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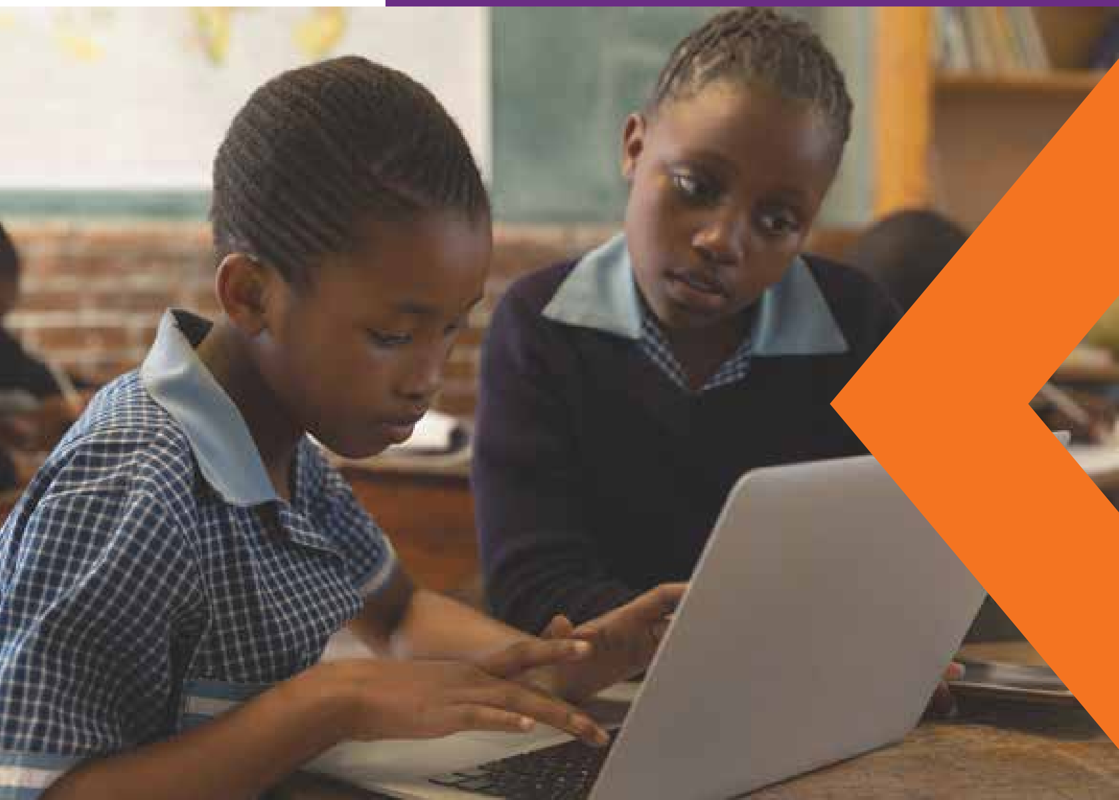
ICTs in early-grade mathematics education in South Africa: A learning brief



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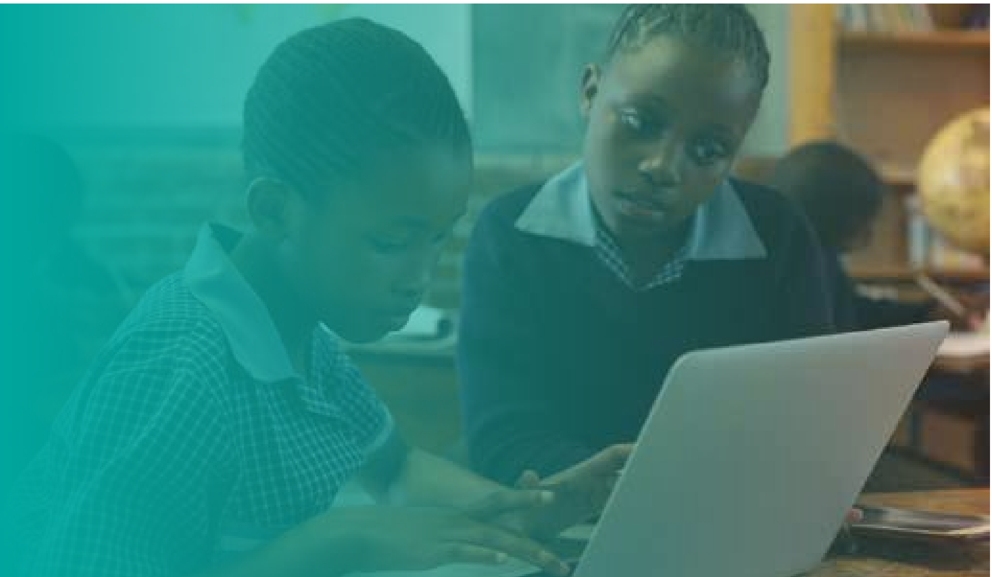

WHY … REVIEW ICT PROGRAMMES IN EARLY-GRADE MATHEMATICS EDUCATION?

> *Without Mathematics, there's nothing you can do. Everything around you is Mathematics. Everything around you is numbers.*
>
> **Shakuntala Devi, mathematician, motivational speaker and author (popularly known as the "human computer")**

Mathematics is powerful and a strong mathematical understanding can unlock opportunities. Shakuntala Devi, quoted here, is testament to this.

She grew up in rural India. Her grandfather taught her mathematics and she became a child prodigy. From an early age she was able to process complex calculations in her head with impressive speed. Later in life she travelled the world demonstrating her skills and motivating young people to engage with mathematics, recognising the importance of nurturing young minds.

Notwithstanding the potential of mathematics, South African learners gravely underperform in this subject. According to the 2015 Trends in International Mathematics and Science Study (TIMMS), 61% of Grade 5 learners are unable to perform addition and subtraction operations on whole numbers (Mullis and Martin, 2017). Spaull and Kotze (2015) argue this is a consequence of accumulated learning gaps, which, by Grade 9, are reported to be as wide as four grade levels. Some of the factors driving underachievement in the early grades include educator under-preparedness, challenges with language proficiency, weak assessment feedback, and a focus on rote learning rather than fluency and conceptual understanding (Zenex Foundation, 2021).

Information and communications technology (ICT) holds enormous potential to strengthen mathematics teaching and learning. The assortment of notations, formulae, figures, symbols and graphs in mathematics are sometimes difficult to demonstrate using 'chalk and talk' methodologies. With ICT applications, tools and software, this 'assortment' can be taught meaningfully and dramatically. The Department of Basic Education's white paper on e-education, Transforming Learning and Teaching through ICTs, concludes that ICTs can accelerate the achievement of national education goals, so government is keenly aware of this potential. Despite this, Graven and Stott (2011:15) state that "whilst South Africa has made some progress since 1998 in terms of the implementation of ICT in education, the majority of schools are still in their infancy … Furthermore, most schools with access are still in the process of learning to integrate ICT into their teaching and learning."

Regardless of ICT's potential, researchers warn that it is not a panacea to address underperformance in mathematics. Padayachee (2017) and Trucano (2013) argue that ICTs are a supplement and not a substitute for education and caution against the perception that technology can replace both educators and textbooks. It is not merely the tool, device, medium or internet, but rather the harvesting of the processes and power of ICTs to make teaching mathematics relevant, engaging, responsive and effective. Umugiraneza, Bansilal and North (2013:1) maintain that, to fully realise its potential, ICT "requires the collaboration of well-trained teachers, working in well-equipped classrooms, using technology innovatively to support a constructive learning atmosphere."

The Zenex Foundation recognises ICT's potential to strengthen mathematics teaching and learning. However, there are constraints in the South African context to the successful implementation of ICT programmes. It is within this context that the Foundation commissioned a national review of early-grade mathematics programmes that integrate ICTs to understand why particular models work. The review analysed Grade R to 4 programmes, in-class or after school, for teachers or learners, implemented between 2016 and 2021 in the public education system. It was conducted in the second half of 2022 by the Centre for the Advancement of Science and Mathematics Education and employed desktop research, an online survey and in-depth interviews with a select sample. The lessons and recommendations emanating serve to inform the Foundation's strategy and contribute to the design and implementation of ICT programmes in the future.

ICT "requires the collaboration of well-trained teachers, working in well-equipped classrooms, using technology innovatively to support a constructive learning atmosphere."

Bansilal and North (2013:1)

WHAT ... ARE ICTs AND THEIR POTENTIAL?

ICT teaching and learning requires both digital hardware and software packages. Calculators, cellphones, tablets, projectors and smartboards are examples of hardware, whilst spreadsheets, Paint, Word, PowerPoint, online videos, internet and web-based platforms are examples of software.

According to the National Council of Teachers of Mathematics (2015:1), ICT teaching and learning in mathematics "includes interactive apps and web-based digital activities that develop calculation skills (working with numbers); dynamic geometry that leads to the discovery of the properties of shapes and objects (space and measurement); data collection, organization and analysis skills."

The enormous potential of ICTs

ICTs can make a significant contribution to early-grade mathematics teaching and learning. Research shows that young children are comfortable and display positive emotions when using computer software, and they can understand, think about, and learn from, technology-based activities (Clements and Sarama, 2005).

Good software encourages children to talk about their work as well as engage in more advanced cognitive types of play (Clements and Sarama, 2005). Many online tools also contain user diagnostic analysis, which instantly feeds data to the educator with the aim of assessing the level of the child and providing extra support if needed.

Play helps children connect with the world around them in tangible ways. ICTs can embrace this by providing platforms for children to play online games and unconsciously they learn mathematics while they play (Anwar et al., 2020), making learning fun and entertaining. Immersion is linked to engagement and is broadly considered as the outcome of a good gaming experience (Bui et al., 2020). Immersion can be divided into three components: sensory, challenge-based, and imaginative – all perfectly aligned to the developmental stage of the early-grade learner. Rewards in the form of emojis, or a collection of stars or points, all add to immersive mathematics teaching and learning experiences. Drill and practice software can also help develop competence in skills like counting and sorting (Clements and Sarama, 2005).

Manipulatives (manipulating shapes and objects on, for example, a touch screen) not only allow children to construct their own cognitive models for abstract mathematical ideas and processes, but also provide a common language with which to communicate these models to the educator and other learners (Odum, 2022). In a study comparing the use of physical sticks and on-screen sticks, children found the computer manipulative easier to use for learning (Clements and Sarama, 2016) as computer manipulatives allow children to perform mathematical transformations on objects on the screen. Computer manipulatives can also help connect concrete and symbolic representations by means of multiple linked representations and feedback, such as showing base-ten blocks dynamically linked to numerals.

ICT education has the "potential to improve quality of learning" and it "mediates and fosters" the learning of "higher order skills".
Meyer and Gent (2016:2)

Learners with higher order and smart skills

ICT teaching and learning enables both mathematics educators and learners to, by themselves, discover knowledge and skills beyond what is taught in class. Meyer and Gent (2016:2) support this view when they point out that ICT education has the "potential to improve quality of learning" and it "mediates and fosters" the learning of "higher order skills".

The Kenan Foundation Asia (2019) asserts that the prosperity of any country lies in the development of learners with smart skills like collaboration, communication, creativity and critical thinking, and argues that ICT is the vehicle through which these skills can be acquired. ICT renders educators and textbooks as the springboards for learning and puts the learners in the driving seat of their education. Umugiraneza, Bansilal and North (2013) argue that ICTs transform the classroom; it allows learning beyond basic information and provides access to innovative applications. They further posit that ICTs expose learners to different learning skills, thus allowing for creativity, and raising the level of thinking, reasoning and problem solving.

WHERE … ARE WE NOW IN SOUTH AFRICA?

The Zenex Foundation's review of the South African policy landscape and early-grade mathematics programmes in public schools serve to inform the Foundation's strategy and contribute to the design and implementation of ICT programmes in future.

A supportive policy environment

The government's policy response speaks to the potential of ICTs to improve teaching and learning with the *Professional Development Framework for Digital Learning* intended to guide implementation within the education sector. The primary target group is educators, who are identified as a key driver of achievement (DBE, 2018).

The Department of Basic Education's *Action Plan to 2024 Towards the Realisation of Schooling 2030* states, "in a context of changing technologies … and given that some technology innovations in the classroom enhance learning more than others, moving forward requires enough local research" (DBE, 2020) and calls for equity and accessibility to ICTs in schools. In a more recent update, in response to the COVID-19 pandemic, it recognises the significant weakness in educators' digital literacy and the shortcomings of ICTs to reach schools and learners who experience device and connectivity constraints (DBE, 2020).

The Department of Communications and Digital Technologies regulations around zero-rating, which directs licensees to provide access to local educational content websites without data charges, are significant. The recent development and roll-out of training for educators on the Teaching Mathematics for Understanding Framework is encouraging and offers considerations for the use of ICTs to transform mathematics teaching and learning. Much of this relates to how the affordances of ICTs can be used for learner-centered assessment to support identification of errors and misconceptions. The use of ICTs for teaching seems largely to focus on the use of visualisation and the opportunity to engage learners in complex problem-solving using dynamic apps.

Varied programme design and implementation approaches

The landscape of early-grade mathematics programmes that integrate ICTs is varied. Underpinning the approaches are different theories of change or rationale for making design choices, as well as consideration of factors to ensure success and scaling-up.

Curricula also differ. Although all programmes are developed from research and evidence on how young children learn best, some are designed to align exactly with CAPS, whereas others align broadly with the national curriculum. Of the ten programmes deemed relevant to the review, seven operated in the Western Cape. The study explored the programmes that were implemented in the period 2016 to 2021, but only three programmes were active during the entire period, as detailed in Table 1:

Table 1: Period of programme implementation

Programme	2016	2017	2018	2019	2020	2021
Edulution						●
EduRise				●	●	●
JumpStart JumpTrack	●	●	●	●	●	●
Learning Gains through Play	●	●	●			
Maths Curruculum Online (MCO)	●	●	●	●	●	●
Mathseeds	●	●	●	●	●	●
MathsUp mobile application		●	●	●	●	●
Matific					●	●
One Billion				●	●	●
Trackosaurus Formative Assessment						●

There is significant variability in the target grades of programmes. Most programmes (60 per cent) target the transition point between Grade 3 and 4 while 50 per cent are aimed at Grades 1, 2 and 5. Most programmes (80 per cent) are implemented independently by NGOs or other implementing organisations. Only two programmes (20 per cent) are implemented in partnership with government.

Seventy per cent of programmes are designed for in-class teaching and learning, while 30 per cent are used for both in-class and extracurricular activities. Programmes target different groups of beneficiaries with the majority (40 per cent) developed exclusively for learners, while 30 per cent provide for both educator professional development and learner support. Ten per cent of programmes target DBE education officials along with educators and learners and another 10 per cent are aimed at school management support, educators and learners.

The survey reveals that 80 per cent of programmes are CAPS aligned. However, alignment to the curriculum varies in extent. Whilst some programmes were developed with the Department of Basic Education to match the CAPS lesson plans exactly, others worked to ensure broad alignment to the CAPS framework. Half of the programmes are accessible through both offline and online modalities; 30 per cent are only accessible online and 20 per cent are accessible offline. Of the programmes accessible online, 60 per cent are zero-rated.

Despite the rapid improvement in software, technology is still marginally integrated into education because of poor infrastructure, inadequate technology, ineffective professional development, low educator self-efficacy, fears and negative perceptions.

(Harell and Bynum, 2018)

Half the programmes use original content that was developed for the specific programmes. In addition, 30 per cent of programmes utilise third-party content while 20 per cent employ modified or adapted open education resources. Half the programmes require ongoing technical support while the others don't need ongoing support.

The complexity and challenges in the current education context

Despite the rapid improvement in mathematical software packages, technology is still marginally integrated into education. Challenges like poor infrastructure, inadequate technology, ineffective professional development, low educator self-efficacy, fears and negative perceptions, are blamed (Harell and Bynum, 2018).

Except for in the Western Cape, many schools remain without adequate infrastructure and services to support ICT integration. A study by Umugiraneza, Bansilal and North (2013) in primary schools in KwaZulu-Natal, found that only ten per cent of educators used ICTs to teach mathematics. While some of the schools had computers, they were reportedly only used for administrative functions. Spaull (2019) acknowledges that access to technology is low in comparison to international standards. Meyer and Gent (2016), in a study on the status of ICT in South Africa, note that educators' negative attitudes towards ICT education, coupled with inadequate digital literacy and high cost of data, all have a negative impact on ICT education implementation.

Interviewed programme developers and implementers were asked to identify challenges to determine if there are any common challenges. The data reveal that programmes are hindered by:

- **Contextual factors** (for example, poor service delivery, poverty, crime, weather events, protest action, inadequate connectivity and overcrowded schools), associated with the complex socio-economic and political context of South Africa, can hinder programme success.
- **Inadequate ICT infrastructure and equipment** (like devices and Wi-Fi) force implementers to either select schools with labs or rely on users having their own devices and connectivity. Some programmes try to fund these resources, but this is expensive and sometimes cannot be secured timeously.
- **Theft and abuse of infrastructure and equipment are a major concern.** In some cases, schools turned down programmes due to fears about security and being targeted for break-ins.
- **Some educators lack foundational digital literacy** and confidence using ICTs.
- **Recruiting skilled and motivated external coaches or change agents is a challenge** and staff costs are high.

HOW … DO WE SHIFT THE NEEDLE IN FUTURE?

The qualitative data gained through interviews identify design choices and implementation experiences that contribute to programme success. Common challenges, experiences and lessons provide mitigation strategies and recommendations to guide stakeholders to better develop, implement, and support early-grade mathematics programmes that integrate ICTs in the future.

Programme design

- **Develop curricula and assessment means that support phased learning – from the initial sensory to the concrete and abstract phases.** Manipulatives allow learners to connect with the world around them. Make lessons fun by using cartoons, animations, songs, games and avatars. Rewards motivate learners to progress and feedback help them pace and direct their learning. Instant feedback ensures greater retention of concepts, as compared to traditional marking and the delay associated with such.
- **Align programmes to CAPS to ensure teacher buy-in.** Teachers are trained and expected to follow the curriculum. Even where programmes are based on international curricula, developers/implementers recognise the importance, and much effort is put into getting programmes aligned as closely as possible. Programme flexibility allows users to teach at the correct level and pace – an important consideration given the South African context where learners may need differentiated instruction.
- **Offer content and activities in all South African languages.** Department of Basic Education policy supports research that shows that learners assimilate information easier in the earlier grades if they are taught in their mother tongue. It is at this developmental stage that acquisition of mathematical concepts is critical (Chiphambo and Feza, 2022) and language is widely accepted to play a critical role. It therefore makes sense that programmes should offer content and activities in the different languages.
- **Analyse data in real time to provide customised interventions for teachers and learners.** Stakeholders (district, school, classroom and individual) can analyse conceptual weaknesses and provide customised training to educators, as well as targeted and even remedial interventions for learners. Teachers can harness the potential of data-driven programmes to plug gaps and differentiate teaching.

Programme implementation

- **Provide training to educators so they are equipped to use technology to enhance teaching and learning.** Educators who play an active role can help children learn through developmentally appropriate use of technology.
- **Work with schools that agree to provide adequate space and security.** Remove tablets from schools during the holidays when crime escalates. Control DNS settings on routers to prevent coaches from abusing equipment by downloading inappropriate content.
- **Strengthen trust and improve results through thorough on-boarding and buy-in.** Established working relationships with the school, district and province offer a solid foundation for new interventions as trust exists and the context of schools is understood. On-boarding is more easily achieved if the programme has the support of the Department of Basic Education.
- **Ensure uptake and retention by providing ongoing, regular, in-person support and encouragement.** Regular meetings with heads of departments, educators and parents provide implementers the opportunity to give feedback on progress and success. Users need continuous technical support to rapidly solve problems and retain buy-in and commitment.
- **Employ external change agents or coaches to help initiate, drive, monitor and implement programmes.** Local youth who are upskilled and supported to assist programme implementation play a critical role in programme success. Address coach fatigue by retraining, providing rewards and recognition.

Sustainability and scaling-up

- **Roll-out ICT infrastructure and services to all schools.** The cost of funding this through external programmes is impeding and will be mitigated if the Department of Basic Education rolls out the required infrastructure, as has been done in the Western Cape.
- **NGOs and independent implementers work as a collective to fundraise** for programme platforms, licensing and access, development, refinement, hosting, subscription, data (if the platform is not zero-rated), adequate devices and ICT infrastructure. Pooled or leveraged funding enables more effective implementation.
- **Simplify the application process for zero-rating and clarify the regulatory environment** to bolster upscaling.
- **Foster close working relationships between programme users and developers.** Through listening and reflecting on concerns, programmes can improve their offerings, including making adjustments to the interface, usability, and/or content to ensure ongoing relevance and alignment to CAPS.
- **Cultivate partnerships with the Department of Basic Education to improve longevity,** reach wider clusters of schools and bolster economies of scale.

A final theme that emerges is that the ICT adoption journey takes time, patience and customised support. Understanding differentiated personalities, challenges and views in schools that often have multigrade and large classes allows for building a community of learning and underpins ownership, teamwork and innovation.

ICTs IN EARLY-GRADE MATHEMATICS EDUCATION IN SOUTH AFRICA:

A VISUAL SUMMARY

Why … review ICT programmes?

National review of Grade R to 4 programmes in the public education system to inform future strategy, design and implementation because …

Mathematics unlock opportunities, but South African learners gravely underperform

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Majority of schools are still in their infancy, but ICTs cannot replace educators and textbooks

What … are ICTs and their potential?

ICT teaching and learning utilises digital hardware and software packages and …

It holds enormous potential by enabling teachers and learners to learn higher order and smart skills

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Play, immersion, and manipulatives help young children connect with the world in tangible ways

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Drill and practice software help develop competence in skills like counting and sorting

Where … are we now in South Africa?

Policy environment

- Professional Development Framework for Digital Learning
- *Action Plan to 2024 Towards the Realisation of Schooling 2030*
- Regulations around zero-rating
- Roll-out of training for educators on the Teaching Mathematics for Understanding Framework

Programme design and implementation

- Different theories of change and most programmes implemented independently
- Majority target Grades 3 and 4 and are aligned to CAPS
- 70% designed for in-class teaching and learning
- 40% target only learners and 30% both educators and learners
- 50% available online and offline with half using original content

Challenges

- Service delivery, poverty, crime, weather events, protests, over-crowded schools
- Inadequate connectivity, infrastructure and equipment
- Theft and abuse
- Low educator digital literacy
- High staff costs associated with external change agents/coaches

How … do we shift the needle in future?

Design

- Develop appropriate curricula for young learners
- Align programmes to CAPS
- Offer programmes in all South African languages
- Analyse data in real time to plug gaps and differentiate learning

Implementation

- Train teachers to use technology
- Work with secure schools
- Establish and nurture relationships to promote on-boarding and buy-in
- Provide ongoing support
- Employ external change agents/ coaches

Sustainability and scaling-up

- Roll-out infrastructure to all schools
- NGOs and implementers work as a collective to fundraise
- Simplify zero-rating
- Nurture relationships between users and developers
- Cultivate partnerships with the Department of Basic Education to reach economies of scale

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