A Synthesis of Early Grade Maths Computer-Based Interventions

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Name of the Report

A synthesis of early grade maths computer-based interventions

Secondary info

A Synthesis report

Who requested this output?

This was requested by the Outcome 1 Facilitator (Education) in May 2019.

This report includes:

- A synthesis of reports on computer-based/assisted learning maths programs for primary grades.
- Impact intervention and diagnostic studies were reviewed.

Acknowledgement

Contribution by Africa Centre for Evidence and DPME IT are acknowledged in conceptualising and developing the Evidence Map.

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1. Introduction and Background

Introduction

Researchers, education specialists and policy developers are exploring innovative ways of positively delivering on educational outcomes. One of the tools aimed at improving learning outcomes, is computer-based learning interventions, which consists of hardware and software-based tools. Empirical evidence on the effectiveness of such tools in improving learning outcomes is, however, thin and in other cases, inconclusive (Carrillo, et al., 2010; Lai et al., 2013; Mo, et al., 2014; Pitchford, 2015).

There are also assertions that computer-based learning interventions have the potential of bridging the teacher gap, especially in cases where there is a lack of motivation, skills, as well as pedagogical and/or content knowledge from the teacher. Computer-based learning interventions are also argued to bridge the teacher absenteeism gap and/or the gap created as a result of the low literacy levels of parents (Lai et al., 2015). Carillo et al. (2010) concurs with this, arguing that computer-based interventions could even work well in contexts with poor quality teachers.

> *"CAL can be partially effective in developing countries, where schools are plagued with poor facilities, unqualified teachers and where computer technologies are relatively new and may be beyond purchase…" (Lai, et al., 2015, p. 35).*

> *"… In developing countries (or in underserved populations in developed countries), where education resources (including school facilities, teachers and parents) are often highly constrained, and access to technology is limited, CAL might be able to address the urgent need of remedial education" (Lai, et al., 2013, p. 210).*

Computer-based learning interventions are therefore, argued to improve achievement through the tool itself, which is regarded as an input and also through exposure, which focuses on improving cognitive abilities. Pritchard (2015) therefore, advocates that computer based learning interventions should be adequately designed and optimised to support foundational and cognitive skills.

Some authors, however, argue that the availability of the technology in developed countries tend not to yield positive results with such programmes since resources are abundant and computers are not unique to these students. The results in developing countries however, seem to yield positive results, even though only a few studies of this nature have been conducted (Lai et al., 2013).

Background

During his State of the Nation Address on February 7, 2019, President Cyril Ramaphosa announced that tablets were going to be provided in every school in the country. This pronouncement has increased the need for education specialists, educators and policy makers in this space to think

critically and respond to this by providing evidence informed insight and guidance about the effectiveness of these tools in delivering educational outcomes.

The assumption that underlies the use of computers and information technology in schools lies in the supposition that information technology has the potential of bridging the teacher capacity gap that exists in the country and help learners cover the curriculum more effectively and efficiently (Hardman, 2005). It is, however, argued that it is not the computer itself that contributes positively towards educational outcomes but how the tool is used. A number of factors, such as teachers' beliefs, perceptions, motivation and objectives, are argued to significantly impact how computers are used as teaching and learning tools (Cox et al., 2005 & Russell & Schneiderheinze, 2005 cited in Hardman, 2005).

The Ministry of Education in China is an example of a country that aspires to set computer rooms in rural schools by 2020. The country announced a five-year plan for integrating information technology into education. This investment requires enormous fiscal resources, and this has created the need to invest in studies that provide insight on how to effectively use computing resources (Mo, et al., 2014). South Africa is currently on a similar path and the *White Paper on Education and Training Notice, 196 of 1995* advocates for the country to invest in research and development on the appropriateness of the use of such tools in enhancing learning and teaching outcomes.

There is thus support from a number of authors, that studies aimed at understanding the circumstances under which computer learning interventions produce positive learner outcomes be conducted (Carillo et al., 2010; Hardman, 2005; Mo, et al., 2014). Carillo et al. (2010) further, argue that such interventions should be evaluated not only on the basis of the input but also on how computers are actually used in classrooms.

This report is thus responding to a request to conduct a synthesis and inform the Outcomes 1 Team of computer based learning interventions. A decision was made to use evidence from an existing evidence map to respond to the request.

Problem Statement

The implementation of the President's announcement to ensure e-tablets in all South African schools with the intention to improve educational outcomes is underway. Literature however, argues that there is not sufficient information – especially in developing countries – on the effectiveness and impact of computer-based interventions. Some studies, especially those in first world countries do not seem to find sufficient evidence of positive outcomes for computer-based learning. There is therefore, a need to understand how and under what conditions computer-based learning can have better learning outcomes.

Scope and Purpose of the Study

The Outcomes 1 Team proposed a few questions, some of which the synthesis seeks to address. Part of the request was to:

- Identify certain areas where computer-based/assisted interventions have worked;
- Identify enabling environments that make computer-based/assisted interventions succeed; and
- Indicate whether the country requires computer and information technology as an enabler to improve educational outcomes.

The synthesis may not be able to respond to all the questions posed but will provide a synthesis of information as contained in the studies that were included in the Early Grade Mathematics Study (EGMS) Evidence Map related to these questions.

The synthesis will therefore, attempt to provide insight into the question on the different contexts in which computer and IT interventions have been asserted to work and also the enabling environment. The Outcomes 1 Team, through this synthesis and other related projects and engagements should be able to draw some conclusion on the extent to which the country needs computer-based/assisted interventions to improve educational outcomes.

2. Methodology

The Systematic Review methodology is useful in that it can collectively synthesise a considerable amount of primary studies and in so doing generate an integrated body of work that can be compared across countries and used to provide insight into policy issues. This can be done within a short period – thereby, saving time.

A synthesis approach was therefore adopted to respond to the posed questions. Existing evidence was sourced from an Early Grade Mathematics Study (EGMS) Evidence Map and analysed to respond to these questions.

Evidence Synthesis

Evidence used for the synthesis was sourced from an evidence base that was developed for the Early Grade Maths Study (EGMS) through the generation of an extensive Evidence Map. A sample of 27 studies were pooled from a map that contains 167 studies[1]. After further cleaning[2], 16 studies remained for analysis.

[1] These 167 studies came through a process of extensive searching, screening, and critical appraisal and was ultimately included based on a strict set of inclusion criteria.
[2] Some of the studies were further excluded because they were duplicates, and others were not addressing the topic at hand.

Research Synthesis Questions

The following guiding questions were asked:

- Where have computer-based/assisted educational interventions worked?
- What can be regarded as an enabling environment for computer-based/assisted educational interventions to work?
- Is this (computer-based/assisted education programmes) what the country needs to improve its educational outcomes?

Limitations

Whilst the study may not be able to answer all the questions posed, information gathered may be utilised to add insight. It should also be noted that the evidence map had a different objective, but was used in this case as the evidence contained was readily available evidence that could be used with confidence to respond to the current request since it went through a rigorous process of searching, screening, and critical appraisal. It is further, reiterated that the studies utilised for the synthesis were focused on early grade mathematics studies and only two diagnostic studies were South African based.

3. Findings

A brief summary of the 16 synthesised studies is provided in this section of the report. As previously mentioned, only studies focusing on computer-based/assisted interventions were drawn from the EGMS Evidence Map.

This section of the report first provides an overview of the number of studies sourced from the Evidence Map, the countries represented by those studies, the trustworthiness of the studies (based on the critical appraisal) and the actual number of studies that reported effectiveness or ineffectiveness of interventions.

Thereafter, insight on the types of, nature of and extent to which the interventions were successful in improving educational outcomes and insight on the lessons that can be drawn from the studies is reported.

Pooled Studies

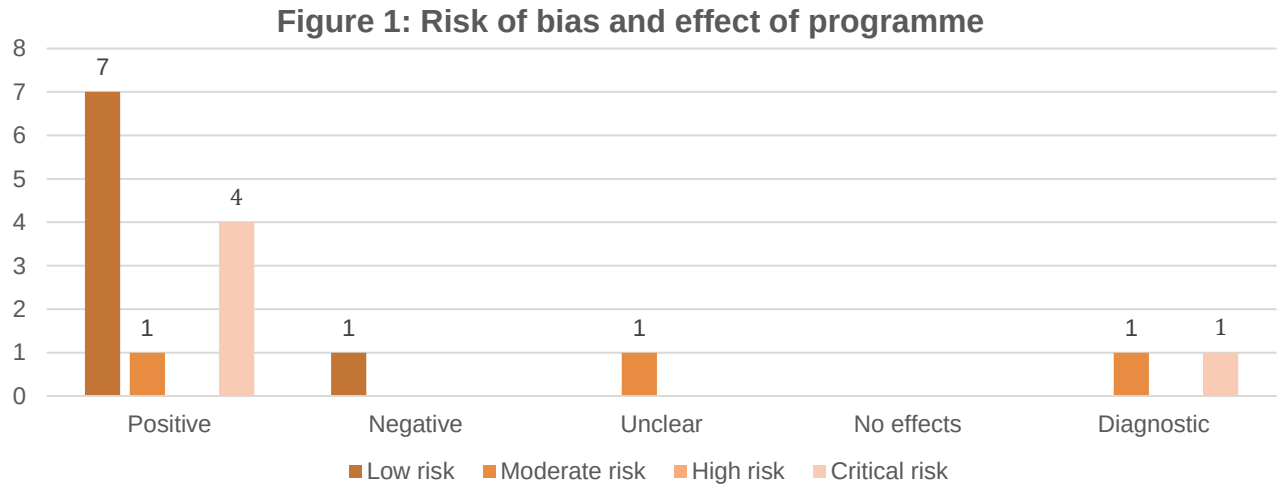
A sample of 27 studies were pooled from the EGMS evidence map and after further cleaning (including the further exclusions of duplicates as well as pieces that did not address the topic), 16 studies remained for analysis.

In synthesising information from these studies, a set of international studies from lower income countries (LIC) and lower middle income countries (LMIC) that assessed the effectiveness or impact of computer-based/assisted programmes (CAP) were used. Of the 16 studies, 2 were South African based diagnostic studies, three were impact studies from China, 2 from Turkey and the others were from Costa Rica, Ecuador, India, Jamaica, Jordan, Malawi, Malaysia, Chile and Mexico.

Where have computer-based/assisted interventions worked?

Trustworthiness of the studies

All the studies – including the diagnostic studies – were critically appraised to ascertain their trustworthiness. The graph below (Figure 1) depicts the critical appraisal of evidence pieces, as well as the effects of the programmes they were written on.



As illustrated in Figure 1 above, 7 of the 16 studies that had low risk of bias were also reported to have positive effects. Three of these studies were conducted in China, and the others were conducted in Ecuador, Kenya, India and Malawi. Only one of the 16 studies had low risk of bias and also reported to have negative results – this study was conducted in Costa Rica.

Only three studies had moderate risks of bias. One of these studies was conducted in Jamaica and was reported to have results that were not clear. The others were conducted in Mexico (with positive effects reported) and South Africa (a diagnostic study).

Figure 1 also illustrates that six of the 16 studies had critical risks of bias. Five of these studies were also reported to have positive effects and the other was a diagnostic study. Two of the five studies were conducted in Turkey and the others were conducted in Malaysia, Jordan and South Africa. Most of the studies with high or critical risk of bias were small scale or medium scale studies.

Types of Interventions

Four of the 7 low risk positive outcome interventions were Computer Assisted Learning Programmes (CAL) and three of these were studies conducted in China's rural, poverty stricken areas and/or areas with migrants and one was conducted in India. One of these studies was a Rapid Control Trial (RCT) conducted in Malawi, one was a Maths Cognitive Tutor (MCT) conducted in Chile, and one was a Más Tecnología conducted in Ecuador and offering 3 different ICT Primary Maths and Reading Programmes (PRIMR); one with a TAC Tutor tablet, one with a Teacher Tablet and another with a Student e-reader.

Objective of the Synthesised Studies

Fourteen (14) of the studies were impact studies aimed at evaluating, investigating, determining and exploring the effects or effectiveness of tablets or computer assisted programmes that aimed at improving learning outcome, particularly in mathematics and/or literacy. Some of the programmes that were evaluated were the CAL Programme, Logo Programming, Primary Maths and Reading Initiative (PRIMR), a computer-based maths word problem solving programme, and a computer-based 2D geometric learning and online supplementary mathematics tuition programme.

Some of the computer-based interventions incorporated visual and audio elements. The computer software for some of the interventions was carefully designed to engage learners in the learning process and the content was also grounded and aligned to a solid curriculum. Certain interventions ensured that the software was individualised and offered at the appropriate developmental stage and cognitive level of the learner.

Two of the 16 studies were South African diagnostic or qualitative studies focusing on teachers' perceptions of computer use to mediate teaching and learning and the use of computer software to promote collaborative learning amongst learners and educators for the enhancement of mathematical skills.

Overview of the Interventions

A summary of some of the information technology or computer-based/assisted interventions from some of the collated studies that had a low risk of bias is provided below.

Malawi

A personalised IPad with a maths software aligned to the national curriculum offered 1 hour per week. Intervention enabled the tracking of usage and data. Colourful and engaging set of activities delivered in local language enabled children to work on their own pace and feedback was received through interaction with the software.

India

A curriculum aligned CAL program offered in urban slum provided learners in Grade 4 with 2 hours of shared computer time per week. Learners played educational games that reinforced mathematics skills. Community based facilitators were trained to provide technical computer support. Positive results persisted even after the end of the project.

Ecuador

A curriculum aligned individualised computer aided programme offered to Grade 3s and 5s for 3 hours per week and designed to improve maths and literacy skills and narrow the gap in educational quality between private and public institutions through ICT. It trained teachers on general computer lessons, how to use software and track learner progress. Positive results on maths but not on language.

China

The CAL intervention group involved computer-assisted math remedial tutoring sessions which were designed to complement the regular in-class math curriculum. It was implemented under the supervision of two teacher-supervisors trained by the research group. Students in the treatment group had two 40-minute CAL sessions per week after school. The sessions were mandatory and attendance was taken by the teacher-supervisors. The content (instructional videos and games) of each session was exactly the same for all students in each of the treatment groups and emphasised basic competencies in the uniform national math curriculum.

In a typical session, two students per computer watched an animated video that reviewed the material that they were receiving instruction on during that particular week during their regular math class sessions. The students then played math games to practice the skills introduced in the video lecture. When playing the games, the students first worked out the solutions with pencils/pens on scratch paper and then submitted the answers on their computers. If a student had a math-related question, he/she was encouraged to discuss with his/her teammate.

The students were not supposed to consult with other teams or the teacher-supervisor. According to our protocol, the teachers were only allowed to help students with scheduling, computer hardware issues and software operations. In fact, in our observations, the sessions were so intense that the attention of the students were fully on the computer and while there was a lot of interaction between the members of the two person teams, there was little communications among the groups or between any of the groups and the teacher-supervisor (Lai, et al., 2013: 215-17).

Jamaica

An intervention in Jamaica provided a holistic approach. Training was provided to teachers, governance structures and leadership, communities and parents. Nutrition and health, teacher material and computers were also provided together with an integrated education management information system (EMIS). There were no visible differences between the comparison and experimental group because there was no difference between the level of school support between the groups, the intervention focused on low performing schools yet the national tests did not take this into cognisance and there was also a spill over, with learners in control schools moving to experimental schools (Lockheed, Harris & Jayasundera, 2010).

From the summaries above, it is noticeable that most of the interventions were computer assisted programmes with maths and/or literacy software packages that were aligned to the national curriculum, had a game component and enabled learners a level of autonomy. The duration of the intervention per week was between one to three hours.

Further insight into the interventions from the 14 impact studies is provided in the section that follows.

Analysis of Report Results

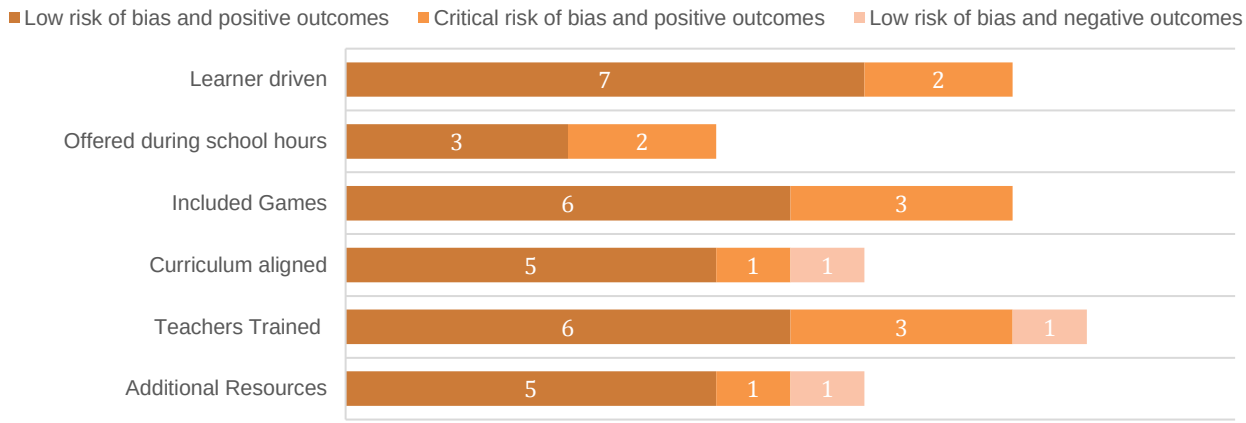
This section of the report provides a high level analysis of lessons learned from the 16 studies that were pooled from the EGMS evidence map. It should be noted that only studies that focused on information technology or computer-based learning were pooled. As has been reported in the earlier sections, the information was pooled from 12 countries, including South Africa.

It is also clear from Figure 1 in the previous section that 13 of the 16 studies reported positive results even though 5 of these studies had a critical risk of bias and only 2 studies had either negative effects or unclear results.

What is the enabling environment for computer-based/assisted interventions?

Figure 2 below, provides a list of some of the major characteristics that defined some of the computer based/assisted interventions and illustrates the number of studies that were reported to include the characteristics as reflected in the diagram below.

Figure 2: Components Included in Computer Interventions



As illustrated in Figure 2, all of the 7 studies that had a low risk of bias and positive effects were learner driven, 6 had a game and/ or video component and had some form of teacher training, 5 were aligned to the curriculum and furnished with additional resources and 3 were offered during school hours. In comparison to the study that had low risk but negative effects, only alignment to the curriculum, training of teachers and additional resources were identified.

Of the 4 studies with high risk of bias and positive effects, 2 were learner driven and offered during school hours, 2 included games and/or videos as well as a teacher training component. Only one of the critical studies was aligned to the curriculum and had additional resources.

All the studies conducted in China were reported to be aligned or synchronised to the curriculum. Some were provided during school hours and others during lunch break or after school. In some of the studies, the computers were not sufficient for learners to use, which would therefore, decrease

time on task as learners needed to share one computer on individualised tasks.

In versus out-of-school programmes

Mo et al. (2014) argue that outcomes of computer and technology studies tend to only focus on the input (CAL) of the intervention than on whether the intervention eats into the daily schedule or time table of the school. The provision of interventions that use school hours versus ones that do not, is argued to have implications on intervention outcomes. Linden (2008 cited in Mo et al., 2014) found that in-school computer assisted programmes were not effective in India and yet similar programmes were found to be effective in China. It was however, argued that there is a high rate of teacher absenteeism and the school day in India is shorter thus producing such outcomes.

Out-of-school CAL interventions are complementary to a curriculum and therefore do not disrupt the daily plans or take time off of the normal planned learning activities of the school. They are also run without the restrictions applicable to formal schooling hence are able to cater for individual learners' needs (Mo, et al., 2014). The out-of-school CAL programmes' success "requires schools to make various structural changes regarding curriculum, staff allocation and meal programmes" (Mo, et al., p. 2014, p. 301), and depend on the availability and volunteerism of teachers or facilitators. Mo et al. (2014) however, assert that as important as the out-of-school computer programme might be, integration of CAL into the main school-day curriculum may help improve its sustainability.

Learner-centred and teacher-centred interventions

Most of the learner driven interventions required less teacher intervention and time. Teachers in a number of the studies with positive effects were trained to provide technical and management support. Learners were thus required to establish a certain level of independence from the teacher. In some cases, for example learners were paired to share a computer, with the intention of encouraging learning, problem solving and guidance from each other. Teacher interference was reduced as teachers were discouraged to provide guidance other than technical assistance (Lai, et al., 2011; 2013; Mo, et al., 2014).

In other studies, learners were only allowed to seek assistance from each other. They were only allowed to seek the teacher's intervention when all else failed. In some of the studies, the teacher's role in assisting learners solve problems was limited and discouraged (Carrillo, et al., 2011; Gunbas, 2012; Lai, 2014; Mo, 2010; Mo, 2015; Pitchford, 2015). Few of the studies with positive outcomes however, were teacher oriented. Only one study targeted principals, parents, communities and the School Governing Body (SGB) but the results of this study were inconclusive (Lockheed, Harris & Jayasundera, 2010).

One of the South African studies was underpinned by the notion that a change in the traditional role of the teacher and teachers' beliefs about how mathematics is taught and learned is required to achieve mathematical competence. The intervention therefore, aimed at putting an emphasis on devoting time in class for exploring and changing the perception of the role of the teacher as a guide

or mediator (Berlinski & Busso, 2013).

Additional Resources

Additional resources over and above computer-based hardware and software such as computer labs, computers, laptops, tablets, etc. were also provided to some of the schools. These resources included additional personnel, community-based workers- and/or learner workbooks.

Not all interventions required internet connectivity. The software for the few interventions that did require internet was also used for monitoring the progress of the learners. Other programmes discouraged the use of internet and disabled even the memory stick access to ensure that the computer was only utilised for the programme.

4. Summary of Results of the Synthesised Studies

The results of the studies indicate that most of the schools that used either tablets, CAL and/or software interventions significantly outperformed or slightly outperformed those that used traditional learning methods. The standard deviations for the studies with positive effects and low risk of bias ranged between 0.12 to 0.30.

Some of the studies found that the interventions improved maths outcomes, increased students' interest in learning through the use of playful computer games, visuals and videos, increased collaboration, especially in cases where learners were able to share ideas with friends in group discussion. Learners were therefore, able to learn from each other and solve their own problems jointly as teams. Their confidence, self-efficacy and interest in learning increased. Some of the interventions created active learning environments and provided autonomy and control over one's environment.

Most of the interventions that seemed to yield positive results also seemed to be aligned to the national curriculum of each country and some were designed such that the topics covered for the week in class were also covered by the computer-based programme. There seemed to be an emphasis on training the teachers to provide technical support to learners and the pairing of children to provide support to each other and solve problems independently with each other.

For most of the interventions that yielded positive effects, the programme was additional to the curriculum, was individualised to the learner's mastery level and was provided either after school or during lunch breaks but also with a caution that in order to sustain the effect of the intervention, there may be a need for mainstreaming. One of the impact studies indicated that learners with less-educated parents and/or with no previous exposure to computers were not discriminated against by the intervention as some of the programmes were individualised and pitched at the level of the learner.

Only two out of the 16 impact studies found contradictory or uncertain results, with the control group

learning significantly more than the treatment group. Both interventions were exclusive from the others in that they were teacher-focused, focused on the provision of additional resources and aligning to the curriculum. Other studies in addition to this were more learner driven, with some providing autonomy, interdependence between learners and increasing interactivity through games, videos and each other and most were offered during school hours. The computer programme in most of the studies with positive outcomes mediated the teacher's role as instructor, therefore, substituted for the lack of teacher knowledge as learners were able to follow instructions from the computer and knew what had to be done.

5. Lessons

Interventions outcomes

Some of the computer aided interventions were found to improve not only educational outcomes but also learners' self-efficacy and confidence and interest in learning and (Lai et al., 2013).

Out of school computer aided interventions were indicated to produce better outcomes as they complemented the curriculum but there were warnings that to sustain the programme, it may need to be integrated to the main curriculum (Mo, et al., 2015).

Some maths computer assisted interventions enhanced literacy outcomes and others did not. It would therefore, be important to know whether computer based/assisted learning is subject specific (Mo, et al., 2015).

Methodological issues

Interventions that focus on learners with low test scores may introduce selection bias, making comparability difficult and in certain instances producing inconclusive or negative results.

Spill over can impact on the results if learners from control schools move to experimental schools (Lockheed, et al., 2010).

Way forward

It is argued that research on how computers are used in schools should consider teachers' epistemic (knowledge) assumptions regarding the new technology, illustrate an understanding of the social, historical and contextual structures inherent in the environment, and deal with how the tools are used in different contexts (Hardman, 2005).

Some authors argue that priority should be on identifying and designing the most effective computer based interventions with the consideration that resources are already constrained.

6. Conclusion

This report seeks to provide a synthesis of evidence by responding to the questions posed by the Outcomes 1 Team and identifying areas where computer-based/assisted interventions have worked as well as identifying enabling environments that make the interventions succeed. It is envisaged that the information gathered from this report and information gathered from other engagements and reports will add insight to the Outcomes 1 Team to make a decision on whether the country requires computer and information technology as an enabler to improve educational outcomes.

A summary of the key findings using the survival measure is provided below:

- 27 studies were drawn from the EGMS Evidence Map and only 16 were related to the study. Of the 16, 12 had positive results, one had negative and another had unclear results and two were South African diagnostic studies. Eight (8) of the 16 studies had low risk of bias and 4 had critical risk of bias. The standard deviations ranged for the studies with positive results and a low risk of bias ranged between 0.12 to 0.30.

- Most of the studies with positive outcomes of the computer-based or assisted programmes were learner driven and provided a certain level of autonomy, increased interest and were interactive as they had a game or video component and allowed learners to learn from each other and use each other to solve problems.

- Most studies with positive outcomes were also aligned with the curriculum and provided some form of teacher support and most training provided was technical and managerial (learner progress) than content.

- The two studies with negative and unclear results seemed to be teacher focused, focused more on the provision of resources and aligning the curriculum. They seemed to pay less attention to the learners and their independence and interests, and rather focused more on equipping the teachers and schools.

- There were also studies that emphasised the importance of working on the teacher's beliefs and the changing role of the teacher.

- Other studies made emphasis on out of school programmes arguing that their complementary nature improves outcomes but further cautioning that in order to sustain the programme, it may need to be streamlined with the normal curriculum.

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