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Measuring the learning gains from engagement with the Green Shoots Maths Curriculum Online

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ABSTRACT

Mathematics Education in South Africa continues to face complex, multifaceted challenges, but as data from this study show, there is reason for hope. The Western Cape Education Department recently implemented the Green Shoots Maths Curriculum Online (MCO) program in 500 of its primary schools. An ABC classification of affective, behavioural, and cognitive learning gain was used to analyse the learning gain for learners, parents, and teachers who use the Green Shoots Maths Curriculum Online (MCO) program. As part of a larger longitudinal Education Design Research project, data in this study were produced through self-reported surveys, MCO usage data, Grade 6 learners' assessment results, and project documentation. Benefits from technology interventions such as the MCO project, tend to be unevenly distributed between resource-rich and resource-poor schools. Findings from this study however indicate that the learning gains for learners, parents and teachers were distributed across all types of schools since learners, parents, and teachers in all these contexts are accessing and using the program. The results from the study may benefit policymakers and education departments who wish to roll out similar programmes, school, and district leaders who manage short and long-term implementations, and teachers and learners wanting to use comparable programs such as this.

INTRODUCTION

Historically, mathematics education in South Africa has faced complex, multifaceted challenges. A substantial body of evidence (Christie *et al.*, 2010; Spaull, 2013; Maringe & Moletsane, 2015; van der Berg *et al.*, 2016) frequently cite learners' consistently low achievement in standardized international benchmarking tests (Mullis *et al.*, 2016; Vijay *et al.*, 2020a, 2020b) and emphasize the deep social inequalities and what Maringe & Moletsane (2015) termed, the "*contexts of multiple deprivation*" in which most of the country's schools operate. These studies repeatedly highlight among the many challenges, schools' limited access to resources; the lack of a culture of teaching and learning witnessed by poor timetabling; high absenteeism among learners and teachers; and problematic pedagogical practices. Existing challenges were intensified by the COVID-19 pandemic, with lockdowns and later platooned schooling resulting in severe learning losses (some learners attended as little as 2 days every 2 weeks during 2021).

The use of educational technologies is a potential solution to improve mathematics education and attainment within South Africa's challenging education contexts. Researchers established various positive links between the use of specific digital technologies and improvements in different aspects of mathematics education (Hardman, 2005; Higgins & Spitulnik, 2008; Tamim *et al.*, 2011; Ndlovu & Lawrence, 2012; Tay *et al.*, 2012; Hardman & Lilley, 2020). However, as many of these researchers point out, the impact of digital technologies cannot be methodologically isolated to prove causality, since it is most often one among a variety of variables that positively impacts learning (Hardman & Raudzingana, 2021). Also, while some researchers (Tondeur *et al.*, 2016; Philipsen *et al.*, 2019; Howard *et al.*, 2020; Hardman & Raudzingana, 2021) address the impact of a technological intervention on teachers' pedagogical practices and learners' attainment, few studies address the greater learning gains that may be attributed to interventions. Moreover, research exploring the link between technologies and mathematics, often reports on studies and ends with a suggestion that large-scale research is needed to study the relationship between digital technologies and broader mathematical outcomes at scale.

Due to its very nature, research on the impact of technology on teaching and learning is frequently situated in contexts rich in resources, connectivity, and devices. However, most South African schools struggle to access such resources, with greater disparities existing between schools in urban centres and their counterparts in rural, farming, or mining areas (Spaull, 2013; Nkengbeza & Heystek, 2017). Few studies investigate the impact of technology implementation in Mathematics classrooms across a diverse education context, and those that do, tend to focus on smaller samples across a few sites, producing findings that may not be generalizable to the diverse, greater South African education context or beyond.

In short, research is needed that searches beyond surface appearances, beyond academic results, and looks at learning of different participants and stakeholders (Isaacs, Roberts & Spencer-Smith, 2019) to illuminate complexity and multi-dimensionality as the system grows and improves. This paper reports on a section of a larger study that addresses these gaps in the literature and seeks to identify the learning gains realized at scale in diverse education contexts, and at different levels of the education system of those participating in a province-wide Mathematics Curriculum Online (MCO) project.

RESEARCH CONTEXT

The study takes place in the Western Cape province of South Africa and involves 500 urban and rural primary schools spread across eight (8) education districts. Green Shoots Education (GS) provides its Maths Curriculum Online (MCO) program to 500 Western Cape Education Department (WCED) primary schools in the province. This paper reports findings of the learning gains for learners, their parents/caregivers, and teachers who participated in this project.

South African schools are rated using a Quintile system. Quintile 1 schools (Q1) are typically resource-constrained and situated in poverty-stricken areas, and are typically no-fee paying, serving the poorest communities. Since learners do not pay school fees, Q1-schools are funded by the Department of Education (Department of Basic Education, 2015). Quintile 5 schools (Q5) have greater access to resources, are situated in more affluent areas, and receive considerably less funding from the department. The project was funded by the WCED so all schools participated in the project at no cost.

The following stakeholders participated from the 500 schools (data accessed: 20 September 2022):

- 306 587 registered Grade 3 to 7 learners of which 192 076 learners are active; and learners' parents
- 7270 teachers including teachers who are also heads of department, grade heads, and members of senior management teams
- 500+ principals and/or deputy principals
- 281 district officials including Maths subject advisors, e-Learning advisors, circuit managers, and other leaders within district offices
- 500 Primary Schools representing:
    - 53 Quintile 1 (Q1) = 11%
    - 87 Quintile 2 (Q2) = 17%
    - 77 Quintile 3 (Q3) = 15%
    - 151 Quintile (Q4) = 30%
    - 132 Quintile (Q5) = 26%

The distribution of schools in each of the WCED districts per quintile is illustrated in Figure 1. The WCED considers its four metro education districts as urban districts (UD) and classifies the remaining four as rural districts (RD). The 500 MCO Project thus includes 310 (62%) urban and 190 (38%) rural schools, which represent 44% of the Q1, Q2, and Q3 schools and 56% of the Q4

& Q5 schools. The project can therefore be considered as representative of all South African schooling contexts.

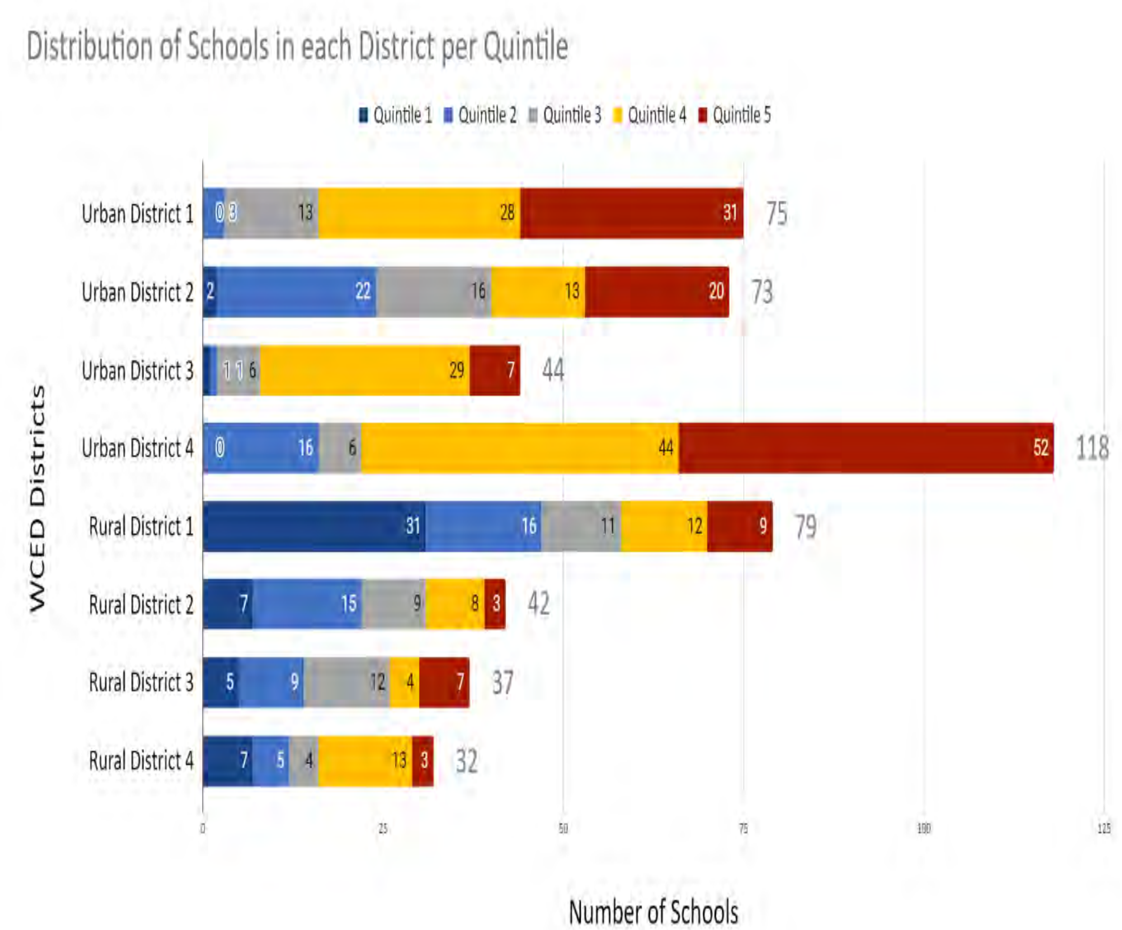

Figure 1: Distribution of Schools in each District per Quintile

The MCO project consists of various online tools that can be ubiquitously accessed by all stakeholders. The MCO Brain Quests (BQs) are sets of online exercises mapped to the curriculum and aligned to the education department's support material. Ideally, learners are to complete each week's BQ in tandem with the work they do in class. In other words, should they be doing multiplication of 3-digit by 2-digit numbers in class, the BQ that they do for the week consists of exercises to practice this. The questions in each BQ are varied to expose learners to different question types. Since most schools have limited devices, learners often share devices to complete BQs. As of July 2022, learners who share a device to complete a BQ can both submit the results they achieve under their unique login credentials, meaning they are both assigned the results. This captures the results from the collaboration between learners, who need to work together to discuss the problems and find the correct solution before submitting the answers.

Upon submission of their BQs, learners receive immediate feedback. If they choose, they can use this feedback to return to the questions they had incorrect to try and solve them again. One teacher explains the benefits of using MCO with her learners:

> "*Learners are exposed to relevant concepts aligned with CAPS, platform is colourful, learner-friendly and encourages learners to attempt solving problems. I also pair stronger learners with ones who struggle to read because the focus is on the maths. Green shoots added more value to teaching, exploring methods, and boosting my learners' confidence, they are more eager to try to solve problems and they enjoy the feedback they get if answers are incorrect.*" [1]

The results of the BQs become immediately available to the class teacher who can track in real-time where problem areas arise in learners' responses to address these in the same session. During BQs teachers are also strongly encouraged to engage with learners and to address challenges or misconceptions as they notice these. The results from the BQs also feed through to the school's senior management team (SMT), and to the district office where officials can identify trends from the data and gain insight into potential challenges. The data is also available to the WCED directorate at the head office to track usage of the program throughout the province and to identify areas from the data where learners are struggling. With the data insights guiding them, the leaders throughout the system can make data-informed decisions regarding teaching and learning, how to improve this, and which areas in the curriculum to target for interventions.

Once a term, learners can complete the MCO School-Based Assessments (MCOSBAs). The MCOSBAs offer a term based benchmarking of progress for all learners who participate from the various schools in the province. District officials from the WCED moderate the assessments to ensure they cover all relevant areas in the curriculum and include the appropriate levelling and range of question types. Assessments are completed online and can include open ended questions where learners show their working that teachers need to mark at the school. Assessment tasks are also available depending on the CAPS term assessment requirements and include investigations and projects. Where applicable, immediate feedback is provided to learners following their assessment submissions. Teachers, SMTs and district officials, as well as the WCED directorate, can access the insights from the assessments on GS Insights - a real-time, queriable dashboard.

GS Insights provides stakeholders with a dashboard that displays BQ-completion data to show usage across the province and curriculum coverage. Different users have different levels of access to the data on Insights; hence a principal can see their school's data and can mine down to the individual learners in their school, but they cannot see data from another school. However, a district team can see the schools' and learners' data in their district, while the WCED directorates can see the whole province's data including data from the different circuits and schools in each district and can mine down to individual learners' data. The WCED are custodians of the data produced by the learners in the province, therefore strict ethical guidelines and rules govern access to this data.

Different stakeholders are learning to use the MCO programme and its many facets, from learners and parents/caregivers to teachers and school leaders, officials, and district leaders, and the WCED directorate. The learning that takes place across the system by the different stakeholders is considered the learning gain of the system. This study seeks to understand and describe the learning gain that takes place for teachers, learners and parents participating in the MCO project, to lay the foundations for quantifying such learning gains in the future.

[1] Note that responses from teacher or learners are posted as in the original, including possible mistakes to ensure validity

LITERATURE REVIEW

Learning gains are described and defined differently by different education sectors/researchers. When used by researchers in primary school settings, learning gain is often equated to the knowledge and skills learners'[2] gained towards a predetermined outcome reflected in assessment results (Robertson & Miller, 2009; Means, 2010; Luyten, Merrell & Tymms, 2017). Higher education has developed this term more thoroughly.

Researchers in higher education contexts define learning gains as measures to describe and provide evidence of the contribution and impact of higher education on learning. Wang, Schembri & Hall (2013) described the learning gains in students' attitudes, scientific skills and understanding in a Microbiology course. From a study of UK universities, McGrath *et al.,* (2015) described learning gain as a measure of 'distance travelled' or the "*difference between two measures of actual student performance*" in terms of students' gain in content knowledge, skills and competencies, and personal development (McGrath *et al.*, 2015, p. xi). Additionally, learning gains differ from *value-added* which McGrath *et al.,* (2015) noted as the difference in the predicted, compared to the actual performance achieved.

Gains in knowledge, skills, competencies, and personal development is a frequent theme in similar research. Tadesse *et al.,* (2022) and Baume (2018) equate learning gains to the academic, professional and/or personal learning gained through engagement with higher education. In their extensive literature review on the topic, Rogaten *et al.,* (2018) suggested using affective, behavioural and cognitive (ABC) learning gains to describe the complexity and multidimensionality of learning and development.

a) Affective learning gains are defined as a change in affect such as confidence, motivation, and attitudes.
b) Behavioural learning gains focus on skills rather than knowledge developed, including for instance, engagement and collaboration, leadership, and study skills.
c) Cognitive learning gains are improvements or developments in knowledge, understanding and cognitive or metacognitive abilities.

Different methods to measure learning gains are reported in the literature (McGrath *et al.*, 2015; Rogaten *et al.*, 2018; Gossman & Powell, 2019; Rogaten & Rienties, 2021; Tadesse *et al.*, 2022):

- Grades offer a way to directly measure learning gains in student achievement between two given points in time. The problem however is that grades are rarely comparable given the range of assessment and grading practices within and across institutions.
- Indirect measures such as surveys ask students to self-report their learning gains. Self-reported surveys and particularly those that require retrospective judgements typically measure affective and behavioural learning gains.
- Standardised or systemic tests offer a more objective measure of learning gains and seek to measure gains in pre-determined knowledge or skills. Where such tests are discipline specific the results are more comparable and have greater validity. Gossman & Powell (2019) noted that if tests are consistently applied, the results can provide longitudinal data for students individually, and comparisons between students across institutions.
- Mixed method approaches combine measurement tools like learning data, grades, and surveys to track performance over time. The development of learning analytics to combine different datasets may improve the complexity of this approach.

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[2] In this study students are distinguished as those attending post-school education, and learners as those attending school.

- o Other qualitative instruments such as interviews or observations allow for a more nuanced understanding of learning gain, in terms of mastery learning for instance. Such instruments typically require students to reflect on the learning, their acquired skills and where gaps may exist. The reflective and evaluative processes inherent in such instruments are especially valuable to students.

While learning gain research is generally situated in education institutions, McGrath *et al.*, (2015) noted that institutions are not the only ones contributing to students' learning. Earlier research by Roschelle, Knudsen & Hegedus (2010) support this view. The researchers argued that large-scale integration of innovative learning technologies, as with the Green Shoots MCO, requires the advanced design of representational and communicative infrastructure, curricular activity systems and classroom practices and routines, which involves multiple stakeholders. Additionally, Means (2010, p. 304) added that stakeholders at all levels "*need to stop thinking of learning software as an intervention in and of itself and to think instead of broader instructional activity systems*".

Drawing on these researchers' work, this study seeks to understand the learning gains of learners, parents/caregivers, and teachers participating in the MCO project using Rogaten *et al.,* (2018) ABC-lens of affective, behavioural and cognitive learning gains.

METHODOLOGY

An education design research approach guides the study. Education design research (EDR), also referred to as Design-Based Research, serves the needs of this research to a) allow for systems-thinking/system thinking, and b) be shaped by iterative, data-driven processes that develop successive approximations of desired interventions (Mckenney & Reeves, 2019). An EDR approach is particularly useful in that it explicitly strives to develop a warranted theory that may benefit various stakeholders beyond the research community (Van den Akker *et al.*, 2006; Mckenney & Reeves, 2019). EDR includes both quantitative and qualitative methods for data production and analysis.

To understand the complexity and multidimensionality of the learning gains for learners, parents/caregivers (hence referred to as parents), and teachers participating in the MCO project, diverse data sources were used as follows:

- Learners and teachers completed self-reported surveys using a combination of Likert response scale items and open questions. Survey participants included:
  - o August 2021: 3270 learners
  - o August 2021 & 2022: 70 teachers
- Project documents and reports from the Green Shoots team
- MCO usage data
- Grade 6 results for Terms 1-3 MCO assessments in 2022

Surveys were completed online, anonymously, and voluntarily. A 'Talk to Us' button on the MCO invited learners to participate and was available for approximately 3 months on the system. Gossman & Powell (2019) warn that such surveys can be 'gamed' where teachers potentially coach students regarding their responses. To avoid this, the 'Talk to Us' button was placed on the MCO page with no request to teachers to encourage learners to complete it. Similarly, teachers who are part of the MCO schools were sent WhatsApp and email messages with the link to the teacher survey (a Google Form). Respondents were not coerced to participate and could ignore the invitation if they chose. They could also withdraw and not complete the surveys at any time, meaning no negative consequences accompanied this withdrawal.

The instruments for data collection were specifically chosen to avoid many of the limitations often associated with learning gains research. Instead of small samples, this study is scaled across multiple schools and districts with highly diverse contexts. Surveys were made available with no time constraint so learners and teachers could complete these at their leisure. This was to avoid the pitfall of adding assessments to an already over-burdened assessment schedule in the school term. The most cited limitation of self-reported data is the objectivity and reliability of self-reported data. Therefore, diverse data sources were used to compare findings, and mitigate this risk. Each year, Grades 3, 6 and 9 learners complete the provincial systemic tests. Since MCO caters primarily to Grade 4–7 learners, the results from the Grade 6 learners in the system were used for comparison, since schools with limited device access, often prioritise the Grade 6 learners to work with MCO, and in so doing, hope to increase their systemic results.

DISCUSSION OF RESULTS

Learning gain was measured for learners, parents and teachers participating in the project.

Learning gains for Learners

Usage of the MCO by learners across the province, per district and school quintile. Grade 6 learners were chosen as a representative sample. The number of Grade 6 learners who are active on the MCO programme is presented in Figure 2, showing the district and quintile distribution. The chart displays the active learners compared to registered learners (who may be on the system but who do not access it).

As can be seen from Figure 2 below, Urban District 4 (UD4) has the most Grade 6 learners with 14 314 active, followed by UD2 with 10 388 registered learners and Rural District 1 (RD1) with 6844 learners. RD3 (3304) and RD4 (3143) have the fewest number of active learners participating in the MCO programme.

Depending on the number of devices and bandwidth (and data) available in each school, some learners may be more active than others, thus impacting their learning gain. A measure of how active learners are on the system is therefore calculated:

$$Activity\ Rate\ (AR)\ for\ each\ school = \frac{\text{Sum BQs completed} \div \text{weeks in the term}}{\text{\#Grade 6 active learners per school}}$$

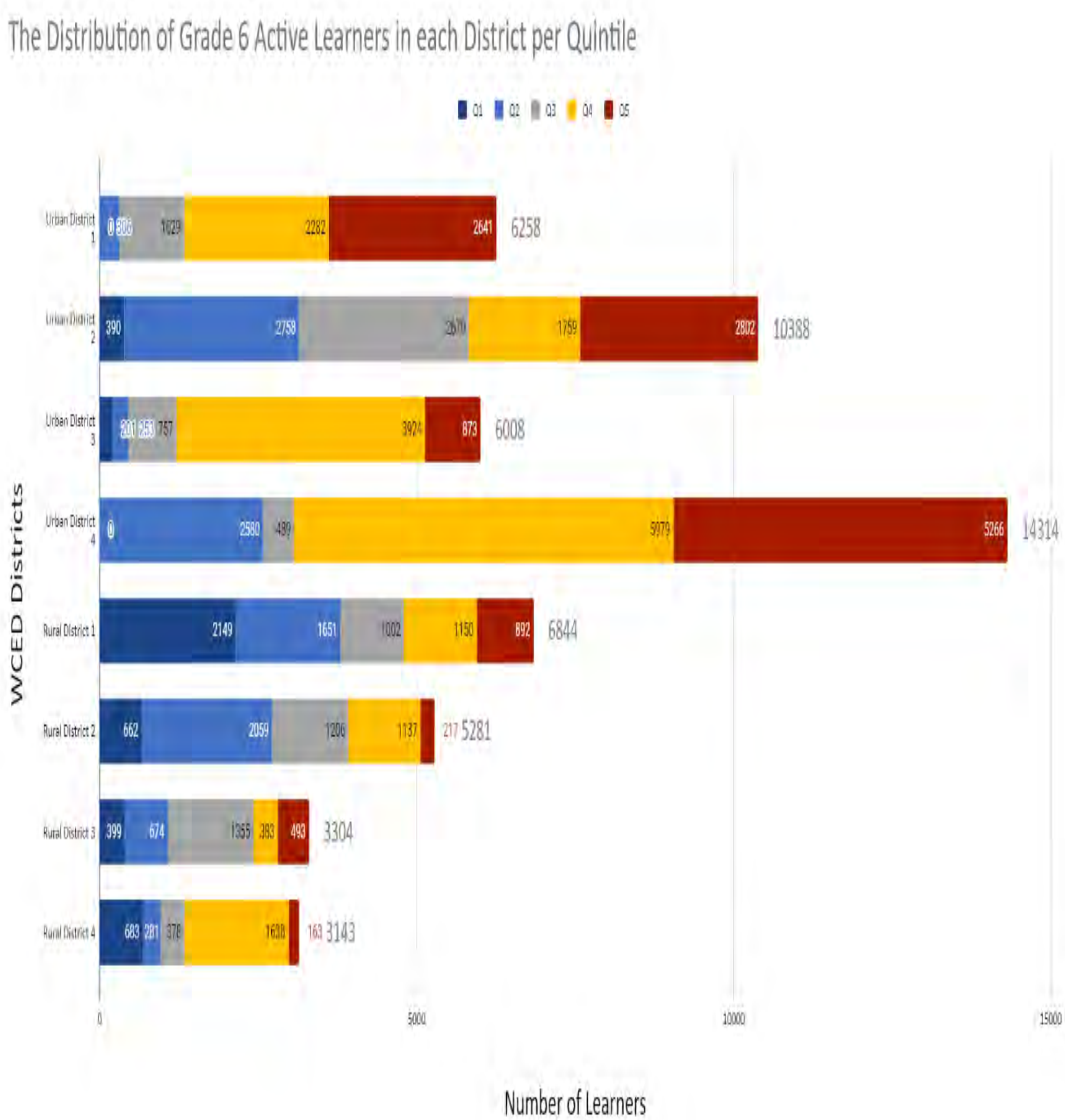

Figure 2: The distribution of Grade 6 active learners in each district per Quintile

The Grade 6 Activity Rate (AR) per school was calculated for Term 3 of 2022 (the most recent data available at the time of authoring) for each district as the sum of the schools in that district's activity rates. The Grade 6 AR per school was then compared across quintiles and across districts. The result of this calculation is included in Table 1 below.

***Table 1:** Quintile and District Activity Rate for Grade 6 MCO learners in Term 3, 2022*

	Urban Districts				Rural Districts				
Quintile	**UD1**	**UD2**	**UD3**	**UD4**	**RD1**	**RD2**	**RD3**	**RD4**	**Quintile Activity Rate**
Q1	0	2.4	0	0	**21**	2.6	2.6	1.4	29.9
Q2	2.5	**11.6**	0.2	9.1	7.5	6.8	6.8	0.6	45.1
Q3	5.7	8.1	3.4	1.4	**9.1**	2.9	4.8	1.2	36.5
Q4	13.6	7.1	10.7	**22.7**	8.7	4	0.5	2.2	69.6
Q5	20.3	10	3.6	**34.4**	4.7	2.7	3.9	2.2	81.8
District Activity Rate	42.1	39.2	18	67.6	50.9	19	18.6	7.6	262.8

The AR data shows that learners across different schooling contexts are engaged with the MCO programme. Comparing the number of Grade 6 learners in the MCO schools, Q1-3 schools represent 44% of Grade 6 learners, Q4 represent 33% and Q5 represent 23%. Comparing the per quintile learner representation to the corresponding activity rates, the fewer Q5 learners seem to be more active than the greater number of Q4 learners. This may suggest that the impact of resource and particularly technology access in Quintile 5 schools may allow more Q5 learners access to MCO on the school timetable, while fewer devices and bandwidth challenges may dilute access for learners in Q4 and lower schools. It is however encouraging to see that access challenges have not stopped learners in lower quintile schools from accessing the system and learning in the process.

The MCO activity in RD1 shows that lower quintile schools can also achieve high ARs. RD1 has 52.9% fewer active learners (6844) than UD4 (14214), and more Q1 schools (31) than any of the other 7 districts. The rural status of the district is due to the many tiny settlements with schools, or schools situated outside of urban settlements (in RD1 these schools are all Q1-3). Typically, rural schools function in very challenging circumstances with frequent interruptions to electricity and Internet connectivity. As can be seen from the data in Table 1, RD1's Q1 & 3 schools scored significantly higher ARs, scoring the highest ARs in the province for this period. For Q1-3 schools to log such high ARs and specifically for RD1's Q1 schools to score a 21AR (a significantly higher AR than in any of the Q1-3 schools in the province) is reason for celebration.

Understanding the different activity rates for the sample Grade 6 learners confirms that learners in all the MCO schools are accessing and using the program. It suggests that the entire system is supporting change in these schools. Teachers are committed to getting learners to the computer labs or on devices to complete the BQs. School leaders create a positive ecosystem that allow learners to access and use MCO. Schools work with the eLearning advisors to ensure that technology infrastructure is available to support access to MCO, while also timetabling the use of MCO in the school. Similarly, the eLearning advisors work with the eLearning Directorate to ensure that connectivity is made available whenever problems arise. Circuit managers work directly with principals and school leaders to make sure learners are active on the system by monitoring activity from the Green Shoots reports and GS Insights. District Maths subject advisors work with teachers to support and guide their curriculum delivery and pacing, and the head office curriculum directorate strategically creates and maintains an enabling ecosystem to make all this possible. However, this is the topic of the greater study, and the current paper focuses only on learners, parents, and teachers.

Learning gains for learners were analysed via usage data, the learner survey results, observations from teachers, and Green Shoots documents across the MCO programme.

Affective Learning Gains

Learners reported a slight change in their perception of Maths since they started working on MCO. 55% of learners indicated that Maths is easy or very easy when they work on MCO, compared to 51% who found Maths, in general, easy, or very easy.

Most learners (83%) noticed an improvement in their confidence since starting MCO. 40% of learners feel confident enough to either help or teach their peers, knowing that this requires them to talk and communicate their mathematical processes and thinking. The data indicates that for more than half of the learners (55%), their completion of the BQs gives them confidence when writing a Maths test, while 45% of learners have not noticed an increase, or feel the same. Teachers also noted a marked improvement in learners' confidence levels to try new concepts or questions, with a teacher stating, the biggest change after starting to use MCO was that

> "…*learners have gained confidence in Maths*."

Learners also enjoy Maths more after using MCO. In an open question, most learners indicated that they enjoy Maths and working with the MCO programme, and although they found Maths challenging, it was also enjoyable. Teachers also noticed learners' increased enjoyment and eagerness, with one commenting:

> "*Thank you for making maths for the learners and me enjoyable*."

Results from the teacher survey indicate that 86.3% of teachers noticed an improvement in the level of ownership learners take in their Maths. A teacher stated:

> "*I love that they even remind me, when they think I've forgotten*" [to take them to the lab for MCO]

Another teacher indicated that the biggest change noticed was:

> "*Enjoyment of the subject. Eagerness and willing to share ideas about concepts they understand. Seeking help when they do not understand. Able to learn from their mistakes and wanting to improve their understanding of math concepts they are unsure of or do not understand*."

The resulting affective learning gains for learners noted **in the study:** increased confidence, enjoyment, ownership, and a more positive perception of Maths.

Behavioural Learning Gains

Learners and teachers most frequently stated learners' behaviour changed as learning gained from the MCO project.

Teachers noticed various positive behaviour changes in learners. 93% of teachers noticed an improvement in learners' engagement with Maths, with 87% stating that learners attempt a greater number of sums when working on MCO compared to the classroom. Teachers also noticed a marked improvement in how learners collaborate, with one teacher stating:

> "*Learners that work in pairs communicate more effectively*."

In a similar vein, another teacher noticed an increase in

> "[learners'] *leadership and being able to guide the weaker ones*"

when they work in pairs on MCO. The Green Shoots team's feedback corroborated this finding, with them stating that learners offer more peer support to each other and that the healthy competition that develops helps learners progress. Such collaboration is rare in Maths online learning as Hardman & Raudzinga (2021) note, since platforms don't generally build in opportunities for collaborative learning.

Help-seeking behaviour is one of the strategies learners need to develop to become more self-regulated. An increase in help-seeking behaviour indicates a learning gain in terms of self-regulation. The Learner Survey indicates that since starting MCO, 81% of learners feel they can recognise when they need help and can employ different strategies to find the help they need, compared to 19% of learners who either guess the answer or click any option rather than seeking help.

Self-regulated learners typically assess their progress toward achieving their goals to know where to adjust. Learners display self-regulated learning behaviour when they know how to check their results, look at the feedback and take appropriate action. Learners' self-reported data indicates that 90% of them check their scores after submitting a BQ or similar task, and 34% say they do so to find out which answers they got wrong, or to compare their answers to the correct answers to improve on their next attempt (31%). A different survey question further probed the action learners took, to corroborate the finding from the previous question. Like the previous question, 10% of learners indicated that they did nothing with their scores. The remaining learners indicate that 28% write the score down, 12% tell a friend, 17% tell their teacher and 33% tell their family at home. Data from these questions therefore indicates that 90% of learners check their results and follow this with further action, displaying self-regulated learning behaviour.

The behaviour learners report when they complete a BQ a second time, can be used to infer their motivation and self-efficacy beliefs. 73% of learners indicate that when they complete a BQ a second time, they do so to 'try and improve their score'. 15% do not mind if they get the same score, and 12% do not want to improve their score. From the 73% who want to improve their score, it may be inferred that they believe they are capable of better results, suggesting that they have developed a sense of self-efficacy and motivation, believing themselves capable of higher marks.

Goal-directed behaviour, from setting goals to monitoring progress towards achieving such goals, is indicative of self-regulated learning behaviour. Almost half (49%) of learners reported that they set goals to achieve in their Brain Quests or Quick Quests: 33% always and 16% often set goals. 39% of learners only sometimes set goals and 12% never set goals. The data thus indicates that most learners are learning to become more self-regulated. The question does not probe what goals they would set for themselves, or whether these goals reflect their learning, which can be investigated in focus group interviews at a later stage.

***The resulting behavioural learning gains for learners noted in the study*:** increased engagement with Maths, greater collaboration with peers, and increase in self-regulated behaviour in terms of goal-directed behaviour, help-seeking, self-efficacy, and motivation.

Cognitive Learning Gains

Participation in the MCO programme developed different cognitive areas for learners. The survey data from teachers and learners, as well as the Green Shoots team documents were used to analyse this area.

Grades are often used as a measure of learning gain. 90% of teachers indicate that their learners' Maths attainment improved since they started using MCO: 18.2% improved slightly, 46.2% improved between 25-50% and 22.7% improved by more than 50%. A teacher noted:

> "… *most learners who cannot perform well in class are doing very well in mco*."

Other teachers noticed that learners' Mental Maths improved, with 65% noticing some improvement, and 24.5% noticing a significant improvement. The results from the term based MCOSBAs were compared to teachers' observations.

A cautionary note: The Grade 6 MCOSBA data was analysed for Terms 1, 2 and 3 of 2022. However, South Africa experienced severe load shedding at the end of Term 3, 2022 with up to 11.5 hours of electricity cuts every day. This prevented many schools at the end of Term 3 from completing the MCO assessments. The results for Term 3 are therefore reported but are considered slightly skewed.

Historically, the number of active learners who completed MCOSBA increased year-on-year since 2020 as can be seen in Figure 3 below; and by the end of Term 3, 2022, of the 192 076 active learners, 43 004 completed the term based MCOSBA. The results of the Grade 6s were analysed for Term 1, 2 and 3 in 2022 and is displayed in Figure 4 below. While this data indicates a general increase in the number of active learners and the MCOSBAs that they submit, it is necessary to understand what they achieved in these MCOs to understand the learning gain.

The 2022 results for MCOSBAs among Grade 6 learners were analysed to understand how many learners achieved above 50% (Pass Rate%) and what the average percentage achievement was each term for the different quintile schools (Average%) as presented in Figure 4. While there is a general improvement in both the pass rate and the average achievement, the results were analysed per quintile to see what impact the MCO Programme had across the spectrum.

In general, the average achievement for Grade 6 learners from Q1-5 increased only slightly from 28% - 30% (↑2%), while the number of learners who achieved above 50%, increased by 5% (described as ↑5%) from 26% to 31%. If one looks at the average change per quintile, the data is more nuanced: Q1↑5%, Q2↑7%, Q3↓-2%, Q4↑5% and Q5↑1%. The number of learners who achieved above 50% increased in all quintiles: Q1↑13%, Q2↑3%, Q3↑8%, Q4↑1 and Q↑5. While Q1-5 learners' average achievement in each term increased gradually, the impact of the MCO on Q1-3 schools was particularly positive. The pass rate for learners in Q1-3 schools showed a greater improvement from Term 1-3, meaning more learners were able to achieve 50% or more in these schools. Considering the lower average achievement in for example Q1 schools where the average increased from 26% - 31%, but the pass rate increased from 18% to 30%, it can be inferred that learners achieved better results. While this does not parallel the teachers' much higher reported increases in learners' achievement, it does corroborate that there was learning gain in learners' grades.

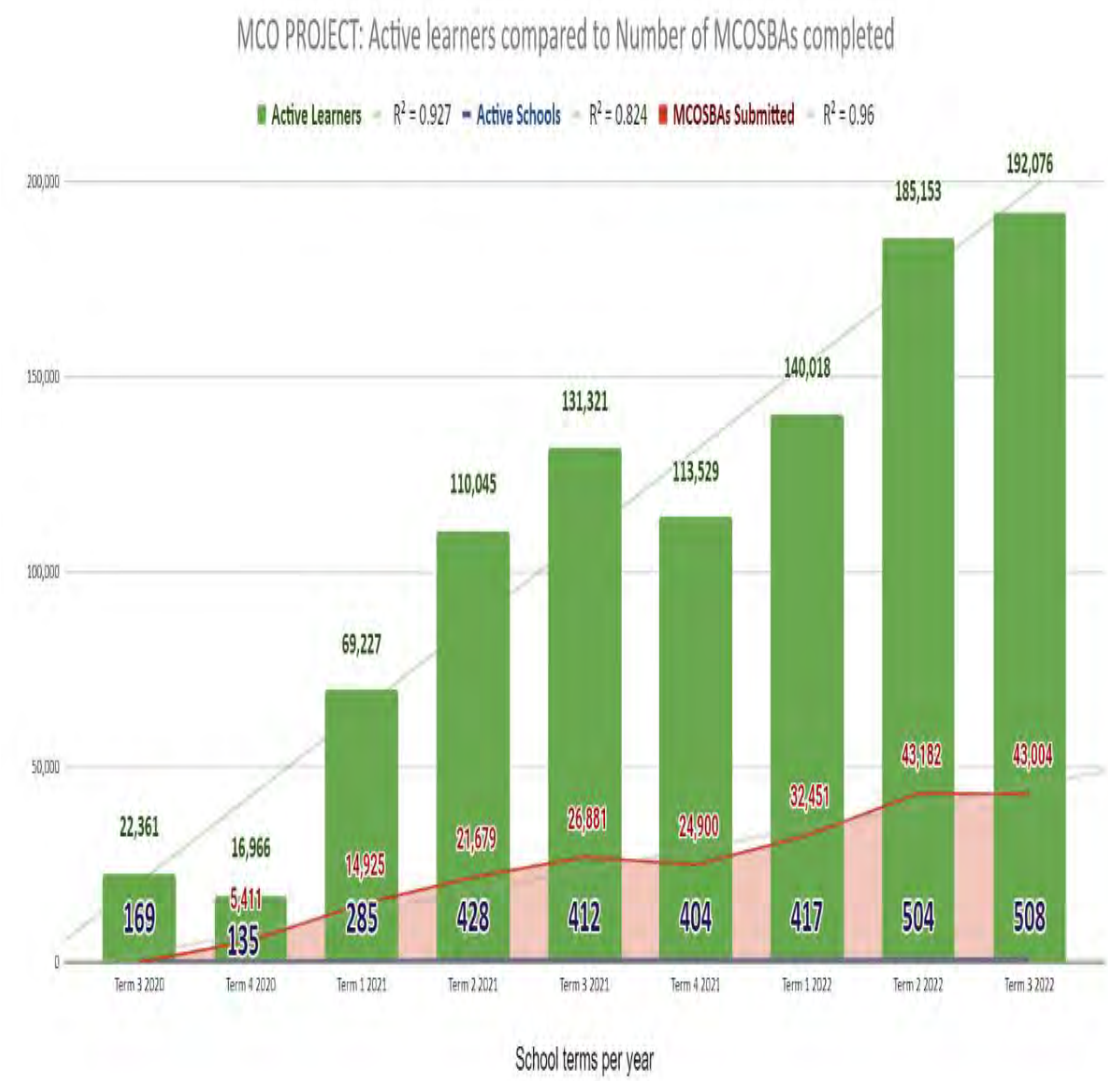

Figure 3: Active Learners compared to the number of MCOSBAS completed

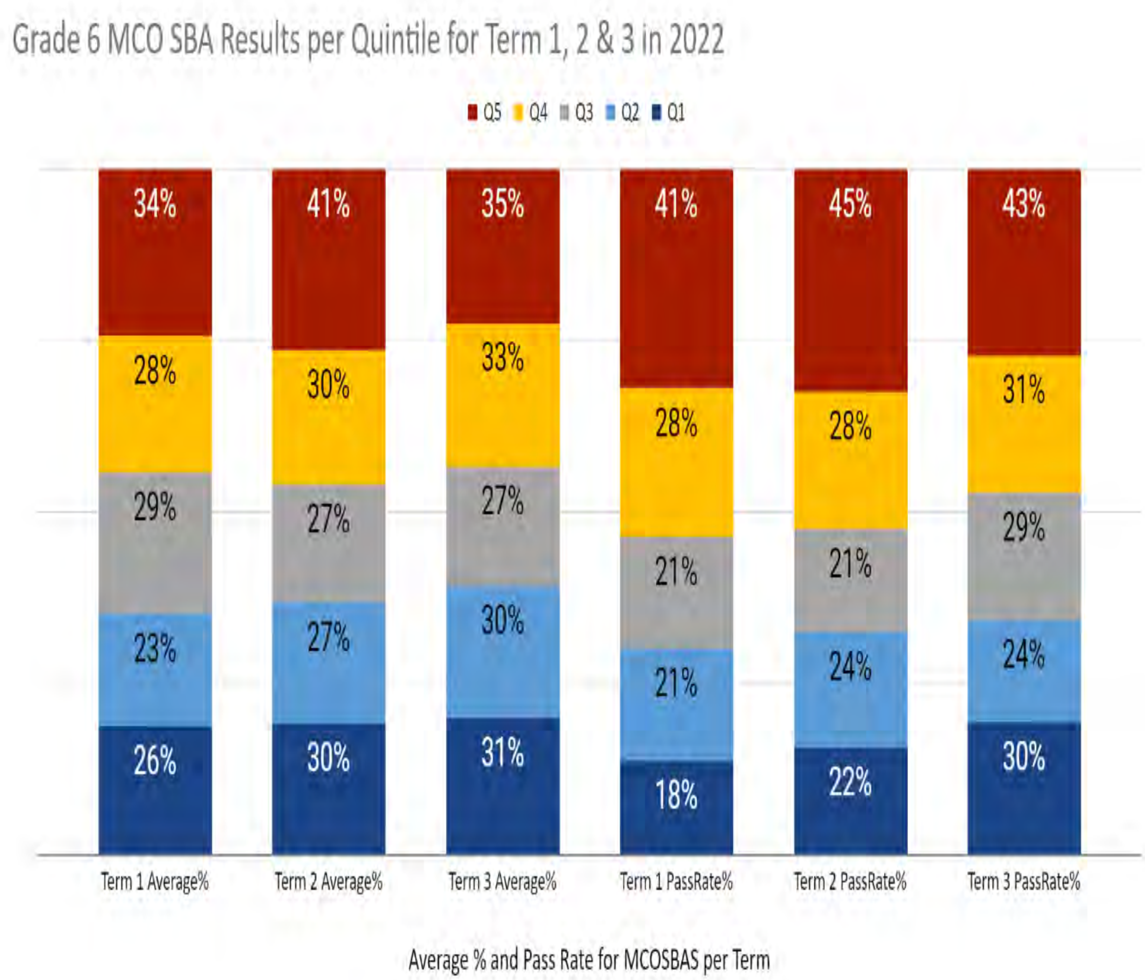

Figure 4: Grade 6 Learners' MCOSBA results: Average Achievement and %Pass Rate per Quintile

Apart from noting gain in learners' achievement, learners and teachers also noted gains in other areas. 93% of teachers noticed an improvement in learners' concentration when using MCO compared to their concentration in the classroom. 86% of teachers note an improvement in learners' Maths literacy and 34% of learners report that they feel more at ease with the language of Mathematics and think it is easier for them to explain their thinking to the class. A teacher explains:

> "*Learners have picked up more mathematical vocabulary whilst using MCO, therefore I can use a bigger variety of mathematical vocabulary during lessons.*"

Another teacher states:

> "*Learners now likes reasoning and ask questions more openly*."

In South Africa with its 11 official languages, learners' increased ability to explain their thinking and ask questions using the academic language of Mathematics is a particularly important learning gain.

Other cognitive-coded themes were identified from learners' and teachers' open questions. 42 learners shared that they liked MCO because they received immediate feedback and could see what they did wrong, which allowed them to revise their work. 206 learners liked working with the MCO since it helped them to improve in Maths and increase their understanding. Teachers and the Green Shoots team noted that the MCO exposed learners to content, question styles, levels and formats that differ from those used in school, with a teacher stating:

> "*The cognitive levels in the programme helps to expose learners to different levels*."

The resulting cognitive learning gains for learners noted in the study: learners' achievement (grades), increased concentration, Mathematics literacy and vocabulary.

Learning gains for Parents

Data from the teacher surveys and GS documents was analysed to understand the potential learning gains for parents or caregivers (referred to as 'parents').

Affective learning gains for parents include feelings of empowerment to support their children and follow or understand their children's successes with MCO. Teachers reported that parents commented on the children's improvement, noting how "*practice makes progress*" and liking that they can support their child's journey. It appears that parents' beliefs have also changed since teachers variously noted comments from parents that it was not just the 'clever kids' who can make progress, but that their children could also improve.

The resulting affective learning gains for parents in the study**:** feeling empowered, able to understand children's progress, can support children, positive beliefs.

Teachers noted parents' changing behaviour when their children started using MCO. Just over half of teachers said parents asked them questions about MCO and how they could support their children at home to use MCO. A further 44% noted that parents provided positive feedback about their children's use of MCO but complained about high-cost data. One teacher explains:

> "*Most of parents are complaining about data, they are unemployed*."

Despite this, the GS team noted an increase in the number of parents who request access to MCO to follow their children's progress. They also worked out that one BQ requires approximately 7c of data. A campaign sharing the low-cost access of MCO is underway to inform parents.

The resulting behavioural learning gains for parents in the study**:** greater engagement by parents with educators; more parents access MCO.

Parents also gained cognitively from engaging with MCO. As more parents requested logins to access their children's results, they learned to use hardware and software, specifically how to use the Green Shoots software. A GS team member notes of this:

> "*Parents gain knowledge on the MCO program and broaden their knowledge. Learn to search the website. Improve their maths knowledge as well*."

The adult literacy and numeracy rates in South Africa are very low, and while the Western Cape has a higher literacy rate, parents across the province are not uniformly able to understand the MCO results. The GS team colour-coded learners' results using a robot system: red for failing results, orange for concerning results, and green for excellent results. This was done to make it easier for parents to quickly understand their children's progress. It is encouraging to see that more parents across the province are asking for login access and that teachers and the GS team indicate that parents are using this to follow their children's progress, a fact corroborated by the 33% of learners who report that they share their results with family at home.

***The resulting cognitive learning gains for parents in the study*:** knowledge to use MCO; able to understand learners' progress; able to use MCO software and get resources from the website

Learning gains for Teachers

286 teachers completed the teacher survey in August 2021 and 2022. Results from this survey as well as the GS documents were analysed.

Teachers' affective learning gains relate to feelings of confidence, less anxiety, and greater enthusiasm and interest. 96% of teachers felt more confident when teaching with MCO, with a teacher stating:

> "*I can use different approaches and am more confident in front of my learners*", and another "*I feel confident in teaching certain methods that I was unsure of. I know exactly what my learners need to improve in*."

Some teachers experienced anxiety for different reasons, which was lowered after using MCO:

> "*I'm not afraid of technology anymore*" and "*Not being fearful of making mistakes and learn from* [MCO]."

93% of teachers also reported feeling more enthusiastic and interested in Maths, as one teacher notes:

> "*I'm enthusiastic because of learners change towards Maths since using MCO*."

The GS team noted similar changes in teachers, noting the increased confidence to teach with technology, and teachers' increased enthusiasm. They add that teachers get particularly excited about MCO when they discover the abundance of resources to support them and lighten their workload.

***The resulting affective learning gains for teachers in the study*:** increased confidence, enthusiasm and interest, lower anxiety.

Teachers noted far more behavioural gains after they started using MCO than affective or cognitive gains. The analysis of teachers' responses and the GS documents indicate that these learning gains refer variously to teaching methods; using GS Insights; differentiation; and whole school impact.

Most teachers (92%) participating in the survey felt that they used more teaching strategies and methods to teach Maths after starting to use MCO. One teacher explains:

> "[MCO] *made me realize that I should use variety of teaching methods*" and another adds: "*I now have different ways of teaching different concepts*."

Many add that through their engagement with MCO, they developed

> "… *more ways and different ways to ask and answer questions*" [about Maths].

Teachers also appreciated the additional resources provided through the MCO programme, as one teacher states:

> "*MCO eliminated a lot of admin and allowed me to focus more on teaching and analysing results*."

One teacher's comment sums this learning gain up well:

> "*I noticed that I use more interesting methods to teach, I use more concrete objects to demonstrate lessons, I set up my assessments with better structure and I use a wider variety of type of questions*."

Teachers' growing access and analysis of learners' MCO data emerged as a repeated theme, both as individuals and as part of the wider school community. Survey results were compared to the GS Insights usage data and GS documentation. The number of registered teachers increased to 7270 by the end of Term 3, 2022; and in this period, the number of teachers accessing the MCO increased from 624 logins in Term 1 to 1407 logins at the end of Term 3, representing a 55.7% increase. Typically, teachers who access MCO do so to review the questions their learners will get or to decide on the topics they want learners to cover in parallel with the work done in the class. It is concerning though that only 1407 of the registered 7270 teachers access MCO. It suggests that only a few teachers (19%) may be strategically using the MCO topics in pace with their curriculum coverage. Alternatively, the remaining 81% may be using MCO less strategically. This topic needs to be probed in great depth as the project unfolds.

Compared to the number of teachers registered on MCO, only 381 of the 500 schools were registered on GS Insights by the end of Term 3, 2022. Schools accessed insights more frequently though, with 2707 logins in Term 1, 2002 (average: 8.7 logins/school); to 5340 logins by the end of Term 3 (average: 14 logins/school). This represents a 49.3% increase, indicating that more school leaders and teachers were using Insights each term. The survey data revealed that 93% of teachers used insights to review learners' scores to identify which learners were struggling the most, and a further 91% reviewed scores to see where learners needed support. Teachers shared what they considered was the biggest change for them since they joined the MCO programme, and for many, accessing the data and using the insights from this, was the highlight. Teachers variously stated:

> "*…I appreciate the insights as it gives a clear understanding in which areas learners are struggling*."

> "*I am able to critically and analytically interpret data.*"
> [The biggest change I noticed was] "*Incorporating ICT into the lesson, getting immediate feedback on learners' performance so that I can see where they need improvement and then do intervention in the areas in need*."

South African teachers, like colleagues around the world, tend to operate in silos. Many teachers prefer to work on their own, and do not habitually collaborate across grades and phases to improve learning in the school. Data from the survey however suggested that such practices may be changing. An overview of the results is shown in Table 2 below.

Table 2: *School-wide Use of GS Insights Findings*

	I share findings with my grade colleagues		I share findings with my school leaders		We discuss findings in each grade group		We discuss findings in our phase group		We use results to plan Maths across the grade		We use results to plan Maths across the phase		We identify top, middle, and bottom learners in the grade to plan interventions or support	
Regularly	171	60%	134	47%	115	41%	92	33.3%	101	36%	96	35.0%	109	40%
Occasionally	75	26%	103	36%	110	40%	105	38.0%	100	36%	87	31.8%	90	33%
Never	18	6%	19	7%	30	11%	51	18.5%	46	17%	56	20.4%	43	16%
No comment	20	7%	27	10%	23	8%	28	10.1%	30	11%	35	12.8%	29	11%

The results in Table 2 indicate that while 60% of teachers regularly share their MCO results with colleagues in their grade, 26% only occasionally, and 6% never do this. A further 47% regularly share their findings with a school leader and 41% discuss it with their grade group, while 36% only occasionally share findings and 40% occasionally discuss it with the grade group. Grade groups tend to use the MCO results and GS Insights more regularly, but a small percentage (36%) use it to plan Maths across the grade. Similarly, only a small group of teachers discuss findings (33%) or plan Maths across the phase (35%). The data indicates that while more teachers regularly discuss their learners' MCO results with colleagues in their grade group, far fewer do so regularly and in formalised contexts. Instead, in more than 70% of schools there does not appear to be formal planning processes in place to review MCO results and findings from GS Insights, and to use these to make data-informed decisions about learning in the school. This area can be probed further through focus-group discussions and observations.

Lastly, differentiation was noted by teachers as a behavioural learning gain. 40% of teachers regularly and 32% occasionally use Insights to identify top, middle, and bottom learners in each grade and then use this to plan support for the bottom learners. Added to this, 70.3% of teachers use the Insights data to identify where learners need extra support and a further 20% occasionally do this. This data shows that teachers are analysing the MCO data (regularly or occasionally) to identify learner needs and to plan how to differentiate their teaching in response; in other words, they are making data-informed decisions. When asked what the biggest change was, many of these teachers indicated that it was their ability to differentiate their teaching after they started participating in the MCO project, saying variously:

> "*MCO help me to see where my learners are struggling so I can give it more time on that concept*"

> "*MCO has made differentiation easier.*"

> "*I get to focus on more challenging areas and this helped learners to improve holistically in all mathematical areas.*"

> "*Gone are the days when you only teach for the average learner. You are able to give support to weaker learners and challenge the bright ones. The levels of difficulty presented by the brain quests make this possible*."

Teachers' ability to differentiate their teaching is an important learning gain, and while it is placed under behavioural learning gains, it also relates to cognitive learning gains, as will be discussed in the next section.

***The resulting behavioural learning gains for teachers in the study*:** flexibility and skill at using different teaching methods, skill at analysing and interpreting data, school-wide analysis and application of data-informed decisions, and the skill to differentiate learning.

Cognitive learning gains were identified from the teacher survey and the various GS team documents. The themes that emerged for cognitive learning gains relate to teachers' increased knowledge about Maths teaching and Maths in general, knowledge about assessment, and their knowledge of differentiation.

Teachers reported that their knowledge related to Maths education increased. 95% noticed an improvement in their subject or content knowledge, with one teacher noting:

> "*I myself understand Maths more*"

and another stating:

> "*My maths vocab has also improved*."

Teachers also noticed a change in their teaching style, their use of a variety of methods and strategies for teaching concepts, and their flexibility to adapt their teaching techniques in response to learners' thinking. A few pertinent responses are noted below:

> "*I have learned a range of teaching math skills and also have varied techniques in questioning (use of mathematical terms). It also allows me to learn from my learners and how they understand concepts and how they got to an answer without my assistance and then work my teaching techniques around their understanding. I can also see where there is misunderstanding of concepts and plan around those areas and not just move on to the next concept.*"

> "*My teaching style changed tremendously and the application of practical demonstration in daily lessons improved the response from and involvement in the lessons*."

> "*I noticed that I use more interesting methods to teach, I use more concrete objects to demonstrate lessons, I set up my assessments with better structure and I use a wider variety of type of questions*."

Pedagogical and content knowledge are key characteristics of a teacher's knowledge base (Shulman, 1987). Content knowledge relates to teachers' ability to understand Maths, while pedagogical knowledge relates to their ability to teach the various aspects of the subject at differentiated levels. Researchers (Venkat & Spaull, 2007; Spaull, 2013; van der Berg *et al.*, 2016) have repeatedly noted South African teachers' limited mathematical pedagogical and content knowledge. Increases at scale to teachers' pedagogical and content knowledge such as those linked to the MCO project, is therefore of particular importance.

Teachers' knowledge of assessment also increased. Many teachers reported that they started using a wider variety of questions, stating for instance:

> "[I'm] *using different cognitive level of questioning and providing open ended questions*."

Teachers also noticed that their awareness of the need to ask differentiated questions using a variety of mathematical phrasings and terms increased. Also, their knowledge of how to set tests and exam papers increased.

> "*I'm more aware of how certain concepts can be tested…* [MOC] *helped me to see where I am going wrong with regards to drawing up question papers, something that I struggle with*."

Historically, school-based assessments have been problematic in South African education contexts. Many teachers found it difficult to set questions at different cognitive levels, and their limited pedagogical knowledge meant that they did not know which learning areas should be tested or how this should be done. As the last teachers' comment above indicates, teachers' engagement with MCO developed their knowledge of and skills to set differentiated question papers, an important learning gain in South African education contexts.

Teachers' knowledge of differentiation and their ability to use data to support their efforts to differentiate also increased. One teacher's notes in this regard:

> "*Gone are the days when you only teach for the average learner. You are able to give support to weaker learners and challenge the bright ones. The levels of difficulty presented by the brain quests make this possible*."

The biggest change many teachers noticed was in their own ability to analyse data from the MCO activities to respond to learners' different needs more quickly. One teacher emphasizes the short time between first noticing an area where learners struggle to quickly intervene, adding:

> "*This reduces my learners' chance to 'sit' with misconceptions for long*."

Teachers, therefore, gained among others, knowledge about differentiation and why it is important to differentiate questions and use different question types. Teachers also learned to access the data from the MCO activities, to analyse the data from these activities, and use their findings to make data-informed decisions that can improve learning.

***The resulting cognitive learning gains for teachers in the study*:** pedagogical and content knowledge, assessment knowledge, and differentiation knowledge; data analysis and data-informed decision-making.

CONCLUSION

The current study sought to understand the impact of the Maths Curriculum Online (MCO) project in Western Cape primary schools on learners, parents/caregivers, and teachers in terms of their affective, behavioural, and cognitive learning gains. This large-scale MCO project is currently implemented in more than 500 primary schools across the province and beyond, involving 7270 teachers, 192 076 active learners and their parents/caregivers, and many other stakeholders. The current study only reports on the learning gains for these three parties.

The research addressed different gaps in literature in terms of diverse contexts, understanding learning gain in the broader context, and in terms of affective, behavioural, and cognitive learning gain. While various studies explored the relationship between digital technologies and mathematics education often using small-scale samples, this study examined the impact of MCO on broader mathematical outcomes at scale. This project is situated in diverse contexts, including 39% rural and 61% urban schools, 11% Q1, 17% Q2, 15% Q3, 30% Q4 and 26% Q5 schools. The large sample size across diverse education contexts suggests that findings may be generalizable.

Instead of seeing the MCO as an intervention in and of itself, the insights from Means (2010) shaped the research question to frame the MCO as being part of a broader instructional activity system.

An Education Design Research approach shaped the methodology, intentionally designing the study to develop warranted theory that would benefit stakeholders beyond the research community, including policymakers, officials at the WCED, school and district leaders, teachers, and parents/caregivers. Instead of studying learning gain in terms of student achievement, the study used ABC lens by Rogaten *et al.,* (2018) to understand affective, behavioural and cognitive learning gain for teachers, learners and their parents/caregivers. Data were produced from teacher and learner surveys, project documents, the MCO usage data, and Grade 6 learners' term 1 – 3, 2022 MCOSBA results. This data was qualitatively and quantitatively analysed to identify learning gains.

The ABC learning gains analytical lens allowed for a more nuanced understanding, which went beyond surface appearances and academic results, to understand how learners, their parents, and teachers developed through their involvement in the project. The study identified learning gains for teachers, learners, and their parents/caregivers who participated in the MCO project. A summary of this is included in Table 3 below.

The learning gains identified from this study indicate that the impact of the MCO project was both complex and multi-dimensional. Findings reported here show how large-scale projects such as the MCO project, can benefit different stakeholders from diverse education contexts if the project is not framed as a stand-alone technology implementation, but as a part of a growing, evolving ecosystem.

More work is required to understand some gaps revealed by the research. Teachers' use of the MCO programme and how they can use this to plan, pace, and deliver the curriculum is a focus for the next stage of the project. As is the use of GS Insight data within schools to understand how such organisations can make data-informed decisions a part of their culture and habits. In the future, learners' MCOSBA data can also be compared to systemic Grade 6 results that are typically published in March (2023), to further interrogate the data and strengthen generalizable findings.

Findings from this study confirm that the MCO project impacted individuals and then multiplied to benefit different system levels. Learners gained from Mathematical knowledge, practices, and cognitive and metacognitive skills. Their parents gained a greater sense of empowerment and ability to understand their children's progress and provide support. Teachers gained greater confidence, lowered anxiety levels, and shared more enjoyment and enthusiasm; their foundational knowledge in Maths increased, teaching strategies, specifically differential methods to use; and how to make data-informed decisions and how to use data to differentiate their teaching. Such individual learning gains multiply within school ecosystems to benefit and further build the culture of teaching and learning. Teachers for instance who want to use the computers for MCO, need to stick to a timetable, necessitating the development and use of a timetable in the school. Similarly, the greater collaboration between colleagues to discuss data from GS Insights creates habits and skills that may impact other subjects within the school. Parents learning to understand one child's progress and how to support them, creates opportunities for siblings to receive similar support. Learners' gaining metacognitive skills to set goals and monitor their progress in Maths, opens opportunities for such skills to impact other subject areas as well. Hence, individual learning gain is multiplied to increase learning gain in the system. The next study looks at how this learning gain is experienced by non-teaching educators at district offices and beyond, to create a means to quantify the increased learning gain in the system. Hope for improved Maths education is being realized in the WCED MCO project.

Table 3*:Summary of Learning Gains for Teachers, Learners and their Parents / Caregivers who participated in the MCO project*

	Affective Learning Gains	Behavioural Learning Gains	Cognitive Learning Gains
	Change in affect for example confidence, motivation, or attitudes	Development of skills rather than knowledge, including for instance engagement and collaboration	Improvement or development in knowledge, understanding or cognitive or metacognitive abilities
Learners	Positive Maths perception Improved confidence enough to help / teach a friend, write a test or try new concepts / questions Greater ownership	Greater engagement and attempting more sums on MCO (compared to class) More engagement in collaborative learning, peer support & healthy competition Self-regulated behaviours: • Goal-directed behaviour • Check progress • Motivated and positive self-efficacy beliefs	Higher grades for MCOSBAs with lower quintile schools experiencing a higher improvement from Term 1 – 3, 2022 Increased concentration Greater Maths literacy and use of Maths vocabulary
Parents / Caregivers	Feeling empowered Able to understand learners' progress Able to support their children More positive belief about Maths	Greater engagement with teachers More parents access MCO	How to use MCO Understand learners' progress Can use MCO and get results from the website
Teachers	Increased confidence Lowered anxiety about Maths teaching / teaching generally Greater enthusiasm, interest, and enjoyment for teaching Maths	Greater variety of teaching methods used Higher use of GS Insights & MCO activity data to understand / analyse learners' data Greater school-wide use of Insights to make data-informed decisions (though not habitual use) Greater differentiation in the class through use of MCO	Increased pedagogical and content knowledge Increased knowledge of assessment, cognitive levels, and question types, and how to use these to support differentiation Increased understanding of differentiation and how to differentiate using data = data-informed decisions

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