works with Dr Zualkerman
Tshilidzi Davan – SABC Education		South Africa	Responded but had no relevant contribution
UNESCO – Feng Chun Miao and Mark West		France	Contacts
UNETE – Miguel Pichardo		Mexico	No response
UNICEF - Angela Bond and Nadi Albino	Ukufunda Project	USA	Responded but had no relevant contribution
USAid – Tony Bloome		USA	Contacts
VSOInt – Dario Gentili and Khanyiwe Shawa	Unlocking Talent	Malawi	Relevant content
Western Cape Education Department – Andre Lamprecht		South Africa	Responded but had no relevant contribution
World Bank – Mike Trucano		USA	Contacts
World Vision – Daniel Lim		USA	Contacts
Zenex Foundation – Fatima Adams		South Africa	Responded but had no relevant contribution

Annexure D: Detailed definitions of terms

This appendix provides a detailed definition of key terms used in this review, with sources cited.

Mobile learning (also known as "mLearning")

We note the definition followed by Strigel & Pouezevara (2012) when they cite Crompton (2013): "mLearning is learning across multiple contexts, through social and content interactions, using personal electronic devices". These researchers draw attention to their use of "contexts", which encompasses learning that is formal, or self-directed, or spontaneous, and where such learning may be context- aware or context-neutral.

We also note Compton's (2013) explanation of "personal electronic devices" as electronic devices that can be simple or advanced mobile phones, portable media players, pocket PCs, portable gameplayers (e.g. Nintendo DS), tablet computers, or even custom handheld devices", which we interpreted to include devices like pocket calculators and portable radios.

We draw attention to our interpretation of the term "personal" within this definition. We view "personal" as encompassing personal use of a device by a single user, or personal use by a small group of learners who share a single device for their personal (though shared) experiences.

We used the definition of mobile technologies used by mEducation Alliance's broad definition of the "collective term for mobile devices… [which] includes mobile phones, e-Readers, tablet computers, flash memory, micro/pico projectors, audiovisual devices, and other similar technologies" (Raftree, 2013, viii).

Mathematics and Numeracy

We took "mathematics" to refer to the formal school subject area as defined by the curriculum of most countries. The word numeracy has been introduced into mathematics curricula "to convey a meaning of not only proficiency with numbers, but confidence and inclination to use numbers in practical problem solving, in familiar and novel contexts". (Anghileri, 2007, p 1). It is the real life application of a mathematical concept, which was learnt in a formal setting. This is similar to the concept definition for numeracy used by Strigel & Pouezevara (2012) "Using mathematical skills and competencies efficiently to make sense of the world".

mNumeracy

"mNumeracy" is used in this review to refer to mobile education for numeracy. It therefore involves the use of mobile devices to improve mathematics learning outcomes and numeracy skills.

Early grades

We define "early grades" as the first four years of formal schooling which commonly takes place within a primary school setting. This includes the more informal kindergarten year (where such is provided as part of the primary school Grade offering) and the first three years of formal schooling. While ages differ by country, this refers to children who are commonly in the 5 to 9 year old age band. We refer to 5 to 9 year-olds as "early graders". We exclude consideration for the learning of children who are younger than this, and/or are in more informal kindergarten or pre-school settings which are not attached to primary schools.

Low income countries

This term is not commonly used in published literature. It has been developed by the World Bank[19] and is defined as countries where the annual per capita income is below $1 045. However, as mNumeracy projects in this group of countries are very rare, and since middle income countries frequently have high GINI coefficients reflecting significant disparities in wealth within a population, we have also included relevant examples from middle income developing countries in this review. As such the review includes Low to Middle Income Countries (LMICs)

[19] *See http://data.worldbank.org/about/country-and-lending-groups*

Annexure E: Detailed description of the data collection process

The process of gathering information for a landscape review is important as the review reveals both that which is found relating to topic, and provides an important record of what was looked for - but found to be absent - in the landscape. We therefore describe our data collection process in some detail.

Initially, information was gathered from members of the existing 'working group on mNumeracy'. A total of nine people or organisations in the 'working group on mNumeracy' were contacted via e-mail. All nine people or organisations responded, but most indicated that they did not have information on projects which met the four criteria of using m-learning; in early grades; in low-income countries; focused on mathematics or numeracy. From the 'working group on mNumeracy', relevant information relating to 3 projects in 2 countries was obtained.

To extend this human network, university and other contacts in the field of primary education that have expertise or experience in the field of mobile learning were contacted via e-mail to either provide information on relevant projects that they were involved in or knew about or insights as to who to approach for further information.

A total of 108 people or organisations were contacted via email (and, occasionally, telephone). At least two, and in most cases, three, emails were sent if there was no response to the initial email. A total of 84 (80%) of the people or organisations responded to our email requests, however, of these only 21 (= 25% of the respondents) had relevant project information to provide for the study. A full list of the persons and organisations contacted appear in Annexure C.

In parallel to this process we conducted web searches and reviews of project websites. Project descriptions were summarised from project websites or project documentation provided by project managers.

We also undertook a process of searching for relevant published research in this area. In order to gather further information on existing and past appropriate mNumeracy projects, the researchers scoured three online English language journal databases (JSTOR; Academic Search Premier; and Web of Science[20]) and a web-based repository (Google Scholar) for articles on projects which use or have used mobiles to improve numeracy, whether focussed on teachers, learners or the parents/community. Keyword searchers for "m-learning", "mobile learning", "numeracy/ mathematics" and developing world/ low income country" (in various combinations) were conducted. The purpose of this review of published research was to build on the existing literature relating to evidence of learning from m-learning interventions in mathematics in low income countries. The intention as to draw on generic lessons emerging from this research work, and to use this published research as a further source of information of possible case studies to include in the brief project descriptions.

In particular, our focus was on journals specialising in areas like early grade education, mathematics and/or numeracy education, and education using Information and Communication Technologies (ICTs) and distance education or open learning. This included, but is not limited to, the following journals: International journal of education and development using information and communication Technology; Review of Science, Mathematics and ICT Education; African Journal of Research in Mathematics, Science and Technology Education; Pythagoras; International journal for technology in mathematics education; International Journal of Instructional Media; Journal of computer-assisted Learning; European Journal of Open, Distance and E-learning; and Open Learning: the Journal of Open, Distance and e-Learning.

Limitations of the data collection

Firstly, the scan was limited in its scope to reviewing projects and research from LMICs. This was a significant constraint as lessons from developed country contexts, which may have been relevant to LMICs, were excluded. Secondly, we are both African with most (although not all) of our work experience on this continent. This may be an advantage in that Africa is central to LMICs. However this is also a research limitation as other LMIC contexts featured less prominently. Thirdly, the research was conducted in English, which limited access to projects and literature in this language. Finally, although we attempted to consider more learning-focused approaches (where the mathematics is the primary focus, rather than the

[20] *The Web of Science (SCI/SSCI) was chosen as the source database because it is a highly-regarded database which collects journals and proceedings which are included in both the Science Citation Index (SCI) and the Social Science Citation Index (SSCI).*

technology), within this realm, research and development projects making use of mobile devices does not always foreground the technology. For example, we are aware of the use of mobile video-cameras for diagnostic assessment in mathematics research, but we this is not commonly documented as part of mNumeracy or seen as mLearning. Similarly we are sure that teacher use devices like flashdrives and calculators to support mathematics learning – however, this not surfacing in the literature or commonly considered as part of mLearning. As such our scan is dominated by observations about mobile-phone and tablet technologies.

Annexure F: Factors assumed to be particular to LMIC contexts

Research attention should be focused on the specific contexts of early grade numeracy in LMICs. This necessitates a focus on one or more of the factors which (in our experience) are likely to be particular to this context:

Mathematics instruction and materials issues:

- Dated mathematics curricula (which are frequently not available digitally), with little attention to reforms in global mathematics education.
- Mathematics curricula that are not made explicitly relevant to children's local context and lives.
- Early grade mathematics classrooms that have a mixture of home-languages and languages of teaching and learning.
- Very large early grade mathematic classes.
- Early grade mathematics classrooms that lack the wide range of basic stationery and concrete materials commonly available in other primary school environments.
- A paucity of local design and development skills in the area of digital learning materials.

Teacher Professional Development Issues

- Teachers who are largely poorly trained, and unlikely to be confident in using new technologies, or new pedagogical approaches to the teaching of mathematics.
- Teachers who are poorly paid and over worked.
- Teacher fear, and teacher unwillingness to engage in new approaches, particularly in contexts of top-down forced compliance from regional managers, mitigates against transformative interventions.
- Mathematics is seldom presented as a sense-making experience for learners.
- Poor mathematical pedagogy is evident in many early grade mathematics classrooms, where there is little group work or differentiated teaching (despite very large classes) and where transmission-mode models of instruction dominate.

Assessment Issues

- Assessment is seldom used for diagnostic purposes (assessment is of learning not for learning).
- Meaningful mathematics assessment is seldom conducted in early grades (where individual or small group discussion of problems is required, as learners cannot yet read and write fluently).
- Teachers are not skilled in administering detailed, meaningful and formative mathematical assessment at the early grades.
- Communicating assessment data in useful ways to learners and parents can be absent.

Parent and Community Issues

- The same level or parental involvement seen in educated families cannot be expected in these contexts due to a wide range of factors.
- Many parents may be illiterate, and/or speak, read or write multiple languages.
- Some parents may be able to contribute their time, but would unlikely to be able to purchase devices, and/or pay for broadband data to support an mNumeracy intervention.

Technology access and equity issues

- Limited resources (so, cost-effective interventions are critical).
- Limited access to appropriate devices by young children.
- The prevalence of a culture of sharing devices.
- Serious equity constraints with regard to appropriate access to devices and affordable broadband bandwidth.

Monitoring, Evaluation and Research Issues

- Little rigorous monitoring and evaluation is conducted.
- Project documentation is frequently very thin or absent.
- Research and evaluation is seldom comparative in nature (attending to neither why mobile? (in comparison to other technologies) or why mobile? (in relation to other possible pedagogic interventions).
- Costs are very seldom tracked in ways that facilitate examination of the cost-effectiveness of interventions.
- Very little peer-reviewed research is published in academic journals reporting on interventions and innovations in this context.

We hope that this review provides a starting point for sharing lessons amongst practitioners and policy makers worldwide on how to further improve the implementation of early grade mNumeracy projects in LMICs. The review reveals that there is little work which is being undertaken within this field, and where programmes are attempting this (often with promising results) little is researched to the point of appearing in a peer-reviewed publication of results.

We urge those who are engaged in this arena to learn from the documented lessons presented in this review; and to include documenting lessons, researching impact, and dissemination of this research as part of their project scope. It is only through a collective effort to document and reflect on evidence of mNumeracy interventions that the limited pool of evidence will grow, and we will avoid repeating lessons already hard learnt.

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