RESEARCH REPORT

E-LEARNING SUDAN PHASES I & II

Research Report for Phases I and II e-Learning Sudan (2012 – 2015)

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EXECUTIVE SUMMARY

With this report, programme partners, War Child Holland, Ahfad University for Women, and Netherlands Organisation for Applied Scientific Research (TNO), will present research findings from e-Learning Sudan, an innovation technology education programme for out-of-school students to access quality education in Sudan.
Beyond the results of rigorous research conducted from 2012 to the present, this report will illuminate the various processes employed for an innovation programme designed to scale. These are important for the humanitarian sector, given the challenging context in which the programme was implemented, some of which can be adapted and applied in future innovation initiatives.

Chapter 1 provides a broader context in which e-Learning Sudan exists: whilst there is consensus that education is a fundamental human right, many global, national, and local education initiatives are falling short of international goals given the strain of such aspirations on already overburdened education systems, which are further exacerbated by conflicts and crises. However, children cannot wait for education systems to 'catch up' with existing demand, and a pathway to access quality education should exist whilst contexts are stabilising (potentially), and education systems are rebuilding / developing their institutional capacities. Can technology provide a solution? Whilst there is optimism for the use of technology to expand immediate reach of the humanitarian education responses, there is a dearth of evidence to support such excitement. This report contributes to the much-needed body of evidence for education technology programmes for the humanitarian and development sectors.

Chapter 2 describes the game design and processes essential to the success of e-Learning Sudan, including the innovation management approach and a strong partner eco-system. Whilst the programme may be adaptable to other contexts–something programme partners are exploring–the actual game design is localised with input from children and community members. Drawing on the innovation management approach, the programme is designed to scale in Sudan in four phases: i) proof of concept: mathematics, ii) scaled trial: mathematics, iii) scaled trial: literacy, and iv) scaling up.

Chapters 3 and 4 document the research design and findings from Phases I and II respectively. In Phase I: Proof of Concept, War Child Holland and its partners attempted to answer one question: can children learn mathematics by playing a game? In short, the answer is yes with statistical significance. With this success, programme partners implemented Phase II: Scaled Trial: Mathematics. Chapter 4 presents the expanded research design and findings from this phase. Here, the programme partners verified the results from Phase I with a larger group of children, in more states and communities, and over a longer period of time. In addition, the research team explored the relationship between psychosocial wellbeing and education, finding positive correlations between higher self-esteem and self-efficacy and higher mathematics scores.

The programme partners are excited to share the research results with the humanitarian sector, contributing to the evidence that education technology can support education systems to reach vulnerable populations, when institutional capacity is weakened and/or is rebuilding due to various conflict and crises events.

ACRONYMS AND ABBREVIATIONS

AIQ	Aspects of Identity Questionnaire
BBSAWS	Babiker Badri Scientific Association for Women's Studies
EFA	Education for All
EGMA	Early Grade Mathematics Assessments
ELS	e-Learning Sudan
GER	Gross Enrolment Rates
ICT	Information and Communications Technology
ICT4E	Information and Communications Technology for Education
IDPs	Internally Displaced Persons
ILO	International Labour Organization
INGO	International Non-governmental Organisation
MDGs	Millennium Development Goals
NCLAE	National Council for Literacy and Adult Education
NK	North Kordofan
ODL	Open and Distance Learning
SDG	Sustainable Development Goal
TNO	Netherlands Organisation for Applied Scientific Research
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children's Emergency Fund
USAID	United States Agency for International Development
WN	White Nile

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1. BACKGROUND AND CONTEXT

The purpose of this report is to provide a deeper understanding of e-Learning Sudan (ELS) programme, a serious mathematics education game designed for out-of-school students in Sudan.

1.1 Purpose

The report will explore the challenges of providing equitable access to education, particularly the context of Sudan, and a possible innovation technology solution that has proven successful in pilot and trial phases. To understand these accomplishments, this report outlines the 'story' of ELS from 2012 to present, including the approach and design of the game, partnerships, and the results and analysis of rigorous research conducted the impact of ELS on learning and associated psychosocial outcomes. Whilst there is an array of literature on Information and Communications Technology for Education (ICT4E) initiatives, there is little that is designed for children in fragile states, and no research focusing specifically on Sudan. Technology moves so quickly that a detailed snapshot of an 'innovative' and technology-driven project will contribute to the sum of academic and sector memory.

Additionally, most literature in this area is practitioner-focused, created by and for International Non-Governmental Organisations (INGOs) and agencies with a view to improving their practice, but rarely with academic rigour or research design in mind (Leigh & Epstein, 2012). It may be that both rigorous research and on-the-ground ICT4E projects are happening, but not in harmony. Indeed, this disconnect between the enthusiasm with which e-Learning projects are pursued, and the commitment to fully understanding them seems common (Unwin, 2013; Cristia, Ibarrarán, Cueto, Santigao, & Severín, 2012).

This report aims to provide an insight into the ELS programme, and to provide a timely contribution to the knowledge of alternatives to traditional, formal solutions for delivering high-quality and equitably accessible education to children.

1.2 Equitable access to quality education: The global landscape

Education is a fundamental human right, enshrined in a range of global statutes. It provides a pathway to lifesaving information, to protective resources and spaces, and it is the most effective pathway to increasing life chances and to reducing poverty and inequality (High-Level Panel of Eminent Persons on the Post-2015 Development Agenda, 2013). But 25 years after the adoption of the World Declaration on Education for All (EFA), and 15 years after the Dakar Framework for Action, which agreed on two education-related Millennium Development Goals (MDGs) and six updated EFA goals, the numbers of children out of school remain alarming.

The current global policy context has additional challenges. The push to achieve the goal of educating every child at least to primary level puts pressure on educational systems that already struggle to cope with demand. In complex emergencies and fragile states where there are multiple developmental and political challenges, there is more pressure, and fewer resources. In addition, the challenges of protection, social development, and psychosocial wellbeing affect children's experience of education. A number of studies agree: access to education can serve as a protective factor for children, including access to support and help with issues of abuse, the provision of life-saving information, and safe spaces (Winthrop & Matsui, 2013; Rose & Greeley, 2006; Burde & Linden, 2012).

The past five years have seen a range of criticisms levelled at the MDGs, with researchers and practitioners arguing the resources spent on trying to meet the MDGs have only been partially successful, because the focus was based too much on 'business as usual' (Waltham & Sayed, 2013; United Nations Educational, Scientific and Cultural Organisation [UNESCO], & United Nations Children's Emergency Fund [UNICEF], 2013). Recent years have seen a "shift in the global conversation on education from a focus on access to access plus learning" (UNESCO, 2013, p. i), including indicators of success from access to a focus on quality (Petrosino, Morgan, Fronius, Tanner-Smith, & Boruch, 2013). However, the resources needed to deliver education via traditional, formal access modalities are unlikely to be found (Burnett & Felsman, 2012). Additional challenges, where children may drop out, fail exams, or not learn during their education (UNESCO & UNICEF, 2013) also invalidate access as a standalone indicator of successful provision.

The proposed Sustainable Development Goal (SDG) on education, along with the Incheon Declaration adopted at the World Education Forum in 2015, outline a vision for sustainable and equitable education spanning pre-primary through to at least lower secondary. There is also recognition of the need to focus on quality as well as on access, and to support the most disadvantaged children.

1.3 Could innovation and technology be a solution?

In the outline of the global policy framework above, traditional approaches are seen as being unlikely to meet the existing needs of education globally in the immediate future. One key area of opportunity has been promoted, namely "the use of ICT in education [which] can increase access to learning opportunities" (UNESCO Institute for Statistics, 2009, p. 9), though the evidence for this advocacy is less clear than the optimism it expresses. Whilst there is material which heralds Information and Communications Technology (ICT) as a relatively simple way of giving children in the developing world access to education (Bender, Kane, Cornish, & Donahue, 2012), there is also scepticism that this enthusiasm may relate specifically to marketing of ICT or distance learning products (Daniel, 2010; Krstic, 2008). Overall, whilst the possible impact of ICT is seen as being significant, many authors (Selinger, 2009; Latchem, 2012) agree with Daniel's (2010) caution: "while computers do enrich children's lives and encourage self-directed learning, they need to be embedded within a wider framework if they are to make a systematic contribution to achieving EFA" (p. 43).

Additional studies in the Global South (Selinger, 2009; Daniel, 2010; Latchem, 2012; Power, Gater, Grant, & Winters, 2014) focused on lessons learnt, agreeing that:

1. Successful projects focus on content and infrastructure instead of on the provision of hardware;
2. A range of partners need to be mobilised, including governments, the private sector, and the creation of an enabling environment; and
3. ICT should be interpreted broadly, and practitioners should be prepared to consider how mixed-media programming might be appropriate for different groups.

The introduction of educational technologies has not changed human beings' fundamental capacity to learn, but it has profoundly changed how ideas and practices are communicated (Beetham & Sharpe, 2007). It is arguable that there are really no models of e-learning per se – only re-enhancements of existing models of learning. The challenge is to describe how technology allows underlying processes common to all learning to function effectively (Mayes & de Freitas, 2007). The role of technology may be primarily to get remote learners into a position to learn as favourably as if they were school-based, rather than offering a new learning method. This example is more a new model of educational delivery than a new model of learning. According to Biggs (1999), good pedagogical design ensures that there is total alignment between the curriculum we teach, the methods we use, the learning environment we choose, and the assessment procedures we adopt. This should be a principled approach and a set of contextualised practices that are constantly adapting to circumstances. With the use of digital technologies, new elements of learning need to be planned or designed in advance.

EDUCATION AND TECHNOLOGY: SOME DEFINITIONS

There is a challenge of terminology, where open or distance learning, eLearning, and technology-enhanced learning mean similar things, but with a different focus. King, Young, Drivere-Richmond, and Schrader (2001) highlight the lack of a coherent definition, though Perraton (2000) warns against becoming consumed in terminology. Visser and colleagues (2005) note that "the term 'distance education' has a universal definition" (p. ix), without articulating said definition. Perraton's (1982) own definition, "an educational process in which a significant portion of the teaching is conducted by someone removed in space and/or time from the learner" (p. 4), is useful, but it needs to be seen in light of new technology that allow teaching to be embedded into the programmes themselves, as is often the case in eLearning. This report will use Jisc's (2013) definition of eLearning as:

'learning facilitated and supported through the use of information and communications technology'. It can cover a spectrum of activities from the use of technology to support learning as part of a 'blended' approach…to learning that is delivered entirely online. (para. 3)

Whilst other elements of the analysis will explore concepts of learning, this paper uses the definition of King and colleagues (2001) of learning as "improved capabilities in knowledge and/or behaviour as a result of mediated experiences that are constrained by interactions with the situation" (p. 7).

1.4 The challenging context in Sudan

Sudan has experienced almost sixty years of conflict, beginning even before independence from the British in 1956. Africa's longest running civil war with what is now South Sudan lasted decades (Thomas-Slayter, 2003), and internal conflict has been rife in some areas of the country, notably Darfur. Before South Sudan seceded in 2011, Sudan was the largest country in Africa, and it remains a vast and diverse nation. Three of the 18 states that make up Sudan are still contested; known as the Three Protocol Areas: Abyei, South Kordofan, and parts of Blue Nile State remain at war, although the context of the conflict (e.g., drivers, actors, etc.), remains dynamic. The rest of the country is marked by stark contrasts, including the poverty and lack of infrastructure apparent in the east, the affluent middle class in Khartoum State and parts of the north-central, and the lives of the almost 8.5% of the population who are pastoralists. Sudan is also home to more than two million internally displaced persons (IDPs) and around 300,000 refugees from neighbouring countries (United Nations High Commissioner for Refugees [UNHCR], 2015). These dynamic populations are almost all based near Sudan's external borders. Across the country, communities suffer unequal access to social services and basic resources as illustrated by the table below showing the percentage of out of school children primary school age children who are out of school, disaggregated by gender, residence, wealth, and state:

	Male (%)	Female (%)	Total (%)
Residence			
Urban	13.6	13.8	13.7
Rural	33.1	39.2	36.1
Wealth			
Poorest	47.8	57.0	52.4
Second	39.7	44.6	42.0
Middle	24.7	30.2	27.4
Fourth	10.1	9.9	10.0
Richest	3.1	4.1	3.6
State			
Northern	7.9	7.9	7.9
River Nile	15.6	15.8	15.7
Red Sea	33.8	24.3	29.4
Kassala	38.8	52.6	45.1
Gedarif	35.9	39.2	37.5
Khartoum	8.7	11.2	9.9
Gezlra	17.1	19.7	18.4
White Nile	24.9	22.6	23.8
Sinnar	30.8	38.7	34.8
Blue Nile	46.3	47.2	46.8
North Kordofan	32.6	33.7	33.2
South Kordofan	33.2	40.7	37.1
North Darfur	25.6	30.6	28.1
West Darfur	39.2	52.8	45.7
South Darfur	37.9	45.2	41.7
Total	27.6	32.1	29.8

Table 1:

Per cent of primary school age children who are out of school, disaggregated by gender, residence, wealth, and state (UNICEF, 2014, p. 37)

Despite these challenges, Sudan is relatively successful with regard to basic education. Rates of net primary enrolment are around 76.4%–adjusted rate based on a net intake rate in primary education of 36.8% of children of school-entry age who enter the first grade of primary school–and completion around 79.3% (Central Bureau of Statistics & UNICEF Sudan, 2014). However, more than 3 million children aged 5-13 are still out of school (UNICEF, 2015). There are significant infrastructure challenges around school resourcing, poor learning outcomes, and low federal spending. The accessibility and quality of education for children in states affected by conflict also dramatically reduces: across the country, gross enrolment rates (GER) ranges from 85% in Al Gezira to 37% in East Darfur (Ministry of Education Sudan, 2014). Children disadvantaged by their location, gender, or socio-economic background are also less likely to join a school, and less likely to complete basic education. Populations on the move such as pastoralist or nomadic groups are not catered for, especially those whose traditional stock routes are cross-border (World Bank, 2012). Three quarters of all nomadic children in Sudan aged 6-13 are out-of-school, and in four of the 15 states where nomadic populations are found, this rises to 100% (UNICEF, 2014).

In this context, complex and mutually reinforcing patterns of disadvantage – poverty, gender inequity, disability, conflict, and displacement – raise barriers to schooling and erode educational opportunities for children (UNICEF, 2014). Formal education opportunities are widely unavailable, and when available, often exclude the most vulnerable children, girls, and those in rural areas. Girls are particularly disadvantaged due to socio-cultural beliefs, negative attitudes towards educating girls, the cost of schooling (both direct and opportunity costs such as the loss of child labour), distances between schools and homes, safety concerns, and child marriage, especially in rural areas.

Any effort to make traditional basic education accessible for today's marginalised children in Sudan would require substantial investment: the recruitment of teachers, significant training provided to existing teachers, class-rooms to be constructed, and government education budgets would need to drastically increase (Ali, 2014). This would take considerable time. New solutions are urgently required for the current generation of out of school children living in Sudan – solutions which tackle issues of access, equity, and quality. Innovative education technology, when coupled with a strong partnership and context-specific approach, could provide these children with a previously unimagined chance to access quality education opportunities.

1.5 e-Learning Sudan (ELS)

To address the aforementioned challenges to education in Sudan, a consortium of stakeholders including the Sudanese Ministry of Education, Ahfad University for Women, War Child Holland and TNO, has developed a serious game for mathematics based on the Sudanese national out-of-school maths curriculum in order make basic education available where formally trained teachers or schools are not present.

The next chapter will describe the ELS intervention in detail.

2. E-LEARNING SUDAN: THE INTERVENTION

e-Learning Sudan (ELS) set out to demonstrate that a viable alternative to traditional education methods—the building of schools with trained teachers and physical content such as textbooks—exists.

2.1 Theory of Change and concept

The theory of change driving e-Learning Sudan is twofold:

1. At child level, the theory of change is: if a child has access to appropriate quality education, then they are more likely to stay engaged with education and have increased resilience and future opportunities.
2. At the level of formative research which can provide the foundation for future iterations of the programme if it is proven successful, the theory of change is: if the power of innovative education technology, is coupled with a strong partnership and context specific approach, then disadvantaged children can be provided with previously unavailable chances to access cost-effective quality education opportunities.

The initial concept intended to make basic education available without teachers or formal institutions, through the delivery of a serious game[1] on hardware that is placed in a community, and supported by local facilitators. ELS utilises a serious game version of the Sudanese national out-of-school maths curriculum. As well as core curriculum subjects, the ELS game design integrates psychosocial wellbeing and life skills such as consequential decision making and solution-thinking. Additionally, engaging children in the design of the graphics and the game has made it recognisable and culturally appropriate, contributing to motivation.

Promoting understanding of mathematics in the early years is critical, as longitudinal research has shown that early mathematical understanding is highly influential on later mathematics and reading performance at school (Duncan et al., 2007), even after controlling for other basic skills that are known to affect school performance. Although the children will need to learn how to read and write in the long term, ELS started with mathematics for pragmatic reasons. The learning of mathematics depends less on language, and there are many successful examples of applications and educational games that support the learning of mathematics. Although these are mostly enrichment materials, used in addition to classroom teaching, they provide a strong basis for the development of a mathematics game that supports autonomous learning.[2] The curriculum in the game is based on the official curriculum for out-of-school children in Sudan for Grades 1, 2, and 3 and, crucially, leads to an official certification (Stubbé, Badri, Telford, Oosterbeek, & van der Hulst, in press). The game consists of two game worlds and various mini-games to practice each mathematics concept through autonomous learning. The game provides instruction, and has a management system that tracks progress and ensures children do the mini-games that first matches, then expands, their knowledge and skills. After completing a series of exercises, the software automatically unlocks new exercises at a higher level, making it possible for children to progressively acquire mathematics competencies. Children learn at their own pace.

1 A serious game is the result of collaborative efforts by experts in game design, pedagogy, and learning design to develop a game to achieve explicit learning outcomes that are measurable.

2 Based on constructivist theory of learning, autonomous learning is self-guided whereby students construct their own understanding based on their experiences and current knowledge.

The development of ELS required key components to provide a foundation for success: the innovation management approach, a strong programme ecosystem, and a contextualised game design.

2.1.1 The innovation management approach

At the simplest level, the *innovation management approach* allows groups of actors to tap into their creativity to introduce new solutions for existing problems. According to this approach, solid research and analysis, collaboration, creativity, and strategic and informed planning create the basis for successful innovation. In addition to creating new solutions for existing problems, the approach is also a discipline based on testing hypotheses, designing for scale, quality management, and building an evidence base.

Kali's (2014) description of design-based research speaks to many of the challenges in undertaking iterative programming and research in dynamic and untested contexts drawing on Collins, Joseph, and Bielaczyc's (2004) work:

> *Design experiments are contextualised in educational settings, but with a focus on generalising from those settings to guide the design process. They fill a niche in the array of experimental methods that is needed to improve educational practice. (p. 21)*

Whilst this study is not a design-based research approach in its entirety, the development of ELS did use the related innovations management approach to address the challenges of working through the different design stages.

The innovations management approach relies on processes of co-creation, bringing different actors together in partnership to solve an acknowledged problem. First described by the economists Prahalad and Ramaswamy (2000), co-creation refers to a process of collective creativity, designers creating a product or service together with end-users. In international development, this refers to designing solutions to a social issue together with a range of relevant stakeholders, from conducting research and conceptualising solutions to making, testing, and scaling up. The user becomes a co-designer, and the designer becomes facilitator in the process (Sanders & Stappers, 2008).

Yet 'true' co-creation is more than a simple collaboration. In a co-creative process, people's different insights and expertise are valued and combined to reach to new and effective solutions. This process requires willingness from everyone involved to continuously adjust the shared understanding of the issue and the proposed solutions. The facilitators have the additional challenge of needing to provide focus and commitment to the final goal, whilst staying open to new and unexpected insights. Moving beyond the creation also requires passion and stamina, and the capacity to engage the enthusiasm of others to both advocate for the utility and value of the innovation, and garner support for continued upscaling.

The innovation management approach is strongly favoured by the gaming industry, which relies on feasibility studies and assessments, economic impact studies, strategic planning, diversification modelling, and co-creation with users.

The development of ELS, from concept to extensive testing—following a strong innovation management staged approach to growth with rigorous appropriate research—has comprised of a number of stages: proof of concept, large scale trial, adaptation, and scale up. Each stage defines:

i. The information and feedback required to prove that the objectives of each stage have been reached, and

ii. The information and feedback required to build the credibility to gain other partners to support the next phase.

This approach allows the programme to mitigate risks inherent to innovation projects in education including lack of government ministry acceptance, project and product design that is inappropriate for the context, and the development of parallel systems that do not feed into national structures.

The programme stages are as follows:

Phase I (2012-2013)	Phase II (2014-2015)	Phase III (2015 - 2017)	Phase IV (2016 onwards)
Proof of Concept Mathematics in Sudan	Scaled Trial Mathematics in Sudan	Scaled Trial Literacy in Sudan	Scaling up in Sudan

Chapters 3 and 4 will describe the research from Phases I and II respectively.

2.1.2 Strong programme eco-system

In educational research, literature on eco-systems focuses on the development of blended learning and the alignment of curriculum, resources, and the learning environment (Zhu, 2012). In addition to this, developing an eco-system around the programme in terms of partnerships, joint contextual understanding, and a shared vision was the other major element of the overall design. Innovative processes are not confined to the product—in this case, the serious game—but also incorporate organisational and system innovation. Working on these aspects jointly created an eco-system in which ELS could grow.

When planning for scale and replication, consideration will be given to the creation of a similar set up in new countries, taking into account the environmental and

The Ministry of Education, Ahfad University, War Child and TNO developing the didactic framework.

Local communities were actively engaged in the implementation of ELS

contextual aspects of the programme. In Sudan, this relied on strong partnerships and allowing the time and space to work through changes to internal processes and to how partnerships are viewed. It was crucial that partnerships were brokered to utilise areas of expertise, and that all partnerships came with capacity building support. Project partners included:

- Ministry of Education, including the National Council for Literacy and Adult Education (NCLAE) and curriculum departments, which formally approved the game, the programme approach, and facilitated implementation at state level;
- Communities, which supported the programme by building and maintaining the learning centres, and supporting facilitator engagement;
- Ahfad University for Women, which led collaboration with the Ministry of Education at national and state levels, led trial implementation at village level, and was part of the research team;
- War Child Holland, which led programme design and management at global level, and was part of the research team;
- TNO, which provided distance learning and applied gaming knowledge, and was part of the research team; and
- UNICEF Sudan and New York, which provided significant communications and sector profiling support, including supporting participation in relevant conferences and summits.

These partnerships were originally developed during Phase I, and then refined in the planning for Phase II. Ensuring that there are clear avenues for local support and management, and communication lines were opened even when the innovation process can be uncomforta-ble, was crucial to creating a framework in which risks could be taken and a ground-breaking project like ELS could be developed. Building these relationships takes

time, and organisational innovations—such as working on procurement processes—can generate extra challenges. In addition, creating a shared lexicon of terms and approaches can take time, and needs to be led by local partners.

2.1.3 Contextualised game design: A theoretical background and relevant application

When developing an educational mathematics game for Sudan, we identified three domains must be taken into account: i) the development of mathematical skills, ii) ICT and education, and iii) education in emergencies. The game, meant to support the autonomous learning of mathematics in countries such as Sudan, requires integration of all three domains to support learning. An optimal combination of requirements for the game was drawn up. This set of requirements may not always be the best choice for each of the research domains separately, but rather takes into account the realities of the context in which learning via a game takes place.

In this section, we will describe the theoretical background of the project using the aforementioned three domains, including a short description of game requirements based on the literature. Following this, we will present game dilemmas related to determining this optimal set of requirements.

2.1.3.1 Development of mathematical skills

Research shows that children develop mathematical skills before beginning formal schooling (Reubens, 2009). Across cultures, children seem to bring similar types of skills to school, but do so at different levels (Guberman, 1996). In general, children from low-income backgrounds begin school with a more limited skill set than those from middle-income backgrounds, shaping the environment in which children grow up that enables them to understand the world, master language, and gain insight in the basic knowledge needed for mathematics (Greenman, Bodovski, & Reed, 2011). This means children with a more limited set of skills will need additional support to ensure success (Chard et al., 2008). Whilst this extra support usually exists for individual children in developed countries, in developing countries early interventions should be provided for all children.

Development rate

The rate of acquisition of mathematical skills can be influenced by the opportunities children have in their communities (Guberman, 1996). Household tasks and chores can get in the way of developing these skills, but they can also enhance the acquisition of these skills because they provide meaningful learning opportunities. Once children begin formal education, they use this informal knowledge when completing new tasks (Baroody & Wilkins, 1999; Ginsberg & Russel, 1981).

Becoming efficient at mathematics requires the automa-tisation of the subsequent stage, rather than repeating the earlier stages. Children need to free up cognitive resources to be able to solve more complex problems (Pellegrino & Goldman, 1987). With continued practice, children become more confident in their computational and problem solving skills (Fuson,2003). This puts a significant emphasis on good early mathematics experiences for children.

Mathematical knowledge in the early years

Between the ages of 3 and 9, the construction of number knowledge develops in more or less the same ways for all children (Reubens, 2009). Once children start formal schooling, they begin to develop a new understanding of mathematics, and with continued practice, they become more familiar with numbers and their values, and their confidence grows: children process information faster in solving mathematical problems.

Across countries, curricular and conceptual goals show similar subjects, in the following order (Reubens, 2009):

1. Developing an understanding of whole numbers, including concepts of correspondence, counting, cardinality, and comparison;
2. Representing, comparing, and ordering whole numbers, and joining and separating sets;
3. Developing understandings of addition and subtraction, and strategies for basic addition and subtraction facts, including whole-number relationships (e.g., tens and ones); and
4. Developing understanding of base-ten numeration system and place-value concepts, including fluency with multi-digit addition and subtraction.

Game requirements

First of all, a mathematics game comprising the curriculum of the first three grades of primary education should include the aforementioned curricular goals. In addition, because this project focuses on vulnerable children with little learning support from parents or teachers, we assume they to have little informal mathematics knowledge. The opportunities to learn from everyday life situations in the communities are scarce. Because of this, the approach for struggling learners was followed.

One of the major issues in supporting struggling learners is to ensure there is a strong basis upon which to build. This corresponds with the concept of mastery learning (Bloom, 1985), where "the students are helped to master each learning unit before proceeding to a more advanced learning task" (p. 4). Furthermore, struggling learners need explicit instruction (Timmermans, 2005; Milo, 2003). Research shows that struggling learners show less engagement during instruction (Bodovski & Farkas, 2007), and if this engagement is increased, performance increases as well. A focus on 'time on task' could help to improve learning results (Carroll, 1963); all children can learn mathematics, but some need more time than others.

To support struggling learners, instruction and exercises on the mathematical skills that are often acquired informally are included in the game. In addition, direct instruction is given: instruction that explains how to 'do it'. The language of instruction is basic, formal Arabic, which most children understand well. The instruction in the videos is provided by slightly older children (14-15 years), which may increase the motivation to watch the instruction videos. Furthermore, these older children can also be seen as role models, increasing motivation to learn and self-efficacy.

2.1.3.2 ICT and education (educational games)

As described in Chapter 1, technology has not changed humans' fundamental capacities to learn, but it has changed how ideas are communicated (Beetham & Sharpe, 2007), With this clarification, one can understand technology as providing new model of educational delivery rather than a new model of learning. Further, Chard et al. (2008) argue that the choice of media does not influence learning, differences in instructional design prevail over the method of delivery. Usually the difference between passive and active learning combined with clear and concise instruction determine variation in learning outcomes. This means in the use of educational games the design of instruction delivered by these games, including gamification, is of crucial importance. This is in line with Wouters, van der Spek, and van Oosterndorp (2009) who argue the alignment of learning outcomes and game type, the alignment of game complexity and human cognitive processes, attention for cognitive and motivational processes, research on specific mitigating effects, like gender, on game effectiveness should be considered in game design.

Various meta-reviews and meta-analyses show the cognitive and motivational effects of educational games in general. In their meta-analysis of 32 studies, Vogel et al. (2006) compare traditional classroom teaching to computer gaming or interactive simulation and found an overall positive effect of educational games: significant higher cognitive gains and a more positive attitude towards learning were observed in subjects using interactive simulations or educational games versus traditional teaching methods. This seems to be the case for boys as well as girls, although the low number of studies that reported statistics for males and females gives reason to consider these results with caution. All age groups showed significant positive results for the use of computer gaming or interactive simulation. The type of activity does not appear to be influential; neither does realism of the pictures in the game. Wouters, van Nimwegen, van Oostendorp, and van der Spek (2013) investigated whether educational games are more effective in terms of learning and more motivating than conventional instruction methods. In their meta-analysis of 39 studies, they find educational games are more effective in terms of learning and retention, but are not more motivating than conventional instruction methods. Learners in educational games learn more than those taught with conventional instruction methods when the game was supplemented with other instruction methods, when multiple training sessions were involved and players worked in groups.

Research on digital mathematics interventions has shown increased motivation (Rosas et al., 2003), more positive attitudes towards mathematics (Ke, 2008), and a better mastery of mathematics for children in Kindergarten and primary education (Praet & Desoete, 2014; Steenbergen-Hu & Cooper, 2013; Li & Xin, 2010; Räsänen, Salminen, Wilson, Aunio, & Dehaene, 2009), but all of these studies were conducted with European or North American children. However, Pitchford (2015) recently evaluated the effectiveness of a tablet intervention for mathematics in a school in Malawi. The author concludes tablet technology can effectively support early year mathematical skills in developing countries if the software is carefully designed to engage the child in the learning process, and the content is grounded in a solid well-constructed curriculum appropriate for the child's development stage.

Effective game characteristics

The use of technology should enable **active learning**, with a focus on the activities and interaction of learners, instead of on content in the sense of pre-prepared learning materials (Collis & Moonen, 2001; Jonassen, Peck, & Wilson, 1999). Another predominant game design feature which determines whether educational games 'work' is the **level of control** that learners have over pace, order, and strategy (Garris, Ahlers, & Driskell, 2002). This determines whether learners have a sense of 'agency', and actually feel that they can influence events in the game. The more learner control, the higher learner motivation. When children learn autonomously by playing an educational game, the game itself should provide **feedback** on correctness of their answers. Where we traditionally place this role with the teacher, sometimes computer-programmes are even better: they are able to always, consequently give feedback, something in which under-resourced, overcrowded classrooms is unlikely. In addition, *adaptive feedback* should be given (i.e., feedback on process as well as on results), allowing for children to react, think again, and receive tips to find the right answer. This approach increases attention and time on task, which in turn positively influences learning results (Carrol, 1963).

Whilst learning without the support of a teacher, children will most likely not stay **motivated** over a long period of time, unless they are intrinsically motivated. Learners who are intrinsically motivated engage in the learning process for "its own sake, for the enjoyment it provides, the learning it permits, or the feelings of accomplishment it evokes" (Lepper & Iyengar, 1999, p. 349). Also, the more intrinsic the motivation, the more durable the learning may be (Trinder, 2013).

In the tradition of Vygotsky (1978), learning is largely seen as a **social activity**. Learning should not simply be the assimilation of new knowledge, but rather, it should be the process by which learners integrate into a knowledge community. Because learning is essentially a social phenomenon, learners are likely to be motivated by rewards provided by the knowledge community (Cremin & Arthur, 2014).

Autonomous learning

The most important constraint for the ELS game design was children use the mathematics game in their own remote communities without either a school or (highly-trained) teachers. Although autonomous learning is often used for advanced learners and adults, it is not a commonly used approach for beginners. One of the most important issues highlighted in the *self-learning* literature for beginning learners is: children do not have enough knowledge to follow instruction or do the exercises without further help (capacity to understand instruction) (Vogel et al., 2006). This may be a result of the language of instruction, where children may not understand the instruction. It can also be due to the instruction itself, which assumes a certain level of knowledge and cannot be understood by children who do not have this knowledge. Lastly, cultural appropriateness can influence the capacity to understand instruction: if the game is not culturally appropriate, children need to put in an extra effort to understand the context. Thus, cognitive capacity cannot be used to understand the mathematical concept.

Game requirements

The mathematics game aims to provide a rich learning experience based on an experiential learning approach: children should learn from active engagement with the environment (Dewey, 1938; Kolb, Boyatzis, & Mainemelis, 2000). For learning to be productive, the children should be actively involved in many different mini-games. This increases the number of exercises they do, and contributes to the time spent on learning. In this way, children can repeat and practice new concepts many times, without having the feeling that it is repetitive (Jonker & Wijers, 2008). For example, for children to master a new concept, they should have access to reproductive and productive exercises. The mini-games should provide several types of activities ranging from a 'multiple choice' activity where children choose the right answer, to 'matching' and 'arranging' numbers and amounts and finally 'writing' the correct answers to problems on the tablet.

To motivate children to actively use the mathematics game for a longer period of time, they should have a certain level of control over what they do first, the pace in which they play the game, and option to go back to subjects they have completed already if they want. The game should provide feedback on the correctness of children's answers. In addition, children should have the opportunity to receive hints and tips that help them to find the right answer.

The mathematics game should include elements that invoke intrinsic motivation to learn. There are three different possibilities for this: i) the game itself should be appealing to the children: graphics, colours, and the narrative should be recognisable and fun; ii) the instruction in the game should be easy to understand, to the point, and easy to relate to; and iii) game-based learning is driven by extrinsic rewards and rewarding to stimulate intrinsic motivation. A crucial factor in intrinsic motivation in educational games is challenge and competition (Malone, 1981), and the game itself, or the setting in which children play it, should allow for this. Therefore, it is important for the game and setting to allow for social interaction between children, as well as children and adults. Children should be able to understand the language of instruction used in the game. The explanation of mathematical concepts given in the instruction should be easy to understand, never assuming that children will have a certain level of knowledge and understanding. In addition, any instruction and explanation should be culturally appropriate to reduce cognitive load.

2.1.3.3 Education in emergencies

Research shows that educational programs with or without the use of ICT have not always been successful in developing countries (UNICEF, 2009; Bitew, 2008; Unwin, 2009). The three most important factors for an educational program to be successful are: i) location, ii) flexibility, and iii) continuity (UNICEF, 2009). For ELS, the specific needs identified were: i) an appropriate location for accessing learning materials and supplementary face-to-face contact, ii) flexibility in learning alongside other demands of the family, which might interrupt a traditional school schedule, and iii) the opportunity for progression into the mainstream educational system if desired by the learner and their family. This is in line with a more general conclusion of Clark (2002) who asserts, "in order for technology to improve learning, it must 'fit' into students' lives...not the other way around" (p. 1). The educational game and context in which children play it should reflect these success factors of educational programs in developing countries.

Game requirements

Given the remote community that often lack any sort of education provision, the game should, therefore, support autonomous learning. In addition, the game should be flexible in terms of the schedule, allowing students to perform household tasks when their caregivers and families require them. Thus, the game should also support self-paced learning, allowing children to follow an individual learning path, skipping a few days whenever household tasks prevent joining learning sessions, and continuing at their own level when they can.

The game should support educational continuity. Children should prepare for official exams in Sudan, which allows them to enrol in regular education. This means the curriculum of the game must be the same as the official curriculum for out-of-school children with official endorsement from the Ministry of Education in Sudan.

2.1.3.4 Dilemmas

This chapter has provided an overview of the literature on the development of mathematical skills, ICT and learning, and education in emergencies as they apply to the development of ELS. Each of these sections led to a number of specific requirements for the game. These requirements, however, differ per research domain. Sometimes they even contradict each other, leading to dilemmas when trying to decide on the optimal set of requirements for the game. These dilemmas are as follows:

Learner control versus guided learning

The first dilemma is the trade-off between learner control and guided learning. Although research shows it is more motivating to allow learners to have a certain level of control within the educational game (Garris et al., 2002), the situation of illiterate children learning autonomously requires a much more guided learning environment. Because learning has to take place without the support of teachers, the approach for struggling learners was chosen, which actually leads to a more guided way of learning (direct instruction and a guided learning path on the basis of mastery). We have tried to partially solve this dilemma by creating a two-level game: the game world in which children have a certain level of control, and the mini-games in which learning is completely guided. Still, if children continue into advanced learning, the game should allow them to have a higher level of control.

Anywhere, anytime

The second dilemma refers to access to the game. One of the most important advantages of game-based learning is that it can take place anywhere and anytime. This increases the possibility for children to learn. In the ELS pilot and trial, tablets were shared. This means the tablets are locked up and only given to the children to use during learning sessions. The pragmatic reason behind this was cost-effectiveness: two children can use one tablet at different times of the day and the tablets are less likely to break. A disadvantage of this approach is that children who move to another village during the pilot cannot bring the tablet and have to stop playing the game.

Adaptive feedback

The third dilemma is the difficulty to provide adaptive feedback. Research shows that two types of feedback have a positive effect on learning: feedback on the correctness of an answer, and feedback regarding learning strategies. Although feedback with respect to a right or wrong answer is easy to integrate into an educational game, it is harder to provide hints and feedback on specific learning strategies. It is not always possible to determine what strategy children have used by simply logging their answer. This makes it hard to suggest a better strategy. Some hints, especially regarding numbers, are included in the mathematics game. Nevertheless, more hints and feedback on learning strategies could be designed.

Social interaction

Finally, there is a dilemma regarding social interaction. Although research shows that children learn more and are more motivated by social interaction, the need to track individual progress children requires the children to use their own device, individually. This means children do not learn in pairs or groups. They are, however, learning in learning sessions: more children learn at the same time and in the same place. During the learning sessions, interaction can take place in the form of children helping each other or showing their progress to others. At the moment, there is no real solution for this dilemma.

See Annex 1 for a table all game design requirements.

2.2 The ELS game

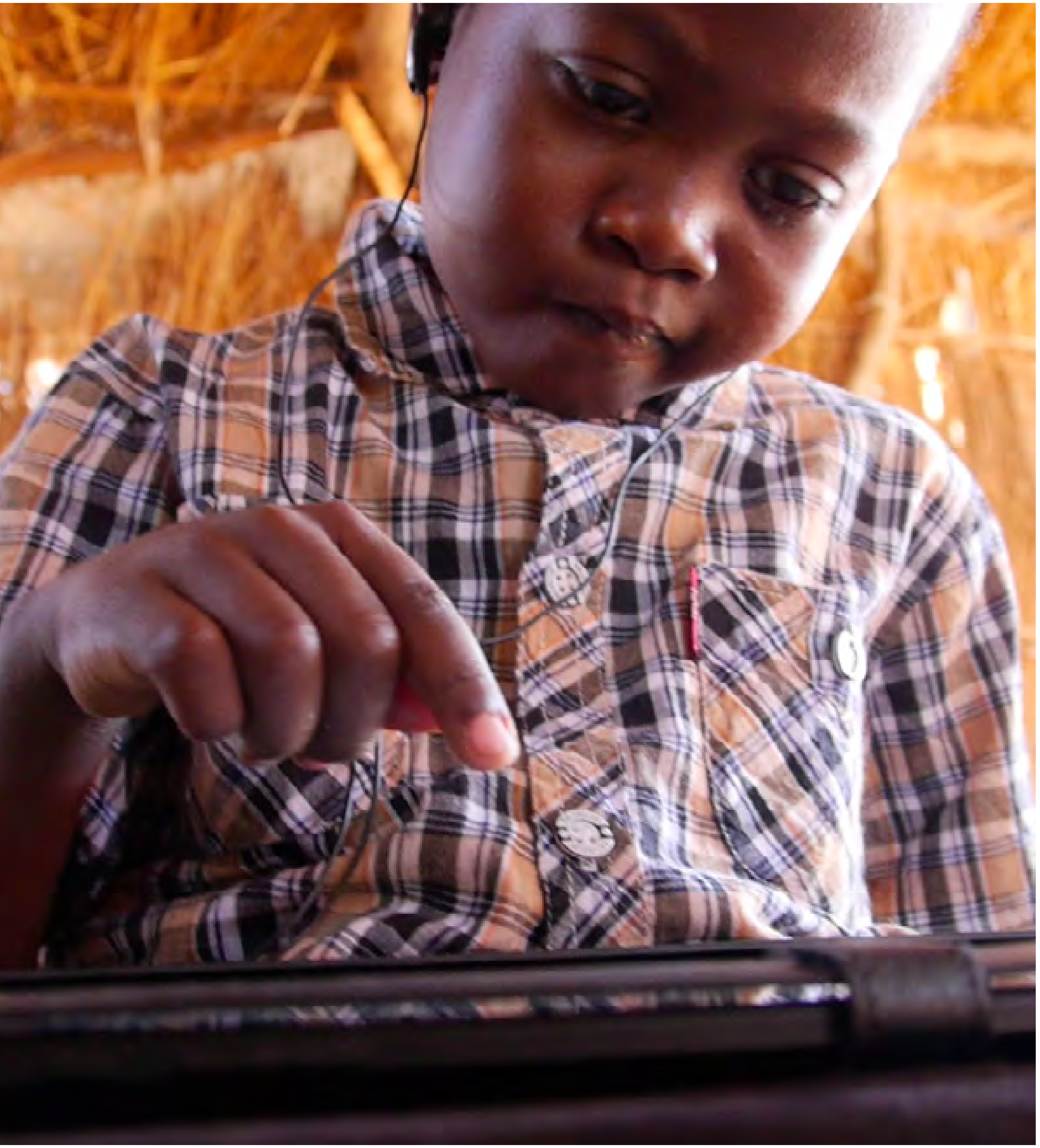
The resulting ELS game incorporates two distinct levels, each with a different pedagogy. The first level is that of game worlds, which provide the connecting narratives for the second level, that of separate mini-games (44 different mini-games, 160 variations of mini-games). Game World I (see Figure 1) asks the player/student to help other children achieve goals in their lives, like becoming a goat herder or doctor, for example. Half of the jobs are familiar roles within the target communities, such as a cook, tractor owner, or brick maker. The other half are known to the children, but are less familiar, like a teacher, nurse, doctor, and engineer. In a playful way, this helps the children to broaden their future perspective. Game World II (see Figure 2) is a shop where children can buy and sell products. By playing the mini-games, children can increase the number of products they can sell and enhance their shop.

The top level of the game environment; that of the game worlds, uses an experiential learning approach predominantly to engage the children. Learners have a certain level of control over their exploration of the game world. For example, children decide whether they watch an instruction video (and when and how often they watch the videos, without limits), check the progress they have made, play a mini-game, or just try out the fun elements in the game world. Within the shop narrative, children can also decide which products to buy and sell. The second level; that of the mini-games, has a different pedagogy, namely mastery learning with direct feedback on performance, and consequently less control over the environment. Each mini-game (see Figure 3) addresses a specific mathematical concept. Some mini-games have variations that can be used for several mathematical concepts, and all mathematic concepts can be practised with several mini-games. This was done to help the children understand the mathematical concept and stay motivated at the same time. Progress through the game is based on performance; the number of correct answers within a certain time-frame determines whether children can continue to a more difficult mathematical concept. This ensures that children always work at their own level and pace.

Figure 3: Screen shots of two mini-games

Figure 1: Game World I: building the community

Figure 2: Game World II: buying and selling in the shop



3. PHASE I: PROOF OF CONCEPT MATHEMATICS IN SUDAN (2012-2013)

From 2011 – 2012, Ahfad University for Women, the NCLAE, TNO, and War Child Holland worked together to design a strong partnership and programme approach. Because the approach of self-directed technology-based learning is completely different from the formal school system in Sudan, a proof of concept was needed, to test the ideas arising from the partnership.

The most important question for this phase was simple, **can children learn mathematics by playing the game?** To answer this question a small part of the game comprising 6 weeks of the curriculum was developed, and tested in three communities.

The first phase was developed as a six-week pilot with 66 children (57% boys and 43% girls) 6-11 years old in three remote villages, plus a control group of 20 children. The children were supervised by local facilitators, who supported the children with any technical problems, and ensured the tablets and solar panels were used properly. The children could work and learn at their own pace. Descriptive statistics of the pre-test showed no differences between the experimental and the control villages: percentage of boys and girls was the same, age variation was similar, and pre-test scores did not differ significantly.

Facilitator selection and training

From the onset to ensure the sustainability of human resources in later phases of the programme, the Ministry of Education provided the personnel to work as facilitators, and Ahfad University for Women provided extensive training. An online course was developed by Ahfad University for Women, focusing on:

- How to use the game,
- How to trouble shoot in the case of simple hardware or software issues,
- How to instruct children on game usage whilst being careful not to actually teach them (as they learn independently using the system),
- How to track and report on each child's progress,
- How to troubleshoot basic technical problems with the system, and
- How to gather the data using the tests and questionnaires.

War Child Holland co-developed sections on:

- Child protection and safeguarding, and
- Child-friendly approaches to running the programme.

After completion of the online course, the facilitators were brought together at Ahfad University for Women to practise what they had learnt, and receive additional face-to-face instruction. To ensure on-going support for facilitators during implementation, communities of practice were established.

The use of trained researchers who are not otherwise involved with the programme aimed to support the neutral collection of data in coherent ways, making sure there is no bias when the data is collected, and all children have similar experiences and answer the questions in the same way.

3.1 Phase I research methods

This phase used a pre- and post-test design between groups. The test used was based on Early Grade Mathematics Assessments (EGMA) (Reubens, 2009) and two validated tests, namely: didactic age equivalent, and readiness to learn mathematics, using the following measures: oral counting fluency, one-to-one correspondence, number identification, quantity discrimination, missing number, and addition word problems. Time limits were not used for the different exercises, and did not include the more difficult mathematics measures like subtraction word problems, addition and subtraction problems, and geometry. It was expected children could not do these tasks, and would be demotivated. The test had 30 questions. Pre-test and post-test were taken orally with the supervisor. The test was designed with a maximum score of 60, with 2 points being given for a correct the first time, and 1 given for a correct answer when it is asked a second time. An incorrect answer both times or no answer at all scores 0 points.

3.2 Phase I results and analysis

The results of Phase I showed a significant increase: children's scores on an oral mathematics test doubled from 19.4/60 on the pre-test to 38.4/60 on the post-test. Children in the control group, a fourth community, did not increase their scores in the same period. The graph below shows the children in the treatment villages have doubled their scores: See Figure 4: Phase I pre-test and post-test results.

The results indicated that all children learned and greatly improved their mathematic skills. Having proved that children can learn mathematics by playing the game in Phase I, Phase II aimed to see if the results can be repeated; if the learning can be sustained over a long period of time; to better understand the factors, which impacted on learning outcomes; and other effects of the intervention.

AVERAGE RESULTS PRE- AND POST-TEST

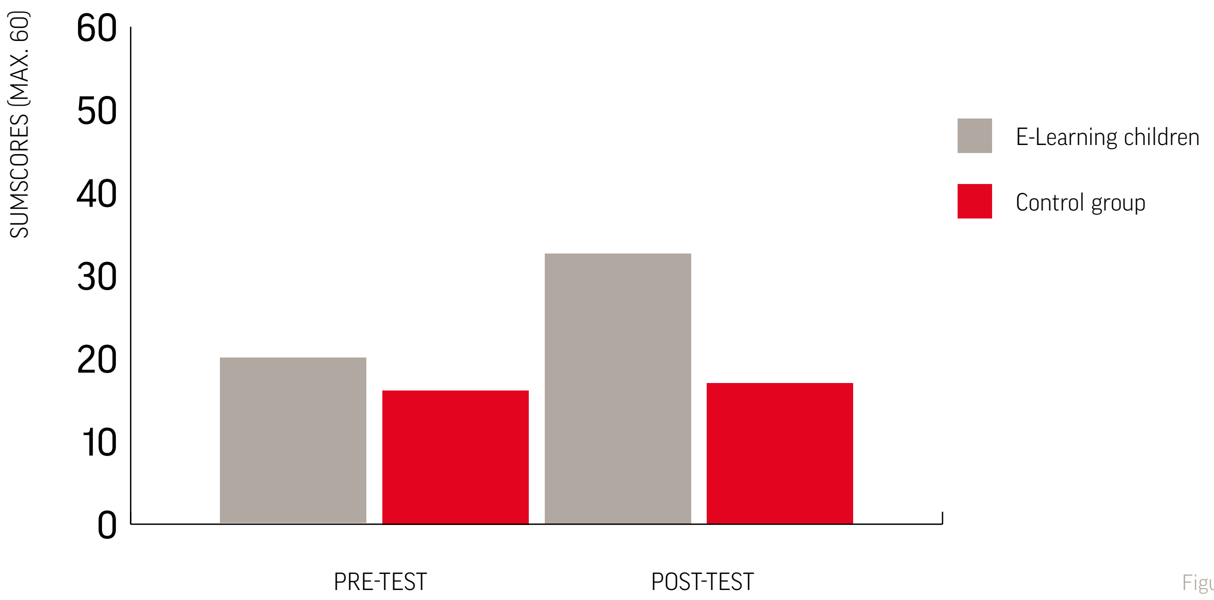


Figure 4:
Phase I pre-test and post-test results

The Early Grade Mathematics Assessments (EGMA) test

4. PHASE II: SCALED TRIAL MATHEMATICS IN SUDAN (2014-2015)

The extensive testing of Phase II took place between October 2014 and March 2015. Nineteen Sudanese villages were involved across Gedaref, North Kordofan, and White Nile States, with 591 participating children, and a planned control group of 200 children.

Beneficiary villages and children were selected by the Ministry of Education and Ahfad University for Women, based on selection criteria developed by War Child Holland and TNO. Children needed to not have attended school before, either formal or informal school programmes, and to be 7-9 years old. This large-scale trial hoped to repeat the 2012 learning results, with a larger group of children, in more states and communities, and over a longer period of time.

Phase II has two research questions:

1. What evidence is there that disadvantaged children in contexts such as Sudan can learn using open and distance learning (ODL) methods, specifically the gamification of an existing curriculum through ELS?
2. What are the impacts on the wellbeing of children of ELS part of the Out-of-School Children in Sudan project? This involves exploring additional benefits for children. For example, does ELS influence the relationship of children with their communities, their self-confidence, and future plans?

The educational research question is based on the following hypotheses:

- Children will learn basic numeracy by using ELS.
- Children who learn from ELS will have more accelerated learning compared to those without access to education.
- Children using ELS will learn as much as or more than children engaged in the official Sudanese out of school system.

Facilitator selection and training

As in Phase I, each community had one or two facilitators. The facilitator encouraged the children to work with the mathematics game and helped with technical problems. The facilitator was not supposed to teach or explain the principles of mathematics. During the week, they lived in the communities, and during the weekends they could go home. The facilitator training consisted of a combination of face-to-face meetings and distance learning, including discussions and assignments. Training topics included child-friendly approaches, educational background of the game, and technical aspects of the game and tablet, similar to Phase I.

4.1 Phase II research methods

The research in Phase II used standardised tools focused on both education and psychosocial research. Measurements were undertaken individually with the 600 children involved in playing the game, and data was also collected through facilitator feedback. This focused more on any issues that may affect the engagement of success of the children, and any technological issues.

Table 2 shows an overview of how the tests and questionnaires were to be used during the pilot. T stands for the time in weeks. T=0 means before the pilot starts. A staggered approach was used: the communities will not start on the same date. Testing is supposed to be done according to the number of weeks the children have been learning with the game.

Instruments \ time	T=0	T=7	T=14	T=20	T=26
Demographic information	X				
Geographic information	X				
Mathematics test	A-PRE	A-POST	36.1	39.2	36.1
B-PRE	B-POST				
C-PRE	C-POST	57.0	52.4	57.0	52.4
D-PRE	D-POST	44.6	42.0	44.6	42.0
Psychosocial questionnaire	X		X		X
Psychosocial focus group meeting				X	
Log files tablets					X
Game interaction questionnaire					X
EGMA					X

Table 2:
Phase II research plan

Due to logistics, the research was not completely carried out according to the research plan. Travelling to the communities proved to be more complex than expected. As a result only two of the mathematics tests were used (Test A: T=0 and T=8, and Test B: T=10 and T=18), and only two measurements with the psychosocial questi-onnaire were carried out (T=0 and T=26). All the other research instruments were used, on time.

The children played the mathematics game for a maximum of 45 minutes per day, five times per week in learning sessions, for 4 to 6 months. Throughout the 6 months, data was collected in the locations on learning outcomes, psychosocial wellbeing of the children, and technical hardware and software issues. Additional information was collected directly from the learning management system on the tablets, which harvested comprehensive data about the use of the game.

Children who participated in the trials with their child-specific numbers

4.1.1 Mathematics research

In developing the educational research, it became clear that there was a need to include an institutionalised test in order to be able to compare results from this research with other countries and contexts. The selected test is the Early Grade Mathematics Assessment (EGMA), a test that was developed in 2009 with support from United States Agency for International Development (USAID), and used globally (Reubens, 2009). The tool focuses on the early years of mathematics learning, that is: mathematics learning with an emphasis on numbers and operations, and on geometry through to the equivalent of second grade. During these early years, a young child builds a foundation necessary for learning in the years that follow. Without this, it is very difficult for children to 'catch up' to where they need to be later. The subject focus is numbers and operations, divided into a number of goals and objectives:

- Prekindergarten: Developing an understanding of whole numbers, including concepts of correspondence, counting, cardinality, and comparison
- Kindergarten: Representing, comparing, and ordering whole numbers, and joining and separating sets
- First Grade: Developing understandings of addition and subtraction and strategies for basic addition facts and subtraction facts, including whole-number relationships (e.g., tens and ones)
- Second grade: Developing understanding of base-ten numeration system and place-value concepts, including fluency with multi-digit addition and subtraction

After the successful results in Phase I, the Phase II pilot aimed to achieve the goals stated for Prekindergarten, Kindergarten, and First Grade. The tests cover a range of concepts, including counting, number identification, addition and subtraction, and shapes. Tests A and B are found as Annexes 2 and 3.

Psychosocial research

4.1.2 Psychosocial research

There are two main tools used in the psychosocial research: questionnaires with the children, and focus-group discussions with children and adults from the community. The questionnaires aimed to generate data about the impact of the project (or the perception of the project) on children's psychosocial wellbeing, categorised within constructs. The focus group discussions aimed to better understand the context in which the project is taking place, support the analysis of the questionnaire-based research, and add cases studies and narrative colour.

4.1.2.1 Construct selection and questionnaire

The psychosocial research is closely aligned to constructs that have been identified in relevant literature. Research and anecdotal experience from applying these concepts in the Global South shows that having a narrow focus and 'keeping it simple' is likely to have the best results in terms of collecting quality data. The main constructs used were:

1. Self-esteem: global self-esteem is typically defined as one's overall sense of worthiness as a person (Schmitt & Allik, 2005);
2. Self-efficacy: one's belief in one's ability to succeed in specific situations (Bandura, 1977);
3. Learning motivation: intrinsic motivation to learn, learning for its inherent satisfaction rather than for some separable consequence (Ryan & Deci, 2000);
4. Social support: the support children feel they receive from their parents, family, and community (Fleuren, Paulussen, van Dommelen, & van Buuren, 2012; Gunn, Jordans, Awan, & Hofman, 2013; Lange, Evers, Jansen, & Dolan, 2002);
5. Future orientation: the ability to recognise potential in the form of future possibilities and alternative choices (Adams & Marshall, 1996; Gunn et al., 2013); and
6. Identity orientation: people derive their sense of self (identity) largely from the social categories to which they belong, this is unique per person (Adams & Marshall, 1996; Cheek, Smith, & Tropp, 2002).

The questionnaire was developed on the basis of validated questionnaires and in cooperation with the School of Psychology in Khartoum (see Annex 4). Before use, the questionnaire was tested with 20 children in Khartoum to assess if children can answer the questions, and to train the researchers in the use of the questionnaire. These questions were asked to all the children, who answered through a graded response using a Likert scale.

Self-esteem was measured using four pictures of a tree (see Figure 5 below). The first tree was bare, the second tree had a few leaves, the third tree had many leaves, and the fourth tree had full leaves as well as flowers. These trees relate to the 'tree of life' that was used for psychosocial research in Sudan. Children were asked to draw a tree that reflects how they feel about themselves. This acts as a four-point Likert scale. Children were asked to point at the tree that showed how they felt about themselves.

Figure 5:
Pictures of trees, 4-point Likert scale for Self-esteem

The other constructs in the psychosocial questionnaire were measured with five cups, ranging from an empty cup to a completely filled cup (see Figure 6, below). This is a five-point Likert scale. Children were asked to respond to statements by pointing at the cup that suits their situation best.

Figure 6:
Picture of cups, 5-point Likert scale
for psychosocial questionnaire

The psychosocial research uses the same questionnaire of 23 statements and responses at each point, with the exception of the focus group discussions, which took place in week 20, at the end of the phase. Children and parents/caregivers were selected for involvement in the focus group discussions depending on if they had enough experience with the game, and able to say something about it. A sample of villages was selected, with three in each of the states, one in each locality. Ten people (children or parents/caregivers whose children either are or are not part of the treatment group) were involved per focus group meeting. Whilst the focus group discussions happened as planned, with trained groups of researchers, the results were limited in use because of lack of documentation of the discussion. This is further explored in the following results and analyses section.

4.2 Phase II Missing data

Three children were excluded from the pilot after conducting the baseline research as they were unsuitable for the programme for one of three reasons: i) they were too young; ii) they had attended school before; or iii) they had hearing disabilities which were too severe for them to use the audio aspects of the game, which contain the instructions. Nine children took part in the intervention, but were excluded from the results and analysis, because they:

- Were absent from more than two mathematics tests (five children);
- Undertook the baseline tests too late, when they had already started playing the game, or there were inconsistencies in the logged data from the game and the observations from the facilitator, meaning that it was not possible to determine the child's engagement (three children); and/or
- Were unable to undertake the oral tests because of hearing and speech impediments (one child).

4.2.1 Dropouts

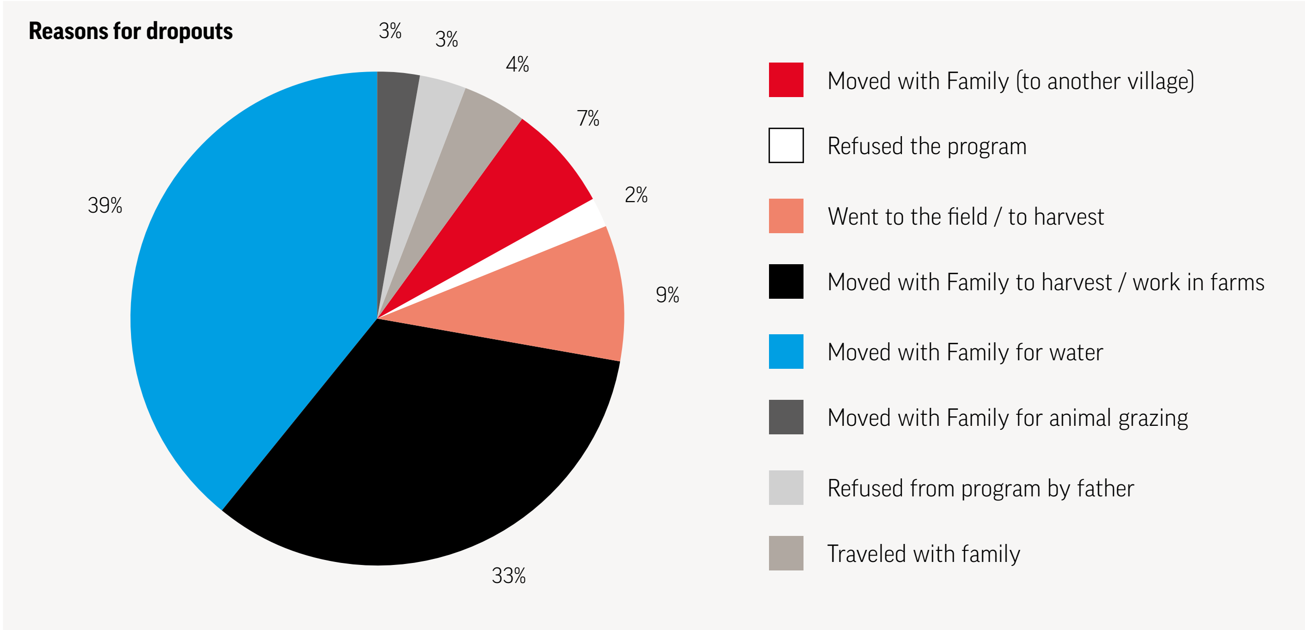
Of the 591 children who took part in the baseline, there were a number of dropouts. A pilot with a large number of participants can expect this, as getting children to sustain their interest and involvement is a recognised challenge in new education interventions. There are two key aspects in terms of dropouts:

- Understanding how many children dropped out, and excluding their data from the overall analysis to understand the results of the intervention with children who completed the programme as anticipated; and
- Understanding the factors which led children to drop out, and to reflect on how these can be addressed in future iterations of the program, or whether they represent a challenge in programme planning and design.

To allow for this reflection, and based on the research around children dropping out from school because of household commitments etc., children who participated during the whole pilot period, but irregularly (e.g., attending only limited number of days per week but coming every week), are not considered dropouts. Nor are children who completed more than 90% of the game regardless of when they left. This decision was based on the facilitator observations and remarks, checked against the logged data.

Facilitators reported that 57 children left the programme before it finished. For most children the reason for drop out was recorded. In addition to the facilitators' remarks, five more children were identified as dropouts: the logged data collected from the tablets showed that they had stopped playing the game before 12 March 2015, and had completed less than 90% of the game. Two other children, who had also stopped playing the game before 12 March 2015 were not considered dropouts, because they had finished more than 90% of the game. This meant a total of 62 children who are considered dropouts: around 10% of the total number of children who began the programme.

Figure 7 shows the description of the dropouts.



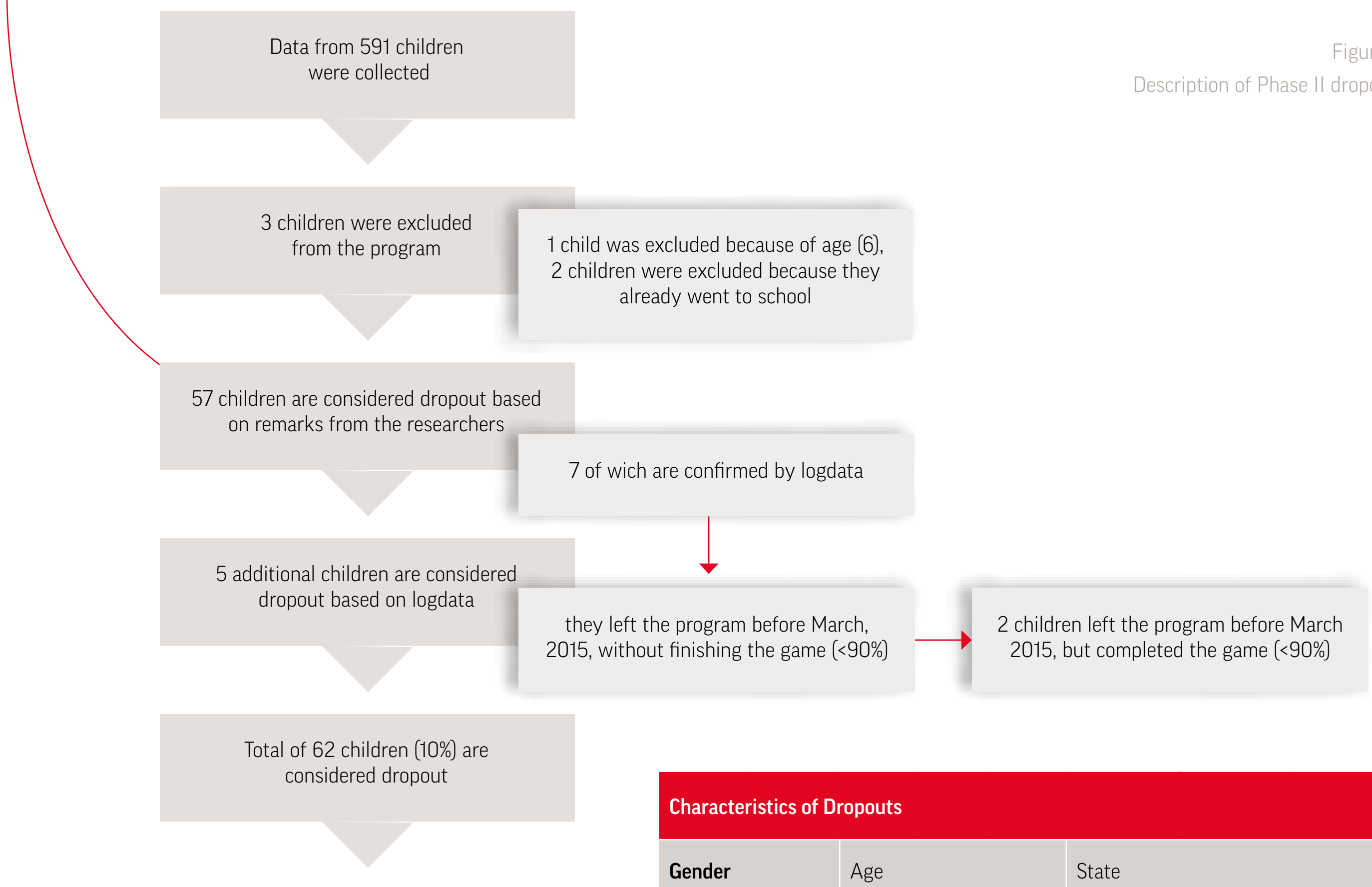


Figure 7:
Description of Phase II dropouts

Characteristics of Dropouts							
Gender		Age			State		
Boy	Girl	7	8	9	White Nile	North Kordofan	Gedaref
55,0%	45,0%	45,8%	33,9%	20,3%	76,7%	10,0%	13,3%
33	27	27	20	12	46	6	8

Whilst 10% of the children dropped out, the majority (almost 90% of these) were from a limited number of communities, and were reported as forced to move with their families to find food and water.

Analysis shows that there are no significant differences between children who dropped out and children who did not across gender and age. **This is a positive finding: boys and girls and children from different age groups have a similar risk of dropping out. This means the learning solution does not put children at a disadvantage based on these characteristics.**

We did find a significant difference for State and the number of siblings children have. The differences for State were reported as due to children moving with their families to find water and harvest crops. In two villages in White Nile most families moved in response to environmental factors. Children with fewer siblings dropped out more often than children with more siblings. The reason for this was not further researched, but it might be easier to move to another village when there are fewer children in the family. This would need to be explored in more detail before drawing any final conclusion.

This applied gaming solution allows children to learn mathematics without a teacher and was designed to respond to the known challenges for children on the move. It is therefore a flexible learning solution, which could respond to the needs of the majority of the students who dropped out. When children travel, they would take the tablet and continue learning. In this pilot, though, the focus was on conducting of rigorous research, where the children had to stay in one village to remain involved. All children that moved to another village were seen as dropouts. Allowing children to take the tablets when they move, and continue learning in the new location, should be considered as part of the scale-up or replication of this intervention. Assuming that the extant factors and results would be the same in a new location, facilitating learning whilst on the move could possibly decrease drop out to 0.5%.

4.2.2 Mathematics tests

The table below shows the number of children that had missing data either for test A (pre- or post-test) or test B (pre- or post-test), or for both tests. Data for a test is considered missing when a child did not take one or both of the tests (pre- and/or post-test). The reason for this is both the pre-test and post-test are needed to assess progress against common questvions.

A-PRE	A-POST	B-PRE	B-POST
2	13	16	47

Table 3:
Missing data mathematics tests

The mathematics tests had to be taken at specific times, if a test was taken at a later moment, children would have played the game for a longer period of time and learned more. This data would change the analyses. For test A, most data was collected. Only two children missed the pre-test, and 13 children missed the post-test. Girls from North Kordofan especially missed the post-test. For test B, 16 children missed the pre-test and 47 missed the post-test, children in North Kordofan especially missed the tests, however, there were only small differences for gender and age. There were hardly any missing data for White Nile participants. This may be due to the fact that White Nile had the highest number of dropouts: children who missed too many tests probably dropped out of the pilot, and do not show in the missing data.

Overall, it took much more time to collect test data and enter them into Excel sheets than was planned for in the research design, which may be one of the reasons for missing data. Future iterations of the programme will improve the digitisation of data collection, which would reduce mistakes and facilitate speed at the same time.

4.2.3 Logged data from the game software

Data logged on 532 tablets was collected, leaving 59 tablets from which logged data was not collected. In Al Arageab in North Kordofan, logistical challenges meant that logged data for 24 children was not collected. Apart from the missing data from this community, there were some missing data (26 files with logged data) divided over the other communities. Logged data was also missing for children who were determined to be dropouts, but their exclusion will not affect the analysis.

Although all children's data should have been collected by their allocated reference numbers rather than their names, this was not followed consistently in all field locations: 386 accounts were based on the child's name written in English, the other 146 were based on the child's name written in Arabic. The Arabic names were transliterated into English, and these, along with those recorded in English only, were matched to the names as they were written in the baseline. These names were then matched to the children's reference numbers.

The transliteration of Arabic names caused some challenges, as multiple spellings of common names were used and spelling mistakes were made. Additionally, Sudanese names tend to be long, with a string of four or five common names making up an individual's full name. In the records, only some of these names were used and logged as 'first' and 'surname', but this was not consistent. Final matching between all the different logged names and the allocated reference numbers was performed by three researchers, individually. Only the name matches that were agreed by all three researchers were included in the final list. Twenty three accounts with logged data could not be matched to names of children from the baseline study, whilst at the same time, 56 children could not be matched to logged (see Table 4).

A total of 77 participating children (not dropouts) did not have matching logged data.

Because of sporadic Internet connection, logged data had to be collected manually from the tablets to laptops and then brought on a USB stick to Khartoum in person. In spite of this, most logged data was collected. This means the logged data of 532 tablets was collected (91%), which under the circumstances is very positive.

The management system of the game can also synchronise the logged data straight from the tablet to a server if there is Internet connectivity. This will facilitate the collection of logged data enormously in areas where Internet is reliable. In areas without Internet connectivity, facilitators can follow the progress of their children by simply uploading the logged data from the tablets to a laptop. A local management system provides a quick overview and statistics. Data from the laptop can then be synchronised with a server from time to time.

Although all the logged data should have been collected by unique child numbers, there were some challenges with standardising this. In total, 508 files of logged data could be matched, around 86%. To prevent this situation in the future, we have added an obligatory field for the child number in the form for new accounts in the management system. It is now not possible to create a new account without entering this number.

Baseline study	Logged data	Matched logged data	Children without matched logged data	Logged data without matches
591	532 (91%)	508 (86%)	83 (14%, including	23

Table 4:
Missing logged data

Child playing the mathematics game

4.2.4 Psychosocial questionnaire

Two children missed the baseline measurement of the psychosocial research, and 26 children did not fill out the questionnaire at the end of the pilot. The table below shows how these missing data were divided over gender, age, and state.

		PS T0	PS T1
Boy/Girl	Boy	2	14
	Girl	0	12
Age	7	0	6
	8	0	9
	9	2	11
State	White Nile	1	4
	North Kordofan	0	0
	Gedaref	1	22

Table 5:
Psychosocial questionnaire missing data were divided over gender, age, and state

4.3 Phase II research results and analysis

Three states participated in Pilot Phase II where children played the game for 6 months: North Kordofan (seven communities), White Nile (seven communities), and Gedaref (five communities). Figure 8 shows the communities per state, and the number of children per community at the start of Phase II.

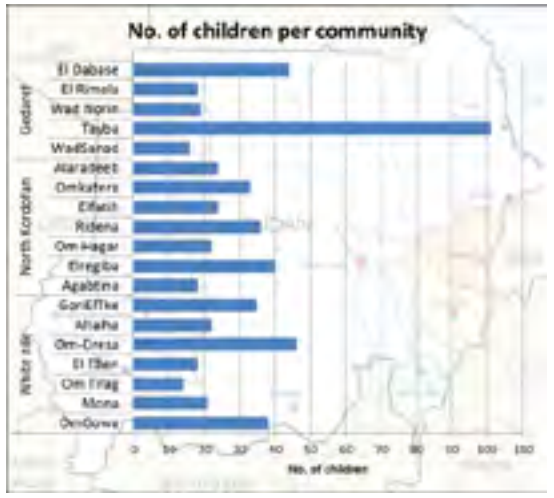


Figure 8:
Communities per state, and the number of children per community at the start of Phase II

A total of 517 children are included in the results and analysis of this study. During the pilot, data was collected from 591 children. Fifty-one percent of the participating children are girls, 49% of them are boys. All the participating children are between 7-9 years old, with an average age of 7.8 years. Children in North Kordofan are slightly younger (average is 7.4 years), compared to the children in Gedaref (8.0 years), and White Nile (7.9 years). There was no significant difference between the average age in the experimental condition and the control group (8.3).

Children were asked if they had both their parents, one parent, or no parents at all. Most children reported they had both their parents, though children from North Kordofan reported more often only having a mother (24%) or no parents at all (1%). On average, children reported having 5.3 siblings. Children reported that 80% of their parents have not finished primary education, and that 20% had finished primary education, of whom only a few have finished secondary education as well. There was no significant difference between fathers' and mothers' educational achievements.

4.3.1 Mathematics research results

Test A
To assess if children have increased their scores on a mathematics test, an Anova repeated measures (SPSS GLM) test was used within subjects factor: Math-A-PRE and Math-A-POST. The average score of children in White Nile, North Kordofan, and Gedaref on the pre-test of test A was 20 (max. 60). The average score on the post-test of test A was 41. The analysis showed that children increased their scores on test A significantly ($F(1,499)=1170.929$; $p < .001$; $r=.85$). There were significant differences between the states ($F(2,99)=21.710$; $p < .001$; $r=.29$); White Nile has a higher score than North Kordofan, and Gedaref on the pre-test (24 points resp. 16 resp. 19) as well as on the post-test (47 points resp. 40, resp 37) of test A (see Table 6). Post-hoc tests employing the Bonferroni correction show that White Nile differs significantly ($p < .001$) from the other two states. There is also a significant interaction between Math and State ($F(2,499)=9.055$; $p < .001$; $r=.21$). All three states perform better on the post-test than on the pre-test, but North Kordofan has a relative greater increase of scores from pre-test to post-test.

There were significant differences between the age-groups, with the younger children scoring lower than the older children ($F(2,499)=14.758$; $p < .001$; $r=.25$). Post-hoc test show that the 9-year-old children differ from the younger ones. There is no significant difference between the 7- and 8-year-olds ($p < .075$) (see Table 6). There was also a significant interaction between Maths and Age ($F(2,499)=5.258$; $p < .010$; $r=.16$) with the younger children increasing their score more than older children.

60																
50																
40				47	40				41	42					43	44
30						37								39		
20	24							20					26			
10		16	19				19				17	19				
0																
		K	G	WNS	K	G	Boy	Girl	Boy	Girl	7	8	9	7	8	9
	State			State			Gender		Gender		Age			Age		
	Pre-Test			Post-test			**Pre-Test**		**Post-test**		**Pre-Test**			**Post-test**		

Table 6:
Differences between pre- and post-tests A

4.3.2 Control group

A control group was planned for the research. The control group received the traditional out-of-school education programme. They also took test A, both pre- and post-tests. However, in the control group, the post-test was taken much later than in the experimental group. The experimental group took post-test A after 6 to 8 weeks, whereas the control groups took post-test A after 3 to 4 months. Because of the data collection issues with the control group regarding the timing of testing, differences between the experimental group and the control groups must be interpreted with caution. Comparisons are made per state, not with the total average scores. **A comparison of the North Kordofan (NK) experimental group with the NK control group shows no significant differences, in pre-test, post-test, or increase of scores between pre- and post-test (see Figure 9). This is a positive finding, as the NK control group received twice as much learning time per day, compared to the experimental group (two times 45 minutes vs. 45 minutes a day).** Moreover, the NK control group had a three-month interval between pre- and post-test, whereas the experimental group had a 6 to 8 week interval between tests. **Roughly, the NK control group has had three times as much opportunity to learn as the NK experimental group.** The NK control group is very small (N=31), which makes it less suitable to compare to the NK experimental group (N=182).

AVERAGE RESULTS TEST A, PRE- AND POST-TEST, NORTH KORDOFAN

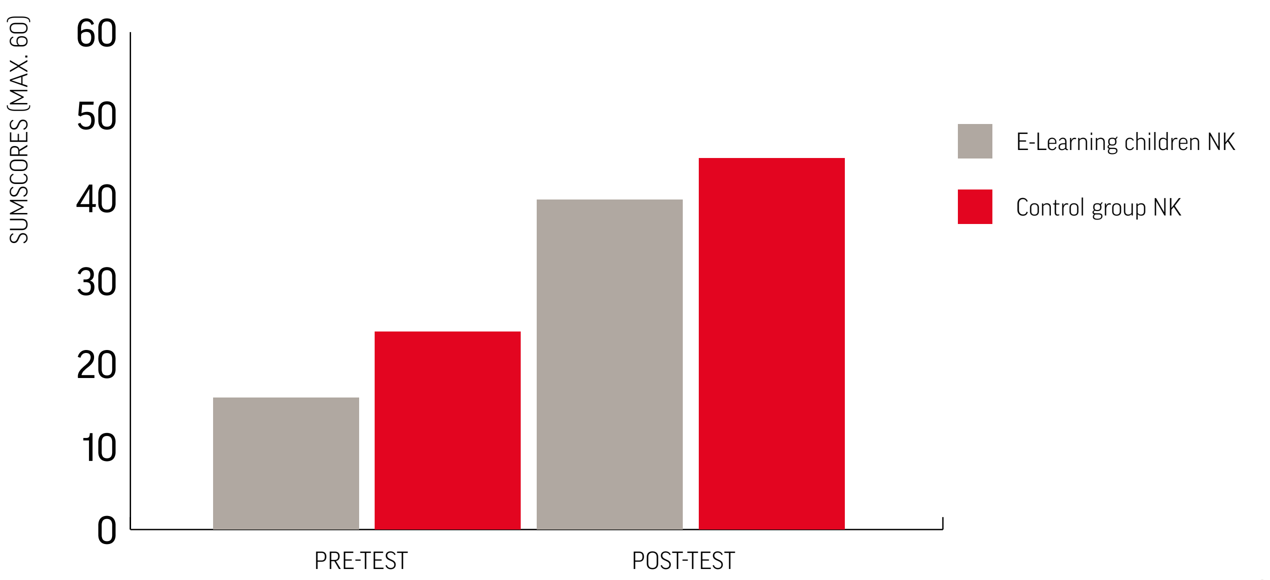


Figure 9:
Average results test A,
pre- and post-test, North Kordofan

A comparison of the White Nile (WN) experimental group (N=148) to the WN control group (N=146) shows that there is a significant difference in increase (31 vs. 36 points) between the two groups (F(1,288)=17.034; p < .001; r=.24). The WN control group on average significantly increased its score more than the experimental group (see Figure 10).

It is important to note that the WN control group had (much) more opportunity to learn: they had two mathematics lessons of 45 minutes per day versus 45 minutes in the WN experimental group, and a much longer interval between pre-test and post-test (6 months vs. 6 to 8 weeks). This means the WN control group had roughly six times more learning time than the children in the WN experimental group. The WN control group had 75% correct on the post-test, which means there was more room for improvement. From this perspective, the difference in the increase of scores is rather small. Children in the WN experimental condition have relatively learned more.

AVERAGE RESULTS TEST A, PRE- AND POST-TEST, WHITE NILE

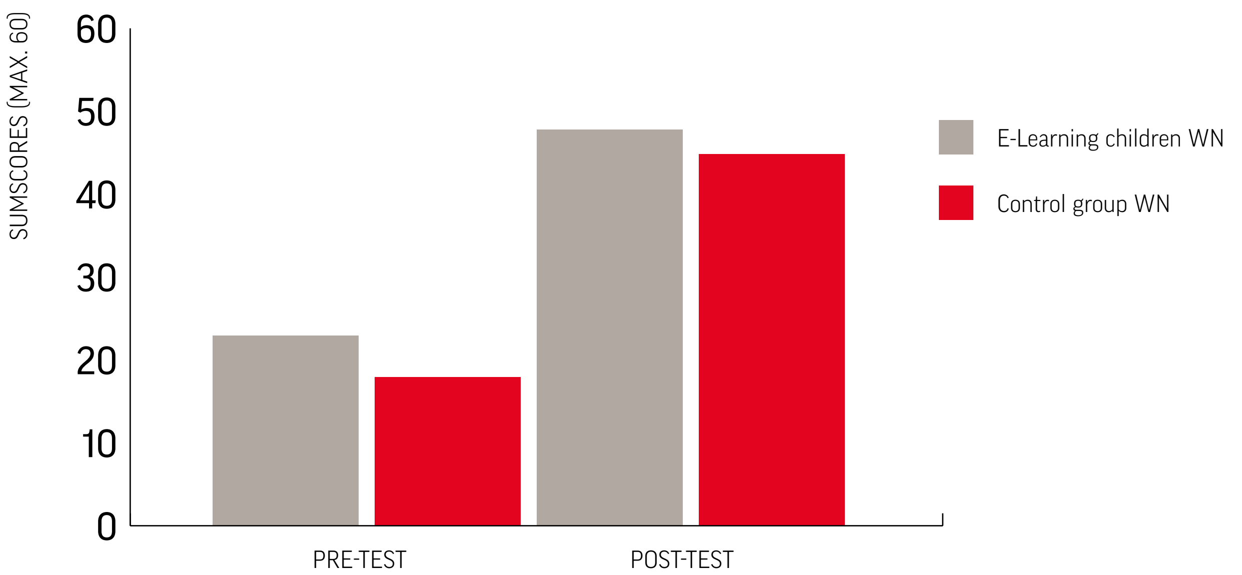


Figure 10:
Average results test A,
pre- and post-test, White Nile

60																
50																
40				42	48				41	42				41	42	43
30	35	34				37	32	33			31	34	35			
20			29													
10																
0																
		K	G	WNS	K	G	Boy	Girl	Boy	Girl	7	8	9	7	8	9
	State			State			Gender		Gender		Age			Age		
	Pre-Test			Post-test			**Pre-Test**		**Post-test**		**Pre-Test**			**Post-test**		

Table 7:
Differences between pre- and post-tests B

Test B

To assess if children have increased their scores on a mathematics test an Anova repeated measures (SPSS GLM) test was used within subjects factor: Math-B-PRE and Math-B-POST. The average score of children in White Nile, North Kordofan, and Gedaref on the pre-test of test B was 32 (max. 60). The average score on the post-test of test B was 41. **The average increase of 9 points is significant** (F(1,456)=160.067; p < .001; r=.51).

The score on the pre-test is remarkably high. Although there was some overlap between test A and test B, this does not explain the notably high scores on the pre-test of test B. In the research plan, the pre-test of test B should have been taken at the same time as the post-test of test A. In reality, it was taken later, with researchers travelling back to the communities. In the meantime, children played the game on a daily basis, and thus increased their knowledge. This may explain the high average on pre-test B.

There were also significant differences between the states (F(2,456)=11.967; p <.001; r=.22) (see Table 7). Post-hoc shows that Gedaref differs significant (Bonferroni) (p < .010) from the two other states with a lower score on the pre-test of B. The interaction by State with pre- and post-tests is also significant (F(2,456)=10.022; p <.001; r=.20); the increase of mathematics scores from pre-test to post-test was highest in North Kordofan. Because the order of the curriculum in the game was different from the Sudanese curriculum used in the out-of-school learning centres, the control groups did not take test B, as they had not been taught the mathematical concepts tested in test B.

GLM analyses showed an improvement of mathematics abilities in both tests over time, independent of the baseline score of the participant and corrected for demographic variables (Math A improvements df=11, F=24, 46, p < 0.00, eta=.38; Math B improvements df=11, F=33.05, p < 0.00, eta=.45).

Improvements in mathematics abilities did not differ between boys and girls (see Table 8).

Note: Repeated GLM corrected for demographic variables: Math A improvements*gender F<0.01, hyp df=1, error df= 502, p=.97, eta=0,00. Repeated GLM corrected for demographic variables: Math B improvements*gender F<1.85 hyp df=1, error df= 453, p=.17, eta=0,04.

	factor	Mean	Standard Error	factor	Mean	Standard Error
Boy	Math A pre	20	.73	Math B pre	32.00	1.17
	Math A post	41	.92	Math B post	39.86	1.09
Girl	Math A pre	20	.71	Math B pre	32.58	1.13
	Math A post	41	.90	Math B post	42.38	1.04

Table 8:
Improvements on tests
A and B in relation to gender

Children being tested

Improvements in Math A scores were significantly different for children with different start positions (F=29.17, hyp df=2, error df=488, p < .00, eta=.11). Children with the lowest score in the baseline study improved the most. This did not apply to Math B: on the whole, according to a multivariate test, there was a trend but not a significant difference between groups (F=2.48, hyp df=2, error df= 443, p=.08, eta= .01). Univariate test contrasting results between groups, however, did differ significantly (p=<.00). This indicates that there was still some difference between groups during Math B improvements, but not as much as during Math A improvements.

4.3.3 Mathematics research analysis

Both mathematics tests show that children have improved their knowledge of mathematics considerably. The average score on both post-tests was 41 on a 60-point scale. There are no significant differences for gender, which is a very positive finding; boys as well as girl can learn by playing the game. There are significant differences for age, with the younger children having a lower score than the older children. This can be explained by the fact that older children probably have more informal mathematical knowledge gained from the real world. The significant differences between states can largely be explained by age.

In test A, the children with the lowest pre-test scores learned most, their scores showed the highest increase. This is a positive finding as it shows that children do not perform better because they already had mathematical knowledge; the playing of the game contributed to the increase of their scores. The reason for this is probably the game starts at the very beginning of mathematics: the first learning goals are actually kindergarten learning goals. Children who do not have this knowledge, learn this by playing the game. Children who already have this knowledge (i.e., higher score on the pre-test) will not learn so much in the beginning. There is also a ceiling effect in the tests: the children who had the highest score on the pre-tests had a score of 48 on the post-test (80% correct). They will go through the game faster, because they make fewer mistakes. These results are similar to those of Phase I (Stubbé et al., in press).

In test B, this effect did not occur. Although there are differences between the scores on the pre-test, all children increased their scores with an average of 10. This increase is not very large, and probably due to the fact that the pre-test of test B was taken too late: the children had already started playing the games that helped them to understand the learning goals of test B. The reason for all children showing the same increase on average can probably be explained by the fact that the differences in informal knowledge before the pilot have levelled out after test A.

A multi-variate regression analysis shows that post-test scores on tests A and B are mainly defined by pre-test scores on the same test. This might imply that playing the game does not support learning mathematical knowledge, but that informal knowledge before the pilot started determines the learning outcomes. Looking at the increase of scores on the tests shows that this is not true. All children significantly improve their knowledge on both tests, and in test A children who have the lowest scores on the pre-test show the highest increase of scores. Furthermore, demographic variables add a little, but still significantly to the explained variance of the model. The relevant variables have a small but significantly negative effect on the maths results. For instance, a higher education of the mother relates to lower maths results, and the longer the distance to the nearest primary school, the better the maths results. It is not clear how this can be explained. It is remarkable that gender and age do not significantly explain variance of the model. In education research, gender and age usually have an effect on learning outcomes. **The fact we did not find this effect in this study suggests the game supports the learning of girls as well as boys.** There can be several reasons for this including: the motivational factors of the game appeal to boys as well as girls, the instructional videos are very clear to boys and girls, etc. However, classroom dynamics are completely different in game-based learning. This might affect the active involvement of boys and girls in a different way.

EARLY GRADE MATHS ASSESSMENT RESULTS AND ANALYSIS

For external validation of the ELS mathematics research, external researchers conducted an Early Grade Mathematics Assessment (EGMA) with 210 children from all three states participating in the large-scale trial. There were no significant differences for gender. For age there was a significant difference for the measurement on problem solving and addition level 2; the 7-year-olds had a significant lower score than the 8- and 9-year-olds. In table 9 below, the average EGMA results of the children in the large-scale trial are compared to those of 3rd year students in Sudan and in Jordan:

The ELS children have had approximately 5 months of education. The other two groups (Jordan and Khartoum) are in Grade 3, and will have had approximately 2 years and 5 months of education. Although ELS children have had 2 years less education than the other two groups, they do have the highest scores on: shapes 1, shapes 2, and word problems. In addition, ELS children have a higher score on missing numbers than the children in Khartoum. The children in Jordan have the highest score on this measure. The ELS children only have a slightly lower score on: number discrimination, addition level 1, and subtraction level 1. Compared to the number of months of education, this is a good result. The ELS children have a much lower score on: number identification, addition level 2, and subtraction level 2. This is due to the fact that the game offered little instruction and practice for these subjects - only numbers up to 20.

There are significant positive correlations between the scores on the mathematics tests A and B (pre- and post-tests), and the measurements of EGMA. Children who had a high score on the mathematics tests, also had a higher score on the EGMA measurements. These correlations are not always strong. The strongest correlations are for addition level 1, subtraction level 1, and problem solving, all correlating more than .50. Although all tests show significant positive correlations with EGMA, post-test B has the strongest correlations. This can be explained by the fact that test B measures more difficult mathematical concepts than test A, and therefore is more similar to EGMA than test A. These correlations show test A and B measure similar concepts of mathematics as EGMA.

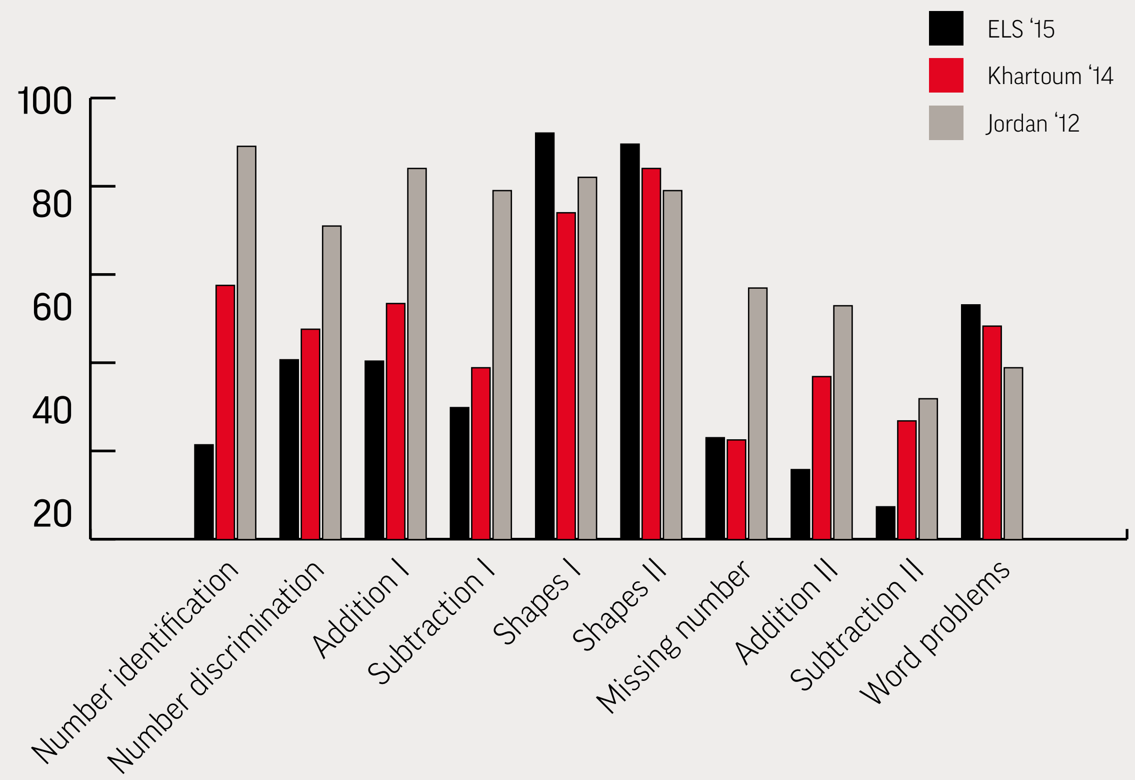


Table 9:
EGMA Scores of Phase II participants, Sudanese students, and Jordanian students

4.3.4 Logged data analysis

The first analyses of the logged data suggest the following correlations with the tests:

- Children who have played the game more often (in days) do not necessarily have better results on the mathematics tests. This means that being present and playing the game does not in itself influence mathematics results. **How far a child progresses through the game is what makes the difference.**
- Children who make fewer mistakes (more mini-games finished without any mistakes) have better results. Although finishing more mini-games without any mistakes might be an indication of a higher level of mathematics knowledge, there is no correlation between the number of mini-games finished without mistakes and the percentage of the game the child has completed.
- The higher the percentage of the game the child has completed, the higher the scores on the mathematics tests. **This is a positive finding that suggests that in later research, we can rely on the percentage completed as an indication of the level of knowledge the child has.**

The logged data show the actions and the performance of children in the game, which gives insight into what users actually did, and how these actions relate to results in the game and in the tests. Because the tablets were not online, there was a problem with the timestamp for 20% of the tablets. The original date on those tablets was in 1970, after an update of the game, this was changed to 2015. The number of months played was therefore not correct, and could not be used for further analyses. Having an Internet connection would solve this problem, automatically ensuring all the tablets have the right date. In the meantime, facilitators should ensure all tablets have the right timestamp.

Although we had intended children to play the game five times a week for 6 months, only about 5% of the children managed to do so. Most of the children (42%) played 2 to 3 days a week on average. Some played 2 to 3 days every week, others played for 2 weeks and then skipped a week. Twenty-two percent played 1 to 2 days a week on average and 11% played 3 to 4 days a week. There are no significant correlations between the average number of days played per week and the results on the mathematics tests. The number of months children are participating in the pilot seems to be more important. Most children (44%) played the game for 5 to 6 months. Seventeen percent of the children played the game for 3 to 4 months, and 6% played for 7 to 8 months. This effect can be explained by the fact that children who played more months actually played more days, irrelevant to the average number of days played. Children who made fewer mistakes in the game (more mini-games finished without any mistakes), have higher scores on the tests. This is not caused by the fact that they can move faster through the game, and have thus completed more game. There is no significant correlation between the percentage completed of the game and the number of games finished without any mistakes. There are two possible explanations for the fact that children who finish more games without any mistakes have higher scores on the tests: either they have more mathematical knowledge, which shows in the tests, or these children work more accurately and make fewer mistakes that could have been avoided.

Finally, the higher the percentage of the game the child has completed, the higher the score on the mathematics tests. In the game, children can only continue with the next mini-game once they have successfully completed the mini-game before. As such, the percentage completed by the child is an indicator of the level of mathematical knowledge the child has. This is a positive finding, as it could reduce the amount of testing required of children when scaling up.

Collecting data from the tablets

4.3.5 Psychosocial research analysis

The psychosocial research aimed to explore whether there were non-academic impacts on the children taking part in the programme. It is challenging to unpack which aspect of the programme had the effect: the technology, the access to education, or the regular visits of outsiders, but for this pilot, it was useful to at least test the validity assessment of the questionnaire and other tools.

In analysing the results of the questionnaire, optimal scaling techniques were used to control for assumptions about interval distributions of the children's answers to each question (Gifi, 1990; SPSS, 1989; Meulman, Heiser, & SPSS, 1999). The unidimensionality of the separate scales was evaluated by Principal Component Analysis with Varimax Rotation and by calculating Cronbach's αs. Finally, scale scores were obtained by adding optimal scaling quantification scores within scales, and transforming scores linearly to a 0-100 scale. Higher scores indicate greater emphasis on the scale's theme.

The overall reliability of the psychosocial questionnaire was good (Crohnbach's α = 0.71). Table 10, below, shows that apart from the measurement of self-esteem (4-point Likert scale with pictures of trees), five scales could be identified. The first scale, Self-efficacy, was reliable (Crohnbach's α = 0.74). The second scale, Motivation and Future Orientation, had a Crohnbach's α of 0.63. Whilst this is low, we take the position that scores of 0.6-0.7 in the context of this research can be counted to be reliable. This is because we undertook the questionnaire with young children who had never answered questi-onnaires before, and who had, anecdotally, probably never thought about themselves in this way. Acceptance of scores between 0.6-0.7 in scales used with young children is supported by literature (George & Mallery, 2003), even in developed countries. The other three scales were not reliable, and were therefore not used in further analyses.

Self-esteem is the only scale that showed significant differences between the two measurements (T=0 and T=24), which increased from 1.9 to 2.5 on a 4-point Likert scale.

Scale	T0 & T24	T0	T24	No of items	Example	Included in analysis based on Crohnbach's
Self-efficacy	.74	.71	.77	4	I can handle whatever comes my way	Yes
Motivation and Future Orientation	.63	.63	.64	4	I like learning new things	Yes
Belong to group	.52	.56	.46	4	I participate in activities in my community	No
Social Support	.46	.47	.45	3	I feel supported to learn by others in my community	No
Identity orientation	.56	.63	.47	3	My relationships with people I feel close to is important to me	No
Total Psychosocial	.71	.67	.74	16	[no example: all items from the psychosocial research together]	

Table 10:
Scales psychosocial research T0 and T24

Psychosocial factors in the baseline, also add to the explained variance of the model. A higher self-esteem and self-efficacy at the beginning of the pilot, relate to higher maths scores at the end. Finally, psychosocial factors measured at the end of the pilot relate to test B results. Self-esteem has a negative relation with test B. However, it is not clear if these scores can be seen as real predictors, as the psychosocial data at the end of the pilot were collected at about the same time as test B-Post was taken. Therefore, causality cannot be assumed.

Psychosocial factors in the baseline also add to the explained variance of the model. A higher self-esteem and self-efficacy at the beginning of the pilot, relate to higher maths scores at the end. This may mean children who think they can learn mathematics, and who believe in themselves, have higher scores on the post-test. There can be two explanations for this: i) children have a higher level of mathematical knowledge, and are therefore more confident they can learn; or ii) children who believe they can learn mathematics have higher scores on the post-tests. Even without knowing the cause and effect of this relationship, it is a positive finding that self-esteem has increased during the pilot, as it has a large effect on learning outcomes.

Only two children missed the baseline measurement of the psychosocial questionnaire. Twenty-six children missed the second measurement, most of which came from Gedaref. This means most of the data (96%) was collected. In spite of the challenges in the reliability of the questionnaire and need to remove three of the scales in this analysis, it is important to continue with the development of the psychosocial questionnaire to create one that is both reliable and easy to answer. Of the three reliable scales, self-esteem is the only one that showed a significant increase in scores between the two measurements. **Being involved in the pilot had a positive effect on children's self-esteem, with no significant differences between boys and girls.** Average scores for all scales were around 50% (out of 100%).

4.4 Research design and implementation challenges

With 19 locations in three states, the research logistics were complex. Despite this, robust research standards were achieved, which represent a best practice approach within the global education sector. There were, however, delays in testing, and the data gathering protocols were not always followed resulting in the need to re-test or discard some data from the analysis (see chapter 4 for details). Overall, ELS was able to compensate for this risk through employing multiple data gathering and analysis processes, for example triangulating the core mathematics testing process with the use of logged data from the software game, and commissioning an external EGMA evaluation. Specific areas for further investigati-on, change, and improvement in future iterations of the programme are:

- Automatisation of data collection, which will address data input errors and ensure data collection protocols are followed;
- A review of the number of researchers to ensure that timescales are manageable;
- Improved training and support on the use of focus group discussions, as well as recording and documen-ting data from these discussions, and;
- A review of the processes planned for the control groups to ensure that these are a central component to initial phases of any programme replication.

5. CONCLUSIONS

The research from ELS Phases I and II reached some significant conclusions, both in terms of the creation of educational resources for the most disadvantaged children, and how innovative programmes can be designed for scale.

5.1 Serious games are an effective learning approach

Whilst Phase I successfully proved children can learn maths from the game, Phase II went further to understand the impact on different children, and the impact outside of learning outcomes. Findings from Phase II include:

- Children learn significantly from the game, with those who know the least learning the most;
- The game is gender neutral and promotes a more gender balanced learning experience, which stimulates and retains boys and girls equally; and
- Compared to traditional education approaches in Sudan and selected countries, ELS is more effective for learning outcomes than traditional education, when measured using EGMA as the standardised assessment.

The high correlation between: i) the learning outcomes achieved by children as indicated by the mathematics testing, and ii) the logged data indicating how much children had played the game, means that moving forward, we will not need to implement such an intense research design. We will most likely be able to move to a combination of using logged data with mathematics testing of samples of children by external evaluators, rather than testing all children.

5.2 Designing the intervention for disadvantaged children in Sudan was a success

ELS was designed specifically for Sudan, with programme elements being localised across curriculum, graphic design, partnerships, and approaches to the community. The intention was to build in the ability to scale up across the country, and to speak to the particular needs of target groups more at risk of non-enrolment or drop out, specifically populations who are rural, girls, nomadic, low-income, or displaced. Whilst some elements were not used within the research phase of ELS, they are intrinsic to the programme design in order to facilitate the engagement of these groups. Results from Phase II show:

- Playing the game all the way through is what makes the difference, rather than the amount of time spent on it. Children could play two to three times a week rather than every day and still succeed at the same rate as those who are there all week. This means that we can respond to the flexibility needed by children with chores or economic activities, or who are on the move.
- The majority of dropouts (90%) were reported for children who are on the move. The game is designed to respond to this known need, and future phases can take this into account by potentially making the delivery of the game mobile.
- As noted above, ELS delivers good learning outcomes for both girls and boys.

- Although the concept of autonomous learning with tablets enables children to take the tablet when they move, and continue learning, the research plan in this phase did not support this flexibility. Children who left had to leave the tablet behind and drop out of the programme. This knowledge can be applied in future iterations of the programme.
- The final difference is between family size, children with fewer siblings dropped out more often than those with more siblings. No hard data was collected as to the reasons behind this, but anecdotally, the additional financial pressures and requirements to undertake household chores, or the potential ease of moving locations with fewer children, were cited.

The game may also offer significant benefits to those 23% of Sudanese children and young people enrolled in primary school children who are over age (UNICEF, 2015). The self-paced nature of the game, combined with a game design that has made allowances for struggling learners may be able to support students who are struggling, and the positive impact on self-esteem may also benefit them.

5.3 ELS has a positive impact on self-esteem

The psychosocial research indicated a significant positive effect on self-esteem experienced by children engaged in ELS. As noted, the psychosocial research tool was specifically designed for ELS. This was done as appropriate tools were not available either from Sudan or from comparable contexts. Whilst some variables within the tool have been proven valid through the research process, other variables used will require further refinement. To support this improvement, funding has been secured for additional applied research focused on the psychosocial aspects of education for vulnerable and disadvantaged children. The contribution to the development of a scientifically validated psychosocial research tool is an additional benefit to Sudan and potentially to the wider sector working on education in fragile states.

5.4 The future of ELS

With consideration of the challenges in Phases I and II as lessons learned, it is clear ELS positively responded to a need, providing children access to quality education, through innovative education technology supported by strong partnerships. Whilst ELS does not address all the education needs of out-of-school Sudanese children, the positive results are a 'large step in the right direction'. In 2016, War Child Holland and its partners will move on to Phase III, a scaled Arabic literacy trial in Sudan, to expand the programme's reach in content with the ultimate goal of reaching significant numbers of out-of-school children in mathematics and literacy by 2020. Beyond Sudan, the ELS programme will expand and upscale under the name Can't Wait to Learn to other contexts applying lessons learnt, and adapting the model and methods to meet the urgent education needs of children affected by conflict.

Group of children who participated in the trials

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ANNEX 1: DEVELOPING GAME REQUIREMENTS IN THE SUDANESE CONTEXT

Game requirements: Aspects	Game requirements: Requirement	Requirement Construct	Game design
Struggling learners	Use the mastery learning approach	One of the major issues in supporting struggling learners is to make sure that there is a strong basis on which to build. This corresponds with the concept of mastery learning (Bloom, 1985), where “the students are helped to master each learning unit before proceeding to a more advanced learning task” (p. 4). Furthermore, struggling learners need explicit instruction (Timmermans, 2005; Milo, 2003). Research shows that struggling learners show less engagement during instruction (Bodovski & Farkas, 2007). If this engagement increases, performance increases as well.	The game guides children through a carefully designed learning path. They learn at their own pace, though, children can only move to a new/more difficult mathematical concept once they have mastered the previous one. This is measured by the number of mistakes made within a certain timeframe.
	Use direct instruction	Direct instruction is given; instruction that explains how to ‘do it’. The instruction in the videos is provided by slightly older children (14-15 years old), which is assumed to increase motivation to watch the instruction videos. These older children can also be seen as role models, increasing motivation to learn and self-efficacy.	The game contains instruction videos, short films, with children as actors, in which mathematical concepts are explained. Each instruction video explains one mathematical concept. Per mathematical concept only one strategy is explained to solve the problem.
	Heavy focus on ‘time on task’	A focus on ‘time on task’ could help to improve learning results (Carroll, 1963), for all children can learn mathematics, but some need more time than others. To support struggling learners, instruction and exercises on mathematical skills that are often acquired informally are included in the game.	The game is attractive and motivating, supporting the focus of children. The mini-games are an important part of the game, in which children actively engage and practise their mathematical skills.

Game requirements: Aspects	Game requirements: Requirement	Requirement Construct	Game design
Experiential learning	Active learning, with many, different activities	The mathematics game aims to provide a rich learning experience based on an experiential learning approach: children should learn from active engagement with the environment (Dewey, 1938; Kolb et al., 2000). Effective use of technology should enable active learning, with a focus on the activities and interaction of learners (Collis & Moonen, 2001; Jonassen et al., 1999). Applied Game Based Learning can act as a technological enabler for such an approach. For learning to be productive, children should be actively involved in many different mini-games. This increases the number of exercises they do and contributes to the time spent on learning. In this way, children should be able to repeat and practice new concepts many times, without having the feeling that it is repetitive (Jonker & Wijers, 2008). For example, for children to master a new concept, they should have access to reproductive and productive exercises.	The mini-games within the game stimulate children to try out mathematical concepts themselves. Children can practise all mathematical concepts with a variety of mini-games ranging from multiple choice to matching answers to giving answers to problems by writing them down. The mini-games always start with real-life situation (concrete), move to a representation of real life (model), and end with abstract problems. The mini-games provide several types of activities ranging from a ‘multiple choice’ activity where children choose the right answer, to ‘matching’ and ‘arranging’ numbers and amounts, and finally ‘writing’ the correct answers to problems on the tablet.

Game requirements		Requirement Construct	Game design
Aspects	Requirement		
Level of control	Learner control over what children do first; pace; and the freedom to go back over activities	One of the predominant game design features that determines whether games work is that of the level of control that learners have over pace, order, and strategy (Garris et al., 2002). It determines whether learners have a sense of 'agency' and actually feel that they can influence events in game. The more learner control, the higher learner motivation. To motivate children to actively use the game for a longer period of time, they should have a certain level of control over what they do first, the pace in which they play the game, and if they want to go back to subjects they have completed already.	The game provides limited control over what children can do first. Children can decide to explore the game world, watch instruction videos, check what they have learned already and play mini-games, either new ones or repeat earlier ones. Children have no control over the order in which they play the new mini-games. The game allows children to play at their own pace, based on the number of correct answers within a certain timeframe. Children who only make a few mistakes progress through the game quickly. Children who make more mistakes will take longer to master the mathematical concept. The game also allows children to go back to previous activities whenever they want.

Game requirements		Requirement Construct	Game design
Aspects	Requirement		
Adequate feedback	Feedback on correctness of answers	When children learn autonomously by playing a game, the game itself should provide feedback on correctness of their answers. Where we traditionally place this role with the teacher, sometimes computer-programmes are even better: they are able to always, consequently give feedback, something in which under-resourced, overcrowded classrooms is unlikely. In addition, **adaptive feedback** should be given (i.e., feedback on process as well as on results). Children should be invited to react, think again, and be given tips to find the right answer. This approach may increase attention, and thus time on task (Carrol, 1963), which in turn positively influences learning results. The game should provide feedback on the correctness of children's answers. In addition, children should be given the opportunity to receive hints and tips that help them to find the right answer.	The game provides immediate feedback on the correctness of answers, using audio and visual elements.
	Feedback on strategy/process		The game does not provide specific feedback on the chosen strategy or process.
	Hints and tips		The game provides some tips and hints (e.g., at the beginning of the game children can click on a 'voice-button' that counts the objects in an answer). At a time when they are still learning numbers, this resource helps them to continue.

Game requirements		Requirement Construct	Game design
Aspects	Requirement		
Motivation	Game should be appealing	Teachers are the most important predictor of learning results (Hattie, 2009), one of the reasons being teachers can motivate children to keep on learning. Whilst learning without the support of a teacher, children will most likely not stay motivated over a long period of time. Learners that are intrinsically motivated engage in the learning process for “its own sake, for the enjoyment it provides, the learning it permits, or the feelings of accomplishment it evokes” (Lepper & Iyengar, 1999, p. 349). Also, the more intrinsic the motivation, the more durable the learning may be (Trinder, 2013). In order to invoke intrinsic motivation to learn the game itself should be appealing to the children; graphics, colours, and the narrative must be recognisable and fun.	The graphics and the colours of the game are based on co-design with the children. The children made drawings of their own environment: clothes, food, animals, plants, and trees. The graphics in the game are based on these drawings. The game worlds were designed after thorough discussions with local partners. The narratives in the game worlds can be recognised by the children and should appeal to them.
	Instruction	Additionally, to invoke intrinsic motivation, the instruction in the game should be easy to understand, to the point, and easy to relate to.	The instruction videos in the game are short and attractive, and have children as actors. The children in the instruction videos acts as role models, thus motivating the children to learn.

Game requirements		Requirement Construct	Game design
Aspects	Requirement		
	Extrinsic awards that stimulate intrinsic motivation	Game-based learning is driven by extrinsic rewards which stimulate intrinsic motivation. A crucial factor in intrinsic motivation in games is challenge (Malone, 1981), and competition. The game itself, or the setting in which it is played, should allow for some challenge and competition.	There are several motivating elements in the game: progress is shown every time the user starts the game. When a child reaches a new level, a star is added to the progress bar. At the same time fireworks go off and there is applause. In Game world 1 the huts become more beautiful, in Game world 2 you can sell more objects in your shop (see Figures 1 and 2 in chapter 2).
Social interaction	Social interaction between children	In the tradition of Vygotsky (1978), learning is largely to be seen as a social activity. Learning should not simply be the assimilation of new knowledge; it is the process by which learners are integrated into a knowledge community. Because learning is essentially a social phenomenon, learners are likely to be motivated by rewards provided by the knowledge community (Cremin & Arthur, 2014). The game itself, or the setting in which it is played, should allow for social interaction between children, but also between children and adults.	Within the game it is not possible to have social interaction between children. But, children play the game in learning session: a group of children playing the game individually, at the same time in the same place. There is social interaction between the children during the session.
	Social interaction between children and adults		When children play the game, it is at the same time in the same place, supervised by a facilitator. There is social interaction between the children and the facilitator during the learning session.

<table>
<tr><th colspan="2">Game requirements</th><th rowspan="2">Requirement Construct</th><th rowspan="2">Game design</th></tr>
<tr><th>Aspects</th><th>Requirement</th></tr>
<tr><td rowspan="2">Capacity to understand instruction</td><td>Children should be able to understand the language of instruction</td><td rowspan="2">To meet the needs for out-of-school children in Sudan, children should be supported to learn without a teacher. Although autonomous learning is often used for advanced learners and adults, it is not a commonly used approach for beginners. One of the most important issues that are highlighted in the literature with self-learning for beginning learners is that children do not have enough knowledge to follow instruction or do the exercises without further help (capacity to understand instruction) (Vogel et al., 2006).
This may be a result of the language of instruction: the children do not understand the instruction. It can also be due to the instruction itself, which assumes a certain level of knowledge and cannot be understood by children who do not have this knowledge.</td><td>The language of instruction is a simple version of Modern Standard Arabic (the way you would speak to children).</td></tr>
<tr><td>Instruction should be easy to understand, without the need for extra knowledge</td><td>The instruction videos explain all necessary mathematical concepts, starting from the very beginning (Kindergarten level). All instruction which builds on earlier instruction videos, repeats the content of those videos before introducing new, more complex concepts.</td></tr>
<tr><td></td><td>Culturally appropriate</td><td>Cultural appropriateness can influence the capacity to understand instruction: if the game is not culturally appropriate, children need to put in an extra effort to understand the context. Thus, mental capacity cannot be used to understand the mathematical concept. Children should be able to understand the language of instruction used in the game. The explanation of mathematical concepts given in the instruction should be easy to understand, never assuming that children will have a certain level of knowledge and understanding. Any instruction and explanation should be culturally appropriate to reduce cognitive load.</td><td>All objects used in the game are objects that the children know in their everyday life. All the people are appropriately dressed and exhibit culturally appropriate behaviour. At the same time, much attention has been given to neutral examples (e.g., fruits and vegetables, bricks) to avoid references to conflict or minority groups. There are boys as well as girls in the game and as actors in the instruction videos.</td></tr>
</table>

ANNEX 2: PHASE II MATHEMATICS TEST A

1. Can you count to 10?

2. Can you count on from 4?

3. Can you count on from 6?

4. Can you count back from 5?

5. Can you count back from 7?

6. Can you tell me how many tomatoes you see?
[picture with 3 tomatoes]

7. Can you tell me how many tomatoes you see?
[picture with 1 tomato]

8. Can you tell me how many tomatoes you see?
[picture with 2 tomatoes]

9. Can you point at the picture which has the most carrots
[two pictures with: 1 carrot and 3 carrots]

10. Can you point at the picture which has the most carrots
[two pictures with: 2 carrots and 5 carrots]

11.Can you say what this number is?
3

12. Can you say what this number is?
6

13. Can you say what this number is?
2

14. Can you say what this number is?
8

15. How many carrots do you see? Point at the right number.
[picture with 3 carrots]
[1 3 5]

How many tomatoes are this? Point at the right number.
[picture with 1 tomato]
[1 2 6]

16. Can you write down the number 3?

17. Can you write down the number 12?

18. Can you write down the number 9?

19. I have one tomato, and I buy two more. How many tomatoes do I have?

20. There are two people in the bus, and three more people get in the bus. How many people are there in the bus?

21. What number comes after the number 7?

22. What number comes before number 6?

23. Can you point at the highest number
5 – 16 – 10

24. Can you point at the lowest number?
11 – 17 – 9

25. Which number should be in the empty box?

9	10		12	13

26. Can you say the answer to this sum?
3 + 1 =

27. Can you say the answer to this sum?
2 + 1 =

28. Can you say the answer to this sum?
1 + 4 =

29. Can you say the answer to this sum?
3 + 2 =

30. Can you say the answer to this sum?
1 + 1 =

ANNEX 3: PHASE II MATHEMATICS TEST B

1. Can you count to 20?

2. Can you count on from 8 [to 20]?

3. Can you count back from 16?

4. How many tomatoes do you see?
[picture with 8 tomatoes]

5. Can you point at the picture with most carrots?
[two pictures with: 12 carrots and 16 carrots]

6. Can you say what number this is?
[17]

7. Can you write down the number 8?

8. Can you write down the number 14?

9. Point at the bead that is number 12 in the line.

10. Point at the person who is number 16 in the queue.
[picture with a queue of 20 people, in 4 groups of 5 people]

11. Can you what number should be in the empty box?

8		10	11	12	13

12. Can you point at the picture which has most goats?
[four pictures with: 16 goats, 9 goats, 19 goats, and 15 goats]

13. Point at the number that is the lowest.
[13 11 18]

14. Point at the number that is the highest.
[18 15 9]

15. Point at the picture with the least tomatoes.
[three pictures with: 6 tomatoes; 3 tomatoes; 4 tomatoes]

16. Point at the number that is bigger than 18.
[12 16 20]

17. Point at the number that is smaller than 15?
[12 16 19]

18. Can you put the numbers in the right order (from low to high)?
[13 -14 -12 -11 – 15]

19. Can you put the pictures in the right order (from most people to least people)?
[four pictures with: 6 people; 12 people; 9 people; 15 people]

20. Can you count back from 20 in steps of 2?
[20, 18 ….]

21. Can you fill in the empty boxes with the right numbers?

2	4	6		

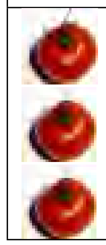
22. Fatma has 4 carrots. She gets 2 more. How many carrots does she have now?

23. There are 7 children in one hut. There are 2 children in another hut. How many children are there in total?

24. Can you say the answer to this sum?
[4+1=]

25. Can you say the answer to this sum?
3+ 5 =

26. How many tomatoes do you need to make 6?

6	
	

27. Can you split number 8 in three different ways?

8	

28. Can you say the numbers you need to make 10? (horizontal)

10	
7	
	5
3	
	4

29. Can you say the answer to this sum?
5 + 2 =

30. Can you say the answer to this sum?
6 + 2 =

ANNEX 4: PHASE II PSYCHOSOCIAL QUESTIONNAIRE

Self-esteem	Ask the children to pick the tree that matches their feelings about themselves.		
Self-efficacy	1	I am certain I can accomplish my goals	(Pintrich & De Groot, 1990)
	2	I can handle whatever comes my way	(Pintrich & De Groot,1990)
	3	I stay confident, even when things are difficult	(Pintrich & De Groot, 1990)
	4	I can do most things as well as my friends	Self-description Questionnaire II (Marsh, 1992)
	5	I expect to do well in my learning	Self-description Questionnaire II (Marsh, 1992)
Motivation	6	I like learning new things	Self-directed learning (Stubbé & Theunissen, 2008)
	7	I think learning new things is important	Self-directed learning (Stubbé & Theunissen, 2008)
	8	I am doing my best to learn new things	Self-directed learning (Stubbé & Theunissen, 2008)
Future orientation	9	I know what I want to become	The Functions of Identity Scale (Serafini, Maitland, & Adams, 2006)
	10	I know what I want to be	The Functions of Identity Scale (Serafini et al., 2006)
	11	In the future, I will do as well as my friends or better	Psychosocial Vulnerability Assessment Tool (Gunn et al., 2013)
Social support	12	When I have a problem, I can talk to my parents or family	1.1.1.1.1.1.1 Xxx (Fleuren et al., 2012); The Parent-Child Interaction Questionnaire-Revised (Lange et al., 2002)
	13	I feel supported to learn by my parents or family	
	14	I feel supported to learn by others in my community	
	15	I am accepted by my community	Psychosocial Vulnerability Assessment Tool (Gunn et al., 2013)
	16	I feel like I am part of the group	Psychosocial Vulnerability Assessment Tool (Gunn et al., 2013)
	17	I participate in activities in my community	Psychosocial Vulnerability Assessment Tool (Gunn, et al., 2013)
	18	I feel I can trust others in my community	Psychosocial Vulnerability Assessment Tool (Gunn, et al., 2013)
Identity orientation	19	My feeling of being a unique person, being distinct from others is important to me	Personal Identity, Aspects of Identity Questionnaire (AIQ) IV (Cheek, et al., 2002)
	20	My reputation, what others think of me, is important to me	Relational identity, AIQ IV (Cheek et al.,2002)
	21	My relationships with people I feel close to is important to me	Social identity, AIQ IV (Cheek et al.,2002)
	22	My feelings of belonging to my community is important to me	Collective identity, AIQ IV (Cheek et al.,2002)