Integrated Maths Project Monitoring & Evaluation Report 2016-2018

Dr Isabel Tarling

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Abbreviations

ANA	Annual National Assessments
GSCRP	Green Shoots Comic Relief Project
IMP	Integrated Maths Programme
MCO	Maths Curriculum Online
MCO SBA	Maths Curriculum Online School Based Assessment
MEL	Monitoring and Evaluation of Learning
PLC	Professional Learning Community
TTA	Technology Teaching Assistant
WCED	Western Cape Education Department

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1. Executive Summary

Comic Relief, an UK based charity, partnered with Green Shoots Education Services, a South African NPC, to provide a Maths Curriculum Online (MCO) to 32 schools in the Northern and Western Cape provinces as part of an Integrated Maths Programme (IMP). Four outcomes were identified to achieve in the three-year lifespan of the project. The IMP firstly needed to contribute to the quality of Maths teaching, developing teachers' pedagogical content knowledge and capacities to use data to improve teaching and learning strategies. Secondly, the project aimed to improve learners' attitude and engagement in Maths, and their ability to set goals and work towards achieving these in the subject. Thirdly, the IMP aimed to raise learners' Maths attainment in terms of the number of learners passing Maths in all grades. Lastly, the IMP wanted to impact the culture[1] in schools and the education department, to make data informed decisions that impact teaching and learning practices at school and district levels. Green Shoots commissioned a three-year monitoring and evaluation study to monitor and evaluate to what extent they achieved these outcomes.

The monitoring and evaluation of the Green Shoots Comic Relief project was conducted between 2016-2018 by Dr Isabel Tarling and Associate Prof Dick Ng'ambi. Data was collected through structured surveys and semi-structured interviews with district officials, principals and focus groups of teachers and learners. Quantitative and qualitative data produced through the surveys and interviews were analysed and reported in two interim reports (2016 and 2017) compiled by both researchers, and this project report compiled by Dr Isabel Tarling.

The analysis of data provides irrefutable evidence that each one of the four outcomes set for the project were met beyond expectation. Data from surveys and interviews with teachers and triangulated with data from principals and district officials, provides evidence that the IMP increased the quality of Maths teaching and learning in schools. Teachers learnt how to interpret the data produced by learners using MCO to identify gaps in learning in whole classes or individuals, to identify where learners are struggling, and through the

[1] Culture in this sense refers to the conceptual world in which education takes place, i.e. the practices, perceptions, thoughts and beliefs, systems and structures in a school that form the complex texture of the everyday life experiences in which teaching and learning occurs.

PLCs, to develop strategies to address these areas. The data also indicates that teachers developed greater confidence in their conceptual understanding and pedagogical knowledge, increasing their pedagogical content knowledge and interest in Maths through their participation in the project.

The data analysis further indicates that learners developed greater agency the longer they participated in MCO and were exposed through repeat use, to the immediate feedback from the system. District officials indicated that learners' attainment in Maths increased by up to 15% during 2017-2018 and attributed this to MCO use. Learners attitude towards the subject and confidence in their Maths abilities also increased during this period. Using state-of-the-art knowledge from the field of learning science, a direct correlation was established between learners' ability to judge their learning and their actual performance, a measure expressed as the degree of calibration. In the initial surveys learners had been exposed to MCO for a few months and appear to be overconfident in their abilities, while their actual performance lagged significantly behind this. In the second year, learners attained higher marks, but the data indicates they were far less confident, suggesting that they were underconfident when judging their learning. As they continued to participate in MCO, in the third year, their judgement of learning and actual performance indicates a far greater degree of calibration. This finding signifies an exciting and previously unexplored contribution to knowledge, showing that through their repeat-exposure to MCO learners were able to improve their degree of calibration and ability to learn. Increasing learners' calibration and ability to learn, is rarely reported in literature and represents a significant contribution to new knowledge in the learning sciences.

The data analysis also provided irrefutable evidence that the IMP achieved change by contributing to the development of a culture of teaching and learning. Green Shoots as an organisation espouses what Avgerou (2010) describes as a socially embedded approach to educational change. Rather than seeing innovation as a generic, application neutral and universally transferrable set of skills, applications or behaviours, a socially embedded approach embeds innovation in local contexts. MCO is thus framed as a technological tool that requires local actors and organisations to make sense of and accommodate it in their daily lives (Avgerou, 2010). Innovation was achieved within local contexts schools and

districts developed different techno-organisational processes, structures and systems as they problematized local challenges and developed solutions to these.

Many of the challenges so prevalent in the resource-constrained under-performing schools across South Africa, were positively impacted by the IMP. The funding provided in partnership between Green Shoots and Comic Relief allowed the IMP to overcome many of the resource-related challenges that prevent many schools from fully utilising technology solutions. Old, outdated computer systems were revamped and maintained for the course of the project while unused tablets were utilised alongside desktops still running on Windows XP. Before the IMP, some of the schools also lacked schedules and timetables to regulate teaching and learning activities. As a consequence of problematizing challenges and identifying needs within local contexts, local actors were equipped to create timetabled use for MCO which in turn impacted the regulated scheduling of other learning events in the school. High absenteeism was also significantly impacted with schools noting up to 100% attendance among learners on days when they had time in the lab for MCO.

Spaull (2013) found that learning challenges typically originate between Grades R-6, and compound to become insurmountable barriers to learning essentially precluding children from learning in higher grades. The IMP is situated in these critical years, working with Grades 3 – 7 learners. Schools as organisations developed techno-organisational structures, processes and systems, becoming in many instances functioning institutions. Learners developed greater agency and calibrated their judgement of learning and actual performance. Teachers gained deep insights and developed conceptual understandings to increase their pedagogical content knowledge, increasing the quality of teaching in the project schools. District officials and principals were capacitated to monitor curriculum delivery and develop targeted strategies to improve this. The data thus indicates that the greatest contribution of this project has been to establish a sustained culture of teaching and learning in schools where this was often lacking before the introduction of the IMP. Since 1994, various largescale systemic initiatives have repeatedly aimed to achieve this, and largely failed as different educational researchers found. In contrast, this team of dedicated, passionate individuals inspired under-performing schools and achieved far beyond what they set out to do. This project should be used as an exemplar for all similar future projects.

2. Project Introduction

Comic Relief, a British charity organisation, in partnership with Green Shoots Education Services NPC, provided funds to provide an Integrated Maths Programme (IMP) to various schools in the Western and Northern Cape of South Africa from 2016 to 2018. The IMP uses Maths Curriculum Online (MCO), a technology assisted learning tool that strives to improve the quality of Maths teaching and learning to Grades 3 – 7 learners. A total of 32 schools, 24 in the Western Cape and 8 in the Northern Cape, received the IMP from 2016 onwards. Learners in Grades 4, 5 and 6 were primarily targeted, however in 22 of the schools (not always the same schools) Grade 3 and 7 learners also benefited from the IMP. In most instances, learners spent either 1 or 2 hours per week on MCO as part of their regular Maths periods.

The IMP had four main objectives. Firstly, IMP wanted to contribute to the quality of Maths teaching, developing teachers' pedagogical content knowledge and capacities to use data to improve teaching and learning strategies. Secondly, the project aimed to improve learners' attitude and engagement in Maths, and their ability to set goals and work towards achieving these in the subject. A third objective of IMP was to raise learners' Maths attainment in terms of the number of learners passing Maths in all grades. Lastly, IMP wanted to impact the culture in schools and the education department, to make data informed decisions that impact teaching and learning practices at school and district levels.

MCO is used in different ways in schools. MCO content is directly aligned to the South African Curriculum and Assessment Policy Statement (CAPS), both in terms of content and pacing requirements. Therefore, of the 5 (on average) Maths lessons in a typical school week, teachers would commonly teach 3 lessons in the general Maths classroom, and 2 lessons in the computer lab. Due to timetable constraints, this is not always possible though, and a minimum of 1 lesson is taught in the computer lab on MCO.

Throughout the term, learners complete various MCO activities. Brain Quests provide practice and ongoing support for achieving learning goals stipulated by CAPS and are completed weekly. Generally, in Weeks 5 and 8 of a term, a standardised summative assessment task is completed on MCO as a School Based Assessment (MCO SBA). Results

from both the Brain Quests and MCO SBAs are immediately available to learners, teachers, principals and district officials. These results can be used to track individual learners per class and per grade, whole phases and schools' progress and usage of MCO.

Overall, the intent of IMP is to impact the manner in which data is used to shape Maths learning in schools and districts. While the number of learners who individually benefit from repeated exposure to MCO is increasing steadily, this is only one aspect of the project. The greater goals for IMP is to generate data that teachers, principals and district officials can use to make data-informed decisions that impact Maths teaching and learning in classrooms, grades, phases and schools, and ultimately whole districts. Data is generated each time learners complete a Brain Quest (BQ) or a standardized MCO SBA, and instantly available to inform teachers of areas where learners need further support or where they can be extended. This data is also available to subject teams and school leaders to measure Maths achievement on a weekly basis. The same data is available to district managers who can identify patterns in Maths achievement across schools and develop targeted strategies and interventions to develop teachers' pedagogical content knowledge during professional development sessions. Since all learners write the same MCO SBA or complete the same BQ questions, the results are standardized and to a large degree reliable, providing a valid and trustworthy measure of real-time Maths performance in the various schools and classrooms across a district.

3. Monitoring and Evaluation

Dr Isabel Tarling and Associate Prof Dick Ng'ambi were commissioned to monitor and evaluate the implementation and outcomes of the IMP between 2016 - 2018. Dr Isabel Tarling is an independent researcher, and A/Prof Dick Ng'ambi lectures at the University of Cape Town. Both researchers have extensive experience in the field of education and educational technologies research. The current report was prepared by Dr Isabel Tarling.

The monitoring & evaluation team were responsible for reviewing and monitoring progress towards meeting the programme objectives. Various established internal MCO monitoring processes provide an up-to-the-minute overview of MCO usage and learners' achievement. This includes a dashboard that all role players can use to access data, presented in an easy

to understand and accessible visual display to increase accessibility and interpretation of data. Visuals from the dashboard can be decomposed to mine down to individual learners' progress on any given day or topic, for a short period or an entire year. The established internal MCO processes however only provide a particular, often quantitative view of the programme's usage, and the impact of MCO across classes, grades and schools. The monitoring and evaluation team were responsible for establishing the extent to which the project's outcomes impacted change to learners, teachers and schools, as well as district practices, analysing and drawing insights from both quantitative and qualitative data.

Green Shoots commissioned the monitoring and evaluation of the IMP to answer three key research questions.

1) What contextual factors impact the effectiveness with which the Green Shoots model is implemented, and/or which IMP elements are essential to the sustainability and successful integration of the programme when scaled?

2) Suggest an effective means to measure learners' progress and produce reliable and detailed evidence to communicate with key stake holders and decision makers.

3) What processes regarding data informed decision-making support change to district and school practices?

Four outcomes were identified for the IMP to answer these research questions:

- **Outcome 1)** Contribute to the quality of Maths teaching.
- **Outcome 2)** Improve learners' attitude to and engagement in Maths.
- **Outcome 3)** Raise learners' attainment in Maths.
- **Outcome 4)** Impact education department practices regarding ICT Integration and data informed decision-making.

The monitoring and evaluation (M&E) process included five phases. Phase 1 involved the review of the Green Shoots records and documentation up until September 2016. This review was conducted during 2016 and employed Activity Theory system analysis. Phase 2

of the M&E process involved the iterative design and development of various questionnaires and interview schedules for learners, teachers, principals and district officials. These instruments addressed the second key question. The third phase of the M&E process involved the management of data processing and analysis, and preparation of written interim reports in December 2016, 2017 and 2018. During 2017 and 2018, phase 4 involved the evaluation and refinement of existing instruments and indicators to refine learner, teacher, principal and district official questionnaires. The final phase of the M&E process involves the overall, longitudinal evaluation of the 2016-2018 data in terms of the project's outcomes and to answer the three research questions.

4. Methodology

A Utility-Focused Evaluation framework was employed to frame the monitoring and evaluation (M&E) process. Utility-focused evaluation works to enhance the utility, feasibility, propriety and accuracy (Patton, 2010) of an evaluation for the intended user, in this case, Green Shoots Education. Utility refers to the relevance and use of the evaluation outcomes to the intended user(s); feasibility to how realistic, prudent, diplomatic and frugal the evaluation proceeded; while the ethical, legal and respectful nature of the evaluation is captured in its proprietary nature; lastly the evaluation needs to be technically accurate. The utility-focused evaluation framework intentionally frames questions, work plans and reviews to address users' needs and requirements, to impact practice in direct and immediate ways. Consequently, the utilisation-focused evaluation process is not static but shaped by the changing needs of the users and open to potential adaptations to evaluation questions, instruments and outcomes throughout the course of the project.

Data was collected to answer the research questions and measure the extent to which the four project outcomes were realized during the project's lifespan. Two research tools, self-completed anonymised online surveys and semi-structured interview schedules were developed. During September - October 2016, 2017 and 2018, learners, teachers, principals and district officials completed the online surveys. Focus groups of these role players participated in the semi-structured interviews during October – November of each year. Interviews were conducted at participants' schools or offices, and recorded when

appropriate written permission was obtained for this. Since participants were assured of the confidentiality of their responses, recordings from the interviews are not made available.

The data collection instruments were used at different points in the project. A summary of how data was collected in relation to the project outcomes, is provided in Table 1. The content of Table 1 indicates the four IMP outcomes, corresponding indicators for each outcome and the data collection instrument/s used.

Table 1 IMP outcomes, indicators and corresponding data collection instruments

IMP OUTCOME	Indicators	Data collection instruments
1: Contribute to the quality of Maths teaching	Teachers draw on a larger range of pedagogic methods used to teach Maths after the implementation of IMP.	Focus group interviews, anonymous online surveys for all participating teachers, principal interviews and anonymous online survey.
	Teachers have improved how they use data to inform Maths teaching and learning.	Focus group interviews, anonymous online surveys for all participating teachers, principal interviews and anonymous online survey.
	Teachers' interest in teaching Maths improved.	Focus group interviews, anonymous online surveys for all participating teachers, learner anonymous online surveys, principal interviews and anonymous online survey.
2: Improve learners' attitude to and engagement in Maths	Students display increased concentration and confidence in Maths.	Reported by learners, teachers & principals in anonymous online surveys & interviews.
	Engagement: aware of current scores, progressing towards goals.	Reported by learners, teachers & principals in anonymous online surveys & interviews.
3: Raise learners' attainment in Maths	What is biggest factor(s) contributing to improved attainment of learners?	Reported by learners, teachers & principals in anonymous online surveys & interviews.
4: Impact Education Department practice regarding ICT Integration and data informed decision-making	Increased collaboration between Maths teachers at a school using MCO data	Focus group interviews, anonymous online surveys for all participating teachers, principal interviews and anonymous online survey.
	Principals & Education Department / District officials use MCO data analysis to feedback to staff/schools	Focus group interviews, anonymous online survey for all participating principals & teachers, interviews with Education Department / district officials & anonymous online surveys.

Participants were given the option to respond in either English or Afrikaans, the languages most commonly spoken in both provinces, for both surveys and interviews. Data collected from the various instruments was stored electronically in a secure, shared cloud folder and backed-up to an offline hard drive. Access to cloud-based data was monitored and controlled to ensure confidentiality and integrity of the data set.

Participants

The IMP was introduced early in 2016 to 32 schools. It was estimated that the project would reach 16 085 learners, 193 teachers and 62 principals and/or Maths subject heads. An additional six youth development posts were created to support the implementation of the project as technical teacher assistants (TTAs).

The targets at the end of the three-year project far exceeded these estimates. At the conclusion of the project, the total number of learners impacted by the IMP had increased by 43%, from 16 085 to 23 098. Factoring in naturally occuring movement from teachers between schools and provinces, at least 237 teachers benefited from their engagement with the IMP by the end of 2018 compared to only 197 in 2016. The TTAs at the different schools also showed some fluctation, with some leaving the project to further their carreers. One TTA who had joined the team in 2016, was appointed to a prominent South African investment bank, which she indicated was partly due to her experience working with the Green Shoots online system. Another TTA was trained in her place and successfully runs the programme. The growth between the target and actual implemented figures exemplifies the ongoing and sustained reach of the IMP over the three year period. Since the Green Shoots team indicated MCO will remain available to schools after the project is concluded, it is hoped that this growth will be continued in future.

The number of learners, teachers, principals and district officials participating in the monitoring and evaluation of the IMP varied between 2016 – 2018. A total of 15 920 learners participated, 6305 in 2016, 4884 in 2017 and 4731 in 2018. The greater majority of learners participating were in Grades 4, 5 and 6, with fewer Grades 3 and 7 learners participating each year. The project plan targeted learners in Grades 4 – 6 in all schools, while in some schools Grades 3s and 7s were also added, explaining the uneven

participation of learners in the surveys. The participation across grades and years is visually represented in *Figure 1*.

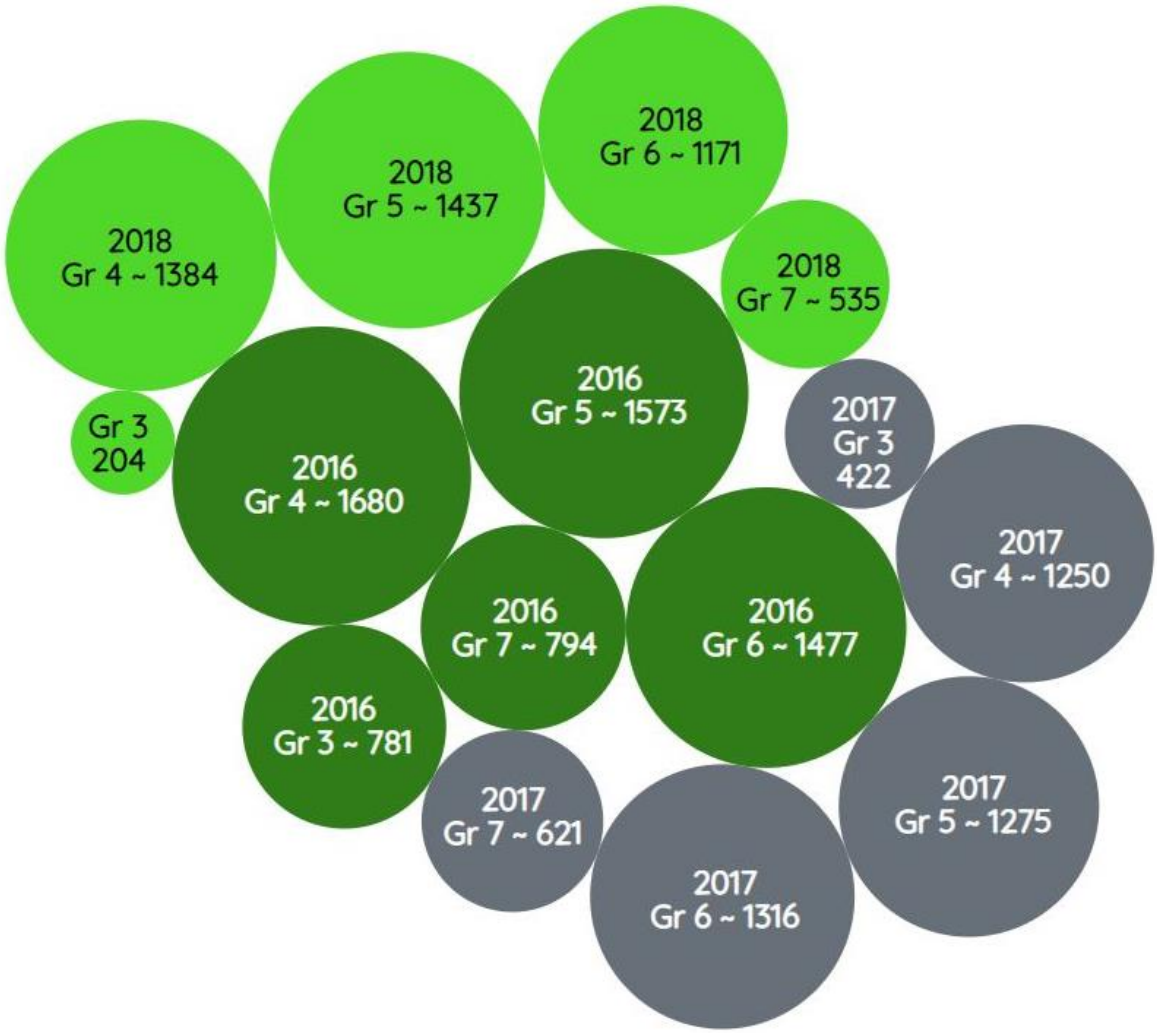


Figure 1 Number of learners between 2016-2018 participating in the study

The number of teachers participating in the online surveys and interviews between 2016 – 2018 also fluctuated. A total of 295 teachers completed the online surveys while a further 36 teachers were interviewed in the three years. As illustrated in *Figure 2*, 137 teachers completed the online survey in 2016, 42 in 2017 and 116 in 2018. Twenty teachers were interviewed in 2017, and only 15 in 2016. In addition, 66 principals completed the surveys and 29 were interviewed. A further 12 district officals completed the surveys and 6 were interviewed. In total, this monitoring and evaluation report constitutes insights drawn from 16 402 participants documented in 16 275 surveys and 127 interviews between 2016 and 2018.

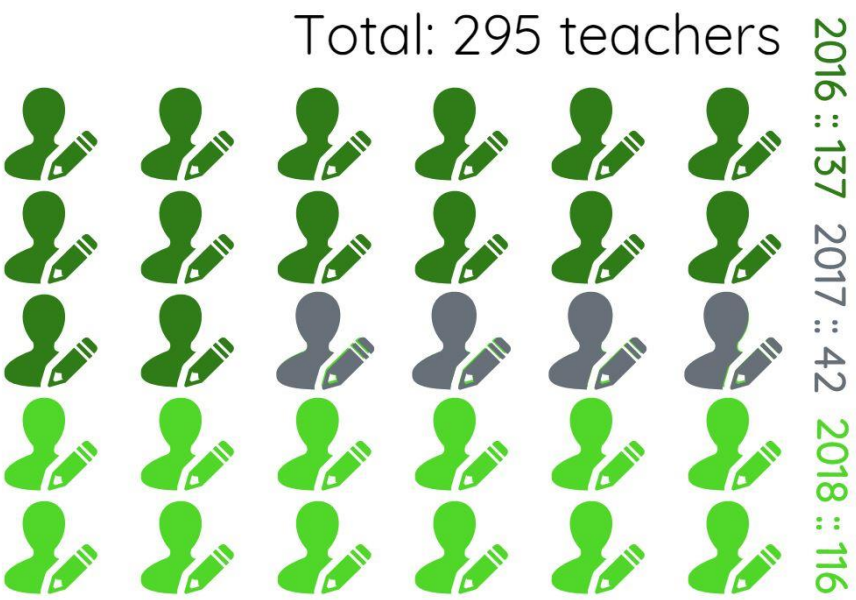


Figure 2 Number of teachers between 2016-2018 participating in the study

Data analysis

The collected data was analysed throughout the course of the project and reported in interim reports, while a retrospective analysis of the entire dataset is reported herein. Initially the data analysis program, NVIVO 11 was used for data analysis, but became unavailable after 2017. Subsequently, MS Excel was extensively used to analyse quantitative data from survey responses.

Data was prepared in different ways for analysis. All data sources were firstly translated from Afrikaans to English where needed to increase comparability during analysis. Numeric values were associated with textual elements of multiple-choice answers to increase comparability of data sources across the three years' surveys. A negative was generally associated with 1 or 2, while positive responses or multiple-choice answers were given a higher rating like 4 or 5. Given the magnitude of the entire data set, and volume of data to analyse, every effort was made to repeat analysis processes using different tools, for example Google Sheets and MS Excel, to confirm findings. Where findings were incongruent and remained this way after multiple analyses, the original source data was consulted, and the process repeated, from translation to numeric association and finally analysis, until all analyses across tools and fields yielded the same results.

Content and narrative analysis was used to analyse the quantitative data. The data produced from interviews and open-ended questions on the surveys was analysed to identify key words and recurrent phrases across the extensive data set. This was refined by focusing on the four main outcomes for the project and the indicators of each outcome. Findings from this analysis are reported herein.

The validity of the research findings was secured at three levels. Descriptive validity refers to the factual accuracy of the data collected, reported and accounted, and was achieved by accurately recording, verifying and documenting recorded data and data preparation processes, as indicated above. Interpretive validity refers to the interpretations gained from the research, and was secured by triangulating multiple data sources before making inferences, and documenting each process of critical analysis for verification. Theoretical understanding requires the analyst to move beyond descriptive and interpretive analysis to draw theoretical abstractions from the data. Theoretical validity was achieved by drawing on state-of-the-art knowledge, considering alternate explanations and/or understandings from literature, and incorporating emerging relationships between constructs.

The highest ethical research standards were maintained throughout the data collection process. In all cases, participants were informed of the research outcomes and their consent to participate clearly explained, emphasizing that participation was voluntary and that they could withdraw at any time without any negative consequences (in English and Afrikaans). Surveys were completed and submitted anonymously, and consent obtained before all interviews were conducted and for these to be recorded.

5. Findings

Findings are discussed in relation to the four main outcomes for the IMP:

- **Outcome 1)** Contribute to the quality of Maths teaching.
- **Outcome 2)** Improve learners' attitude to and engagement in Maths.
- **Outcome 3)** Raise learners' attainment in Maths.
- **Outcome 4)** Impact education department practices regarding ICT Integration and data informed decision-making.

Findings from this evaluation are then used to answer the three research questions for this study.

5.1 Impact the quality of Maths teaching

Two indicators were used to measure the impact of the IMP on the quality of Maths teaching in the project schools. Firstly, the extent to which teachers could use the data from MCO to identify learners or groups of learners needing specific support. Secondly the impact of the IMP on teachers' interest in teaching Maths.

Teachers noted a significant change in the way they taught Maths following their use of MCO. During 2016 – 2018, between 73 - 76% of teachers noted that they observed changes which included their use of the data and their interest in teaching Maths. In this period, 83 – 85% of teachers indicated that they used a greater variety of methods to teach Maths concepts after starting to use MCO. When compared to principals' survey data, 93% of principals in 2016 compared to 100% in 2018 indicated that teachers' Maths subject knowledge had improved. Similarly, principals noted that teachers used a wider variety of methods and were more confident to teach Maths after one year (92% in 2016) and three years (100% in 2018). One Maths Head of Department (HOD), Mrs R. explains:

> Interviewer: '*Have you noticed a difference in the way that teachers are teaching Maths now that they are using the Green Shoots MCO?'*
>
> Mrs R., HOD: '*We now have a committee, a Maths committee… we sit down and talk around about some concepts where the learners are struggling. We help each other, how to go with that lesson. We meet twice in a month. … I observe lessons you know for IQMS. I see a big difference.'*

Similar observations were made by other principals and Maths HODs. An Integrated Quality Management System (IQMS) is used in South African schools to monitor teachers and hold them accountable for curriculum pace and coverage. As Mrs R. noted, Maths lessons are regularly observed and all principals and HODs reported a positive change following the introduction of MCO. Interviewees indicated that language remained a challenge especially in Grade 4 where many learners change from mother-tongue teaching, to English as

language of learning and teaching. Interviewees however indicated that the quality of teaching and particularly teachers' Maths pedagogical content knowledge had improved. One principal for instance, explained that although teachers were qualified to teach Maths, their use of MCO deepened their methodology of teaching Maths, which greatly contributed to the quality of Maths teaching and learning in the school.

Indicator a) Extent to which teachers are able to use data to identify learners/groups of learners who need specific support

Teachers' surveys provided insight into their use of MCO data, results of which is included in Figure 3. Year on year, teachers' regular use of MCO data increased significantly. The chart is a collation of various sub-questions in the surveys and represents teachers' regular use of

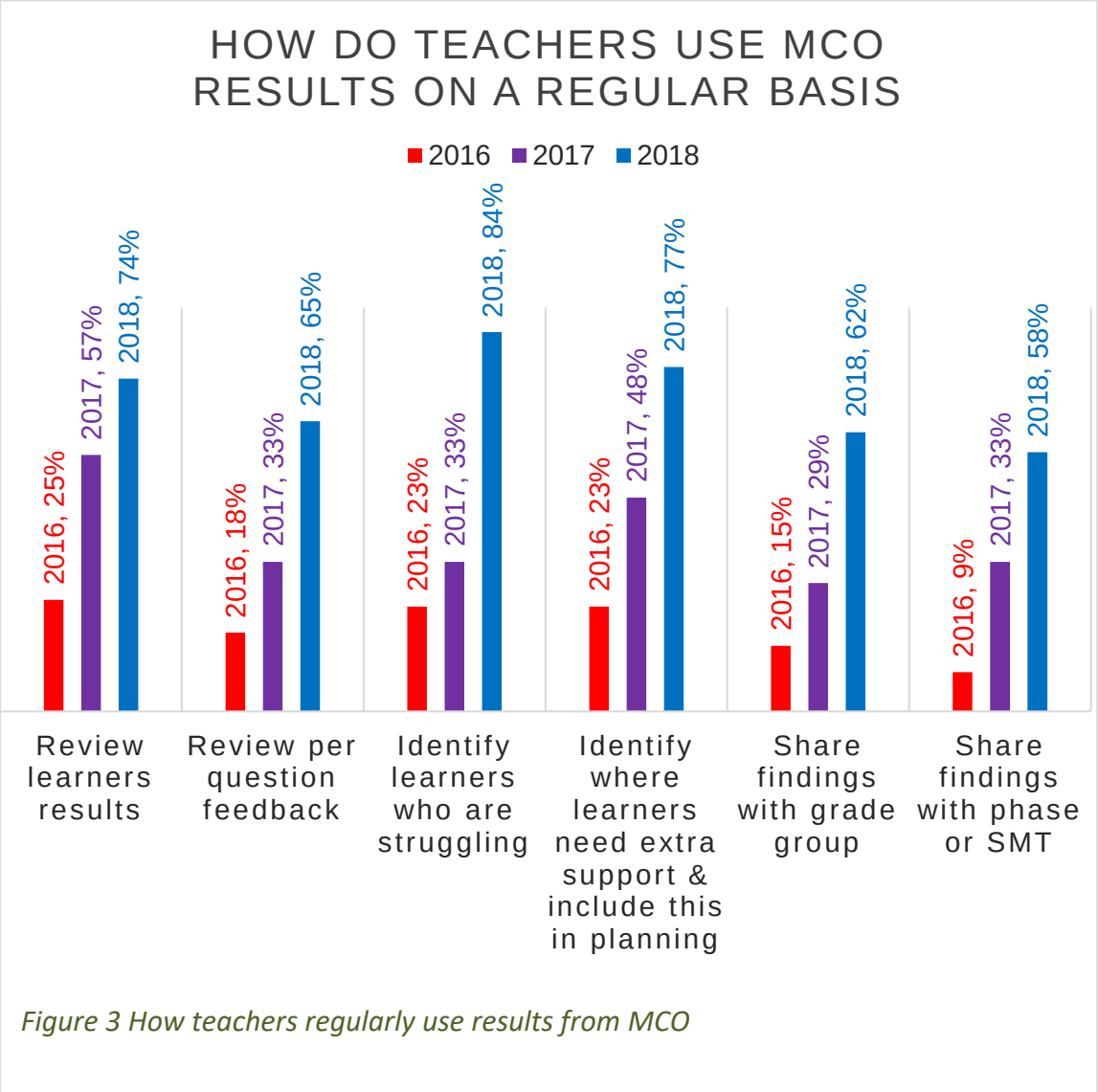


Figure 3 How teachers regularly use results from MCO

MCO data. Results from the surveys were triangulated with focus-group interviews from teachers, and the survey and interview data from principals.

As can be seen in the chart, teachers' regular use of MCO data increased an average of 51% in each of the indicators. This score represents teachers' comments that they 'often' or 'always' use MCO data, equating to regular use. As can be seen in Figure 3 between 2016 and 2018, 49% more teachers used MCO data to review learners results and 47% more teachers used it to review learners per question feedback. In 2016 only 23% of teachers used MCO data to identify which learners were struggling compared to 84% in 2018, an increase of 61%. Similarly, 77% of teachers in 2018 compared to 23% in 2016 used the data to identify where learners need extra support and to plan how to provide this support. More teachers shared their learners' MCO results with their grade group (15% in 2016 vs 62% in 2018) and with their phase group or the senior management team (9% in 2016 compared to 58% in 2018).

Teachers' self-reported increase in the use of MCO data was triangulated with data from surveys and interview data. Interviews with both teachers, district officials / Maths subject advisers and principals confirmed that teachers used the data to identify areas that learners find challenging, and then adapted their planning in accordance - to either re-teach areas or to provide additional support to learners. Principals' surveys overwhelmingly indicated that teachers used MCO data to identify where learners struggle with Maths (92% in 2016 vs 100% in 2018), and interview data confirmed that teachers then adapted their planning in accordance. The district officials / Maths subject advisers noted that teachers used MCO data to pace their curriculum coverage more accurately. One subject adviser noted:

> Maths subject adviser: '*The access to the real-time data has enabled teachers to plan their lessons and interventions with more clarity and focus. Individual learner results also enable teachers to design fit-for-purpose interventions per learner.'*

The data indicates therefore that the first indicator has been met. MCO data has had an undeniably positive impact on teachers' practice, and particularly enabled teachers to identify learners or groups of learners who require additional support.

Indicator b) Extent to which teachers' interest in teaching Maths improved

The effective impact of the IMP on teachers' interest in teaching Maths was determined using the different data sources and measurement scales as represented in Figure 4. During the three years, teachers steadily felt more confident to teach Maths, a score that increased from 84% in 2016 to 94% in 2018. This score was triangulated with interview data and verified with inter-question comparisons, which persistently showed an increase in teachers' judgement of their confidence to teach Maths over the three years. Two principals thousands of kilometres apart, Mrs L. and Mr M., attributed teachers increased confident to their increased pedagogical content knowledge following their engagement with MCO. Mrs L. observed that since 2017/2018, teachers no longer taught directly from the textbook, but were teaching practically, using their projector to explain concepts to the learners. Another deputy principal, Mr P. also observed a greater confidence in teachers, and particularly their ability to dovetail the curriculum needs with MCO. Teachers at his school no longer saw MCO as a stand-alone event, but as an integrated aspect of Maths learning. Teachers' increased confidence in their own abilities and MCO programme, Mr P. argued, increased the Brain Quest completion rates and in turn increased learners' attainment in MCO SBAs. Since most learners in the school had been able to complete their SBAs, their goal for 2019 was to improve the quality of passes.

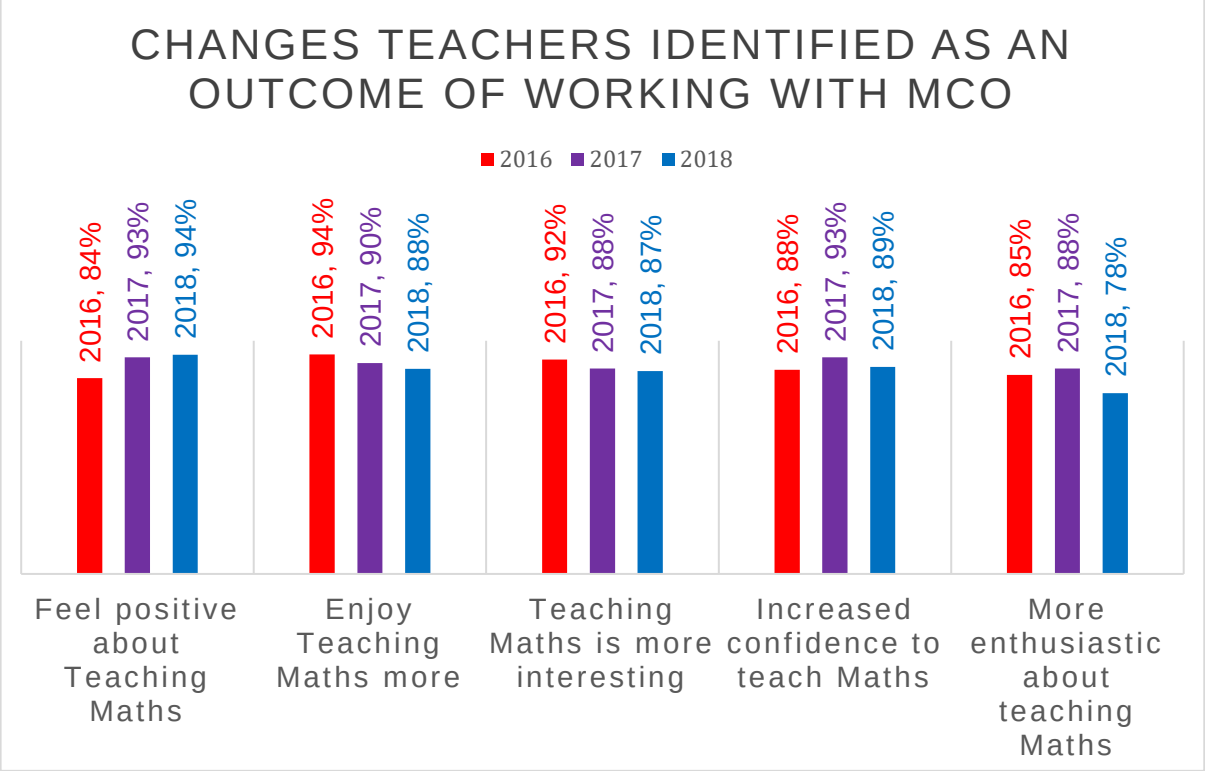


Figure 4 The affective impact of MCO on Maths teachers

Other indicators of teachers' increased interest, apart from an increase in confidence were also noted. Initially, in 2016, 94% of teachers indicated that they enjoyed teaching Maths more and 92% found it more interesting, yet both figures declined slightly over the three years, to 88% and 87% respectively (see Figure 4). Similarly, in the first two years of the project, more teachers felt that they were more confident and enthusiastic about teaching Maths, than in previous years, scores increasing from 88 – 93% (confidence) and 85 – 88% (enthusiasm) in this period. Between 2017 and 2018 teachers' scores reduced in these aspects, for example, only 78% of teachers felt they were more enthusiastic, and only 89% felt more confident. One argument for the fluctuations in scores could be related to varying teacher retention at schools, hence the same teachers did not complete the test each year. However, in many schools the Maths teachers did not change significantly. It may therefore be more likely that in the survey, teachers may have been comparing themselves against their 2016/2017 scores, and therefore did not feel more confident having increased in confidence and enthusiasm in the first two years of the project. It is more likely that the scores were stabilizing and that teachers' were seeing higher levels of enthusiasm and confidence as the norm.

The survey results were compared to interview and survey data from other participants. In all data sources teachers were observed or self-reported to be more positive towards Maths, and more interested in the subject. In this regard, one teacher noted:

> Teacher, Mrs M.: '*I've realised that a teacher becomes a student. You are forever learning. So I've learnt a lot. The approaches that they have developed in this different activities, they have helped me a lot. So I've used different textbooks and them, so I think I'm well developed. I've gained and I've seen changes in my learners. Since this thing was in place my learners' results have improved and I am very happy. When you go away it is going to be a problem but I think I am going to continue using it because it is of good help to me. Even if you are gone, it is there to stay and continue.*' [sic]

As with Mrs M., other teachers noted that they did not feel reluctant or scared about teaching Maths any longer. Some even started extra-Maths sessions or clubs on weekends and in holidays, to improve learners Maths attainment. Language is a significant barrier to learners' Maths achievement, and teachers hoped the extra Maths lessons would support their development. Teachers also started Maths committees or subject groups that meets every few weeks to discuss learners' progress and ways to support or extend Maths

learning. These actions suggest that teachers displayed greater agency regarding their Maths teaching and learning activities, as an outcome of their increased interest in the subject.

The data thus indicates that teachers' interest in teaching Maths as a consequence of working with MCO, has improved.

5.2 Improve learners' attitude to and engagement in Maths

Over the course of the three-year study, learners' attitudes, confidence and engagement in Maths improved, whether working with MCO or in the general class without MCO. Various data sources were analysed to reach this conclusion. Throughout the three-years, learners' enthusiasm for working on the computers to complete their MCO remained high, and impacted their general approach to Maths learning. Therefore, when analysing results it was assumed that learners' enthusiasm for working with technology could potentially scew results due to the '*novelty value*', especially in the first or even second year of the project. However, it is fair to assume that the novelty value eroded after the third year of working with the computers especially for learners who worked with MCO during 2016 and 2017. Of course the Grade 3 and 4 learners who worked with MCO for the first time in 2017 or 2018, experienced higher novelty value, as did learners who joined schools during 2017 and 2018 for the first time. Consequently, learners' results were analysed year on year, to show their scores longitudinally and minimize the impact of novelty value. Since the same schools participated in the surveys each year, it is likely that the same Grade 3 learners who completed the survey in 2016, would complete the Grade 4 survey in 2017 and Grade 5 survey in 2018. Similarly, the same Grade 4 learners from 2016, would complete the survey as Grade 5 learners in 2017 and Grade 6 learners in 2018, and Grade 5s in 2016 would be Grade 6s in 2017 and Grade 7s in 2018. The longitudinal analysis thus reflects this repeat use of the programme.

The data analysis relating to Outcome 2 and 3 are consequently discussed, broadly addressing general findings, then addressing the specific indicators for each outcome.

General findings related to learners' attitude and engagement in Maths

Learners were generally eager to work with MCO and displayed considerable agency in self-organisation and taking responsibility for their learning. As was a general comment in the three years, the learners reminded teachers when it was time for their 'Green Shoots' and looked forward to it all week. Even when they were ill, many learners reportedly attended school rather than miss their session on the computers. One teacher, Mrs M., explained how learners approach Green Shoots, a comment that was frequently repeated by most interviewees and survey respondents:

> Teacher, Mrs M.: '*Whenever it's time for MCO, the learners remind me, Mam, it's time for computer lesson. And then they take out their books where they are going to use it for calculations and then they walk in rows to the computer silently. When they enter they sit down because the computers are few they share so they pin their number in. So like today this one is pinning, next time will be the other one. They pin in their numbers and they know exactly we are doing Brain Quest 4, 5, 6. They don't even ask they know. Then they get into the lesson and before that I go also through the work and then I explain where it is necessary to explain and afterwards they do the activities and if there is someone that does not understand, then they just raise their hands and then I explain that and afterwards the one that has finished then raise their hands and then I come and have a look at the marks, how much he or she has obtained and after that there remains silence. After that, after everything then I explain where I see there was a problem then I try to explain the problem. Then afterwards we leave again in silence.*'

Interviewees and survey participants frequently related similar narratives, achieving various intended and unintended outcomes of MCO Green Shoots Comic Relief project.

Indicator a) Extent to which learners know their own FAT results/check their Brain Quest scores

A comparison of learners' average Brain Quest (BQ) completion for 2016, 2017 and 2018 indicates that more learners consistently completed the BQs each year. An extract of the Grade 6 average completion of the BQ is included in Figure 5. This is the final year of the

Intermediate Phase and also in the Western Cape, the year when the provincial standardized Literacy and Numeracy assessments are conducted. As can be seen in the chart, the BQ usages for 26 of the 32 schools participating in the IMP, improved and more learners regularly completed the BQs each year of the project. In the first year of the programme's implementation, the Green Shoots team typically aim to achieve 'Bums-on-Seats', getting teachers to regularly take learners to the computer room and letting them complete the BQs. The second year of the programme in a school, emphasizes teaching and learning with MCO, and sees teachers typically use MCO no longer as an 'add-on' but an integrated section of their Maths teaching and learning (as Mr P. indicated above).

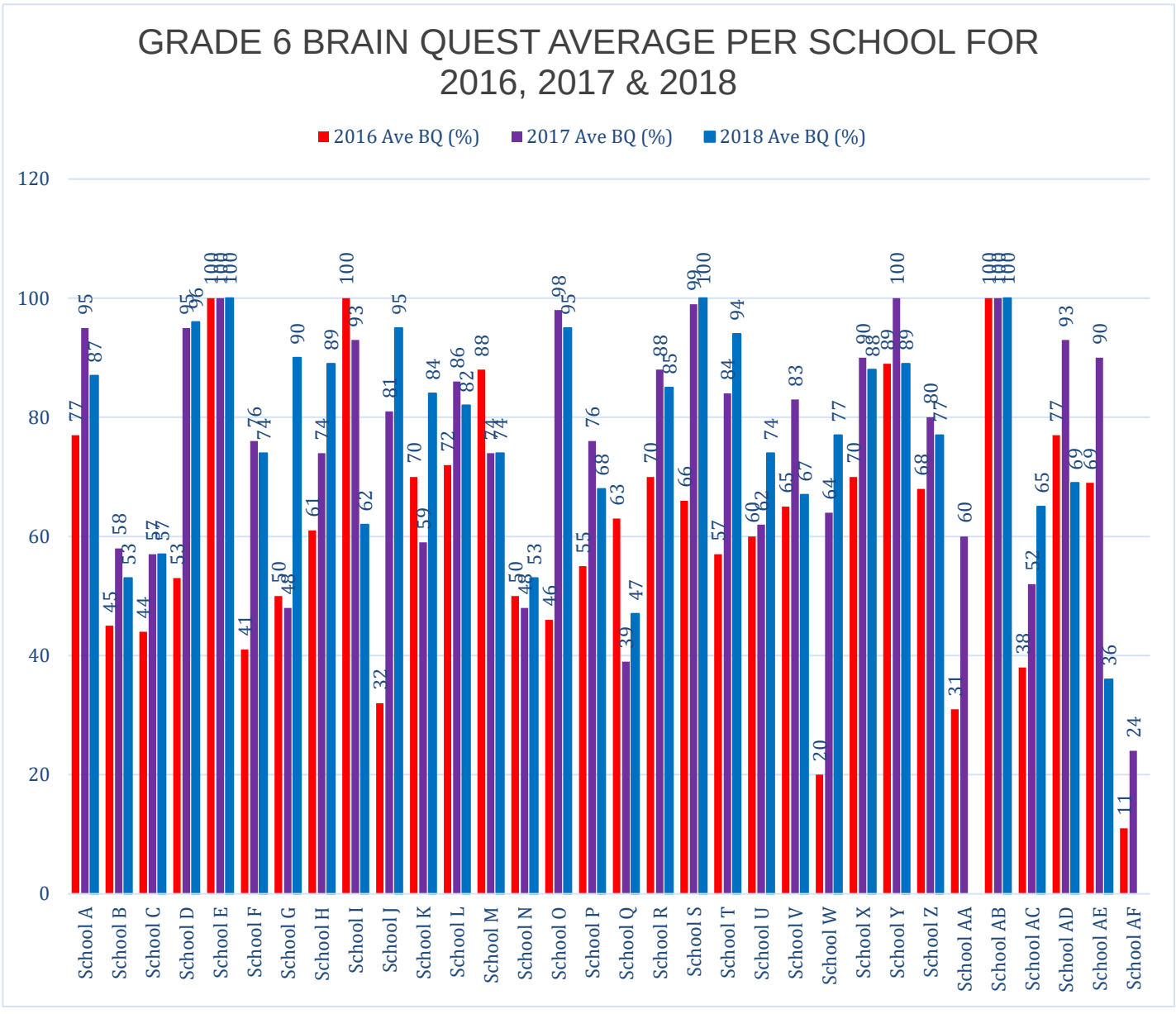


Figure 5 Brain Quest average scores per school for 2016, 2017 & 2018

Between the second and third year, the Green Shoots team work to get teachers, schools and principals, as well as district officials to use the data generated from MCO to inform their planning and response to learners.

Interview and survey data measured how learners used their BQ results, as included in Figure 6. During the period 2016-2018, the number of learners who regularly looked at their scores increased steadily. In many schools, learners only started using the programme in Grade 4, while in others MCO is introduced to Grade 3 learners. However, in both instances, and across the three years, learners who did not look at their scores decreased over time as can be seen in Figure 6.

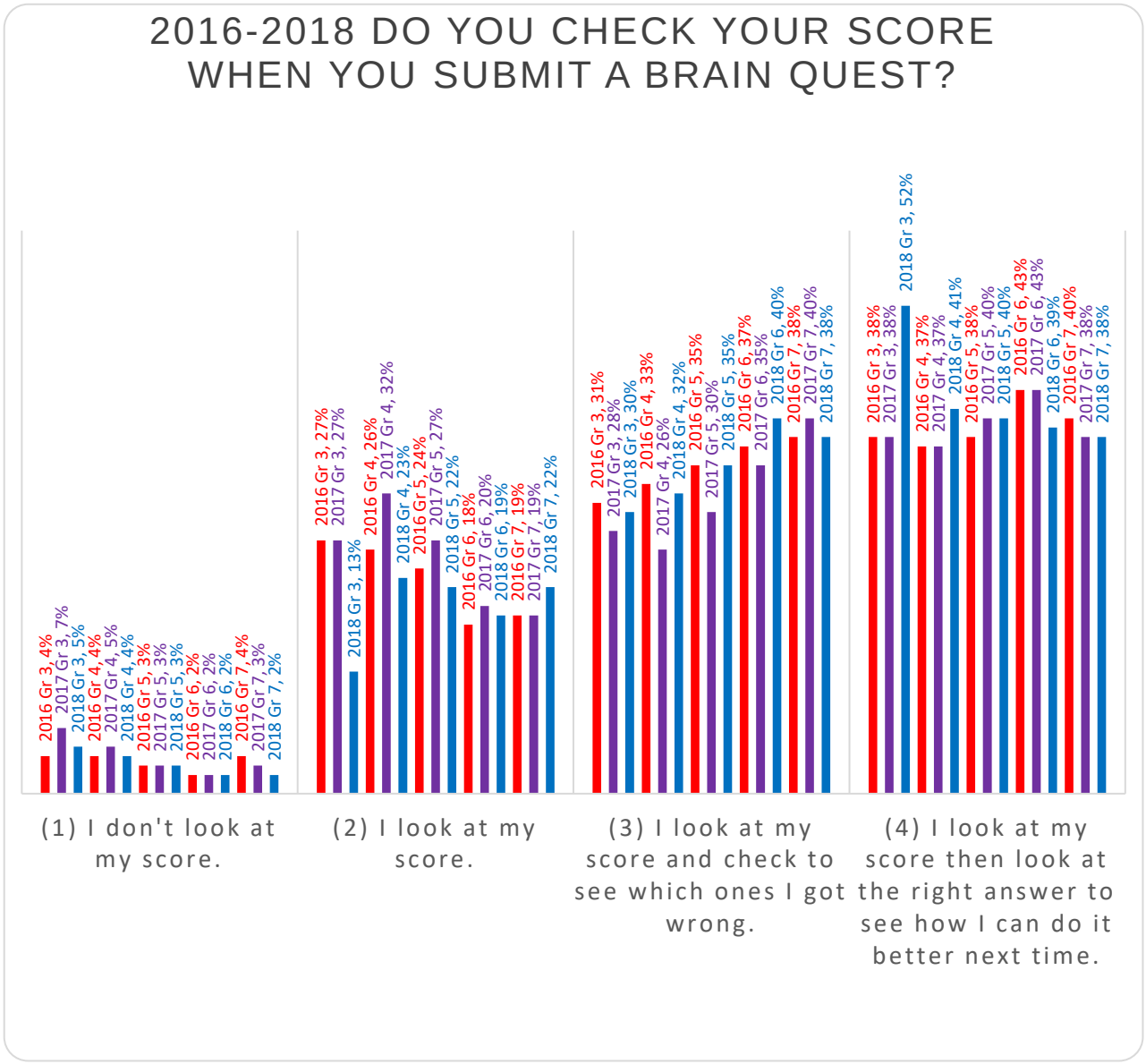


Figure 6 Value learners place on BQ scores

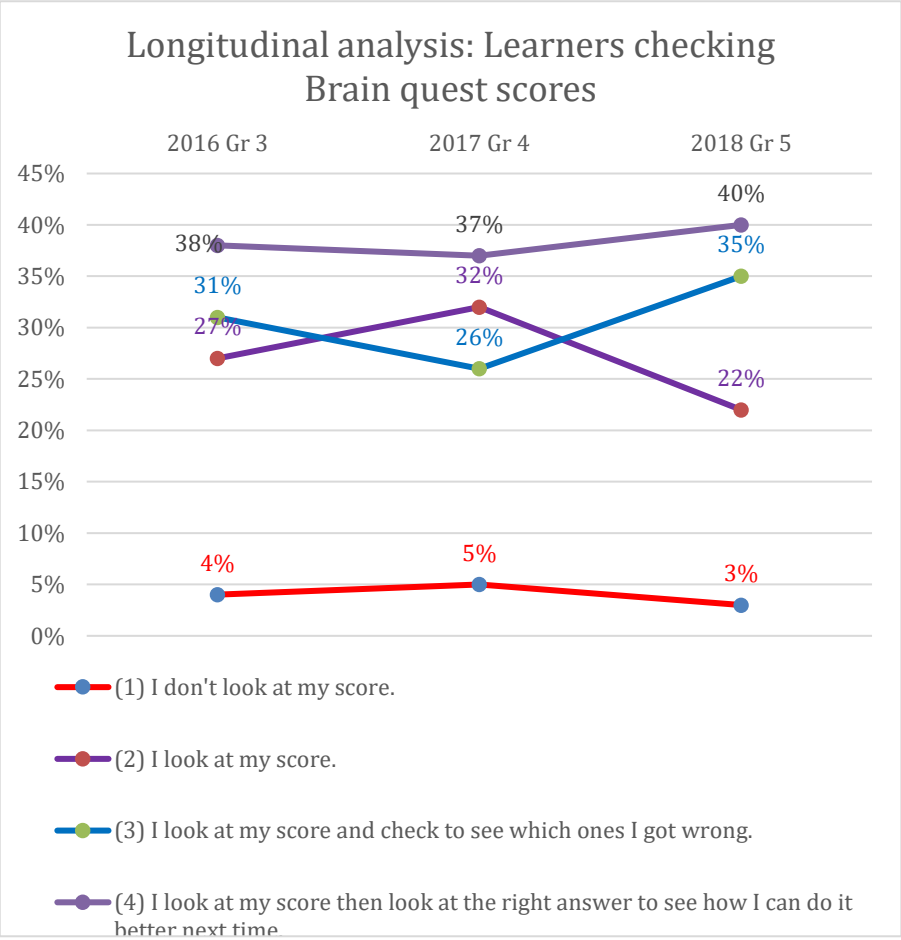
The survey also indicated a marked decrease in learners who only look at their scores and did nothing else. Instead, most learners over the three years and more notably in Grades 6 and 7, took an active role and either checked which problems they answered incorrectly, or checked to see how they could improve on future attempts. These increased measures suggest an increase in learners' agency for their learning and achievement in Maths. More so, it suggests that learners are more aware of their actual achievement, knowing which answers they get wrong and how they could improve on this.

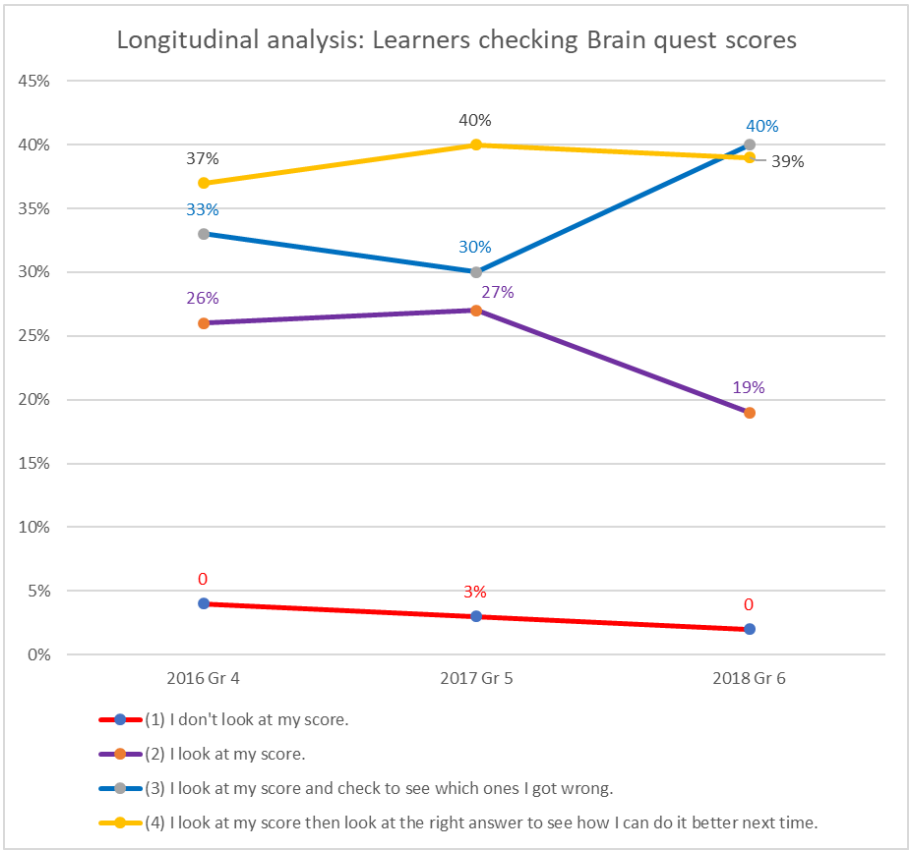
A longitudinal analysis of learners' survey responses was also conducted, the results of which are included in Figure 7. Learners who participated in the three consecutive years, 2016, 2017 and 2018, can be seen to develop greater agency during this period. The longer learners worked with MCO, the more learners checked their scores to see which answers they 'got wrong' and where they could improve. In comparison, each year the number of learners who did not check their scores, or who only looked at their scores without doing anything else, decreased.

A similar longitudinal analysis of learners' actions following a BQ supported the finding that learners developed greater agency the longer they participated in MCO. As indicated in Figure 8, the number of learners who did '*nothing*' with their scores, remained relatively low. In comparison, the longer learners participated in MCO, the more likely they were to tell their friends or a teacher, and to write down their scores. The increase in learners who wrote down their scores also suggests a greater internal motivation to keep track of and manage their own progress. This is corroborated by the significantly greater number of learners who work to improve their scores when attempting a BQ for the second time.

Goal setting, a characteristic of learners' agency, also improved the longer learners used MCO. As indicated in Figure 9, year on year and in parallel to advancing grades, more learners set goals for their achievement in Maths with up to 95% of Gr 7s at the end of 2018 setting goals for their Maths achievement. The survey data corroborated findings from interview data, in which the greater majority of learners in the focus group interviews indicated that they set goals for their achievement in Maths.

Learners' also persistently worked to increase their scores between 2016-2018, correlating to the consistently higher number of learners who actively monitor their BQ scores. As indicated in Figure 7, data from learners' surveys indicate that those who attempt a BQ a second time, do so to improve their scores. The greatest increase was for the cohort of Grade 4s starting in 2016 (81%), Grade 5s in 2017 (85%) and Grade 6s in 2018 (87%), who indicated that they try to improve their scores when attempting a BQ for the second time.





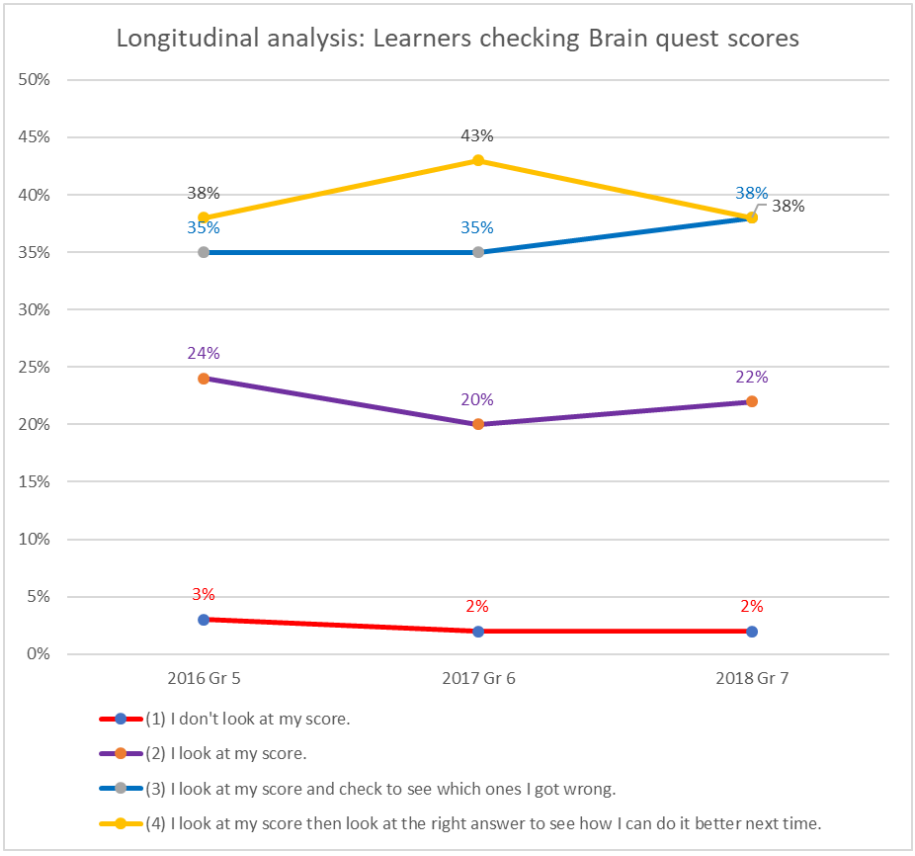
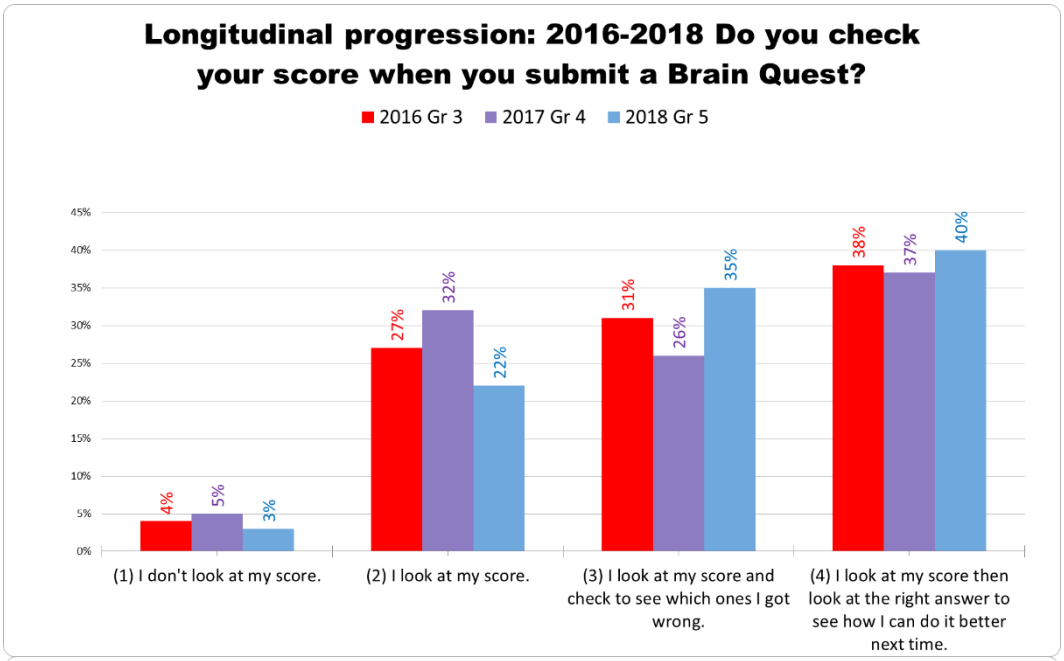
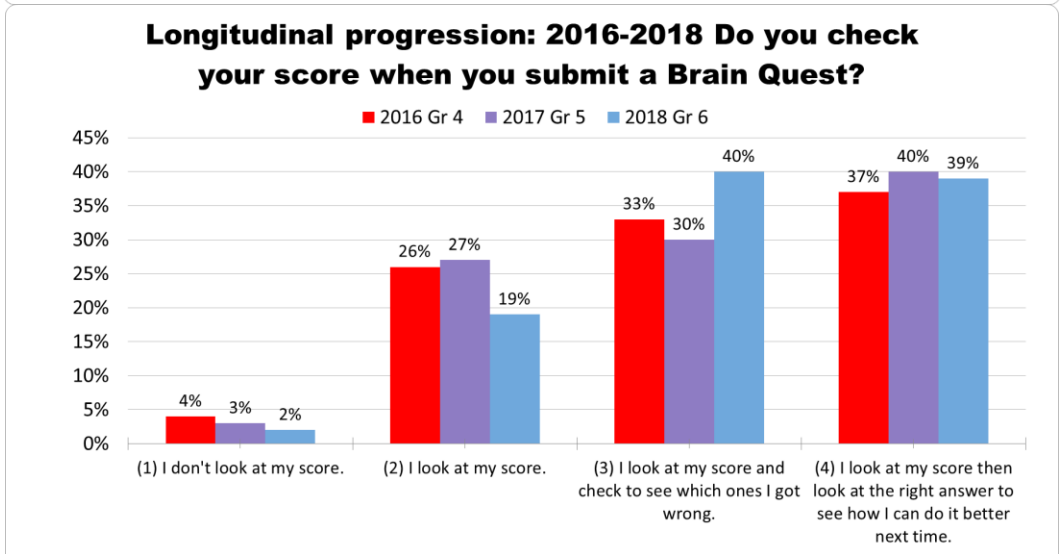


Figure 7 Longitudinal analysis of learners' checking Brain Quest Scores





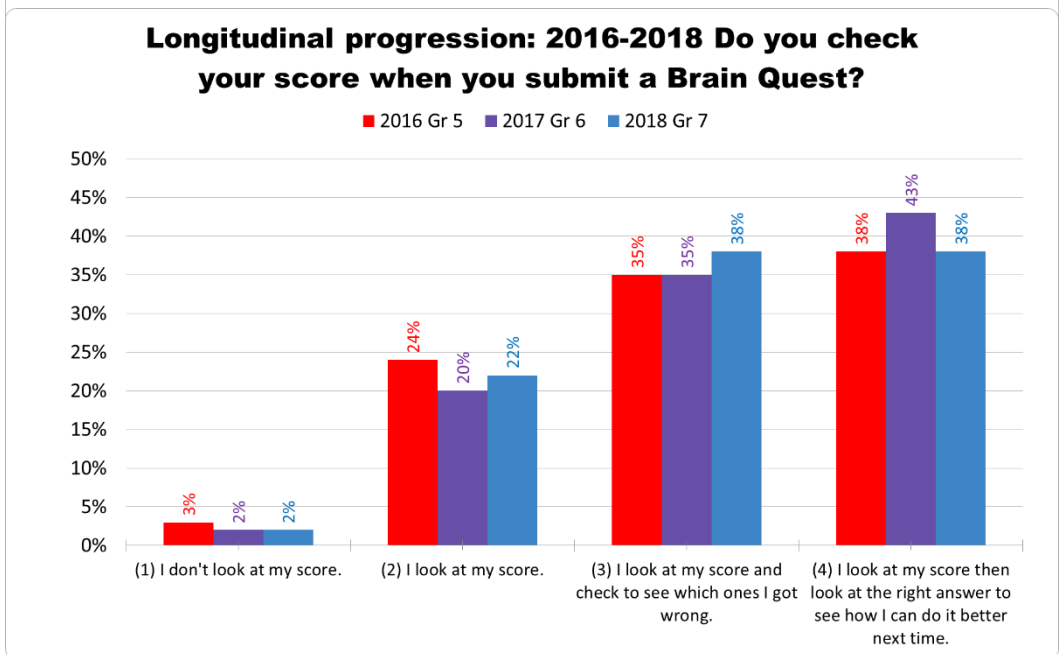


Figure 8 Longitudinal analysis of learners' activities after Brain Quests

In many schools, teachers reported that they felt under pressure to achieve in the provincial standardized assessments for Grade 6. This is also the grade in which the Intermediate Phase comes to an end, with the Grade 7s falling within the Senior or High School Phase although technically still in Primary School. In some schools, teachers therefore place less emphasis on the Grade 7s MCO tasks. It is however encouraging to see that 90% (2016), 93% (2017) and 90% (2018) of the Grade 7s completed the BQs a second time to improve their scores. This shows a commitment to achieve and a strong degree of agency on behalf of learners.

The survey data furthermore indicated that learners managed challenges when completing the BQs in increasingly sophisticated ways. When confronted with a problem they could not solve, the number of learners who either picked (4) *I guess which answer it must be*, or (5) *I just click on any answer*, decreased from 2016 to 2018 across all grades. Instead, more learners indicated that they either asked the teacher, or consulted their Maths books for clues. In particular, learners consulted more with teachers to help them solve problems, which increased over time. For example, in 2016, 35% of the Grade 4s asked a teacher, 42% of the Grade 5s and 45% of the Grade 6s. Similarly, in 2016, 38% of the Grade 3 compared to 46% of the cohort in 2018, asked a teacher. Learners who consulted their Maths books remained at approximately 26 - 28% and showed a marginal increase except for the Gr 7s in 2016 and 2017. Similarly, learners who always remembered to take a book and pencil increased. For example, in 2016, only 26% of learners remembered to take a book and pencil, compared to 54% of Grade 5s in 2018. Similarly, 35% of Grade 4s in 2016 compared to 58% of Grade 6s in 2018 remembered to take a book and pencil to the computer lab without being reminded to do so by their teacher. In comparison, teachers increasingly transferred responsibility to learners to remember their books and pencils, with only 61% of teachers in 2017 compared to 71% in 2016 reminding learners to take their books and pencils. Similarly, teachers observed that 24% of learners in 2016 compared to 36% of learners in 2017 remembered to take their books and pencils.

These various insights in totality suggest that learners developed greater agency through their involvement with the IMP. This can be inferred from the greater awareness they displayed with regards to their scores, them remembering to take the tools they need (books and pencils) to support their ‘workings-out’ during BQs (validated by teachers’

observations) and their striving to improve their scores when conducting a BQ for the second time. Far fewer learners passively clicked or guessed an answer across the three years, but actively participated in their learning processes by asking teachers for assistance or consulting their Maths books. In totality it can be concluded from these findings that learners developed greater agency as an outcome of their engagement in the IMP.

Indicator b) Extent to which learners have set a personal goal for achievement in end of year FAT

As indicated in Figure 9, the number of learners who indicated that they never set goals for personal achievement decreased each year from 2016 to 2018. Instead, the number of learners who regularly set personal goals for their Maths achievement increased.

Learners attitude towards and engagement in Maths with or without the IMP improved over the three years as seen in their increased anticipation and enjoyment derived from

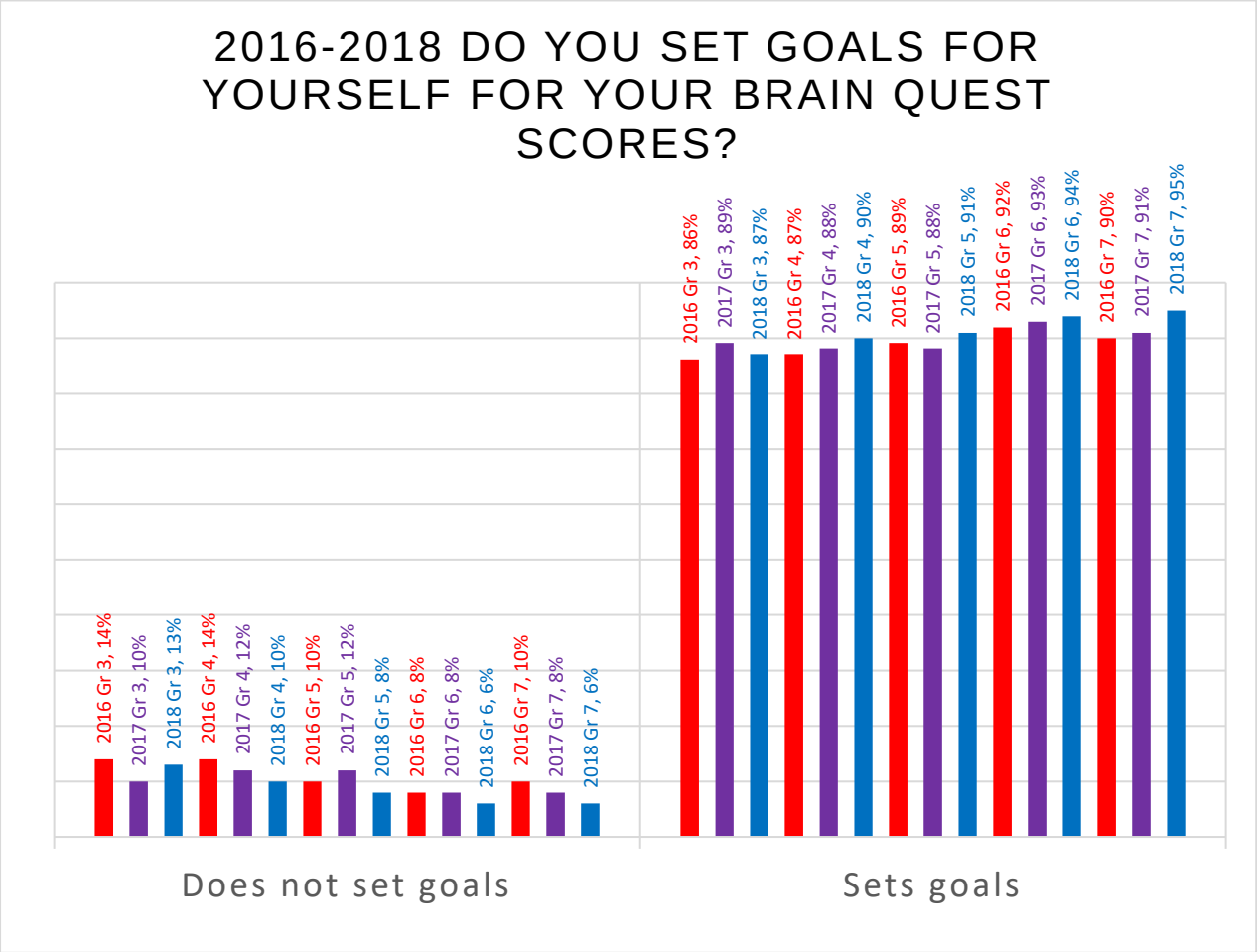


Figure 9 Number of learners who set achievement goals

participating in Maths. A greater number of learners looked forward to Maths lessons in general and when working on MCO (see Figure 10). More learners looked forward to Maths lessons using MCO, than Maths in general, but fewer learners did not want to miss their MCO lesson than their general Maths lesson. On the other hand, similar numbers of learners indicated that they really did not like Maths or don't care if they did not go to Maths in general or MCO. The number of learners who did not want to miss their MCO lessons increased across the three years, with up to 48% of Grade 7s in 2018 compared to 44% in 2016, not wanting to miss MCO. Various survey questions were conflated on the one chart (see Figure 10) but were included in different parts of the survey to measure learners' attitude towards the subject and reduce the influence of device use or novelty value that may impact learners' answers. Hence, as can be seen in Figure 10, with the impact of device use reduced, learners' attitude towards Maths in general, the way in which they looked forward to Maths with/out MCO, and how they did not want to miss their Maths lesson in

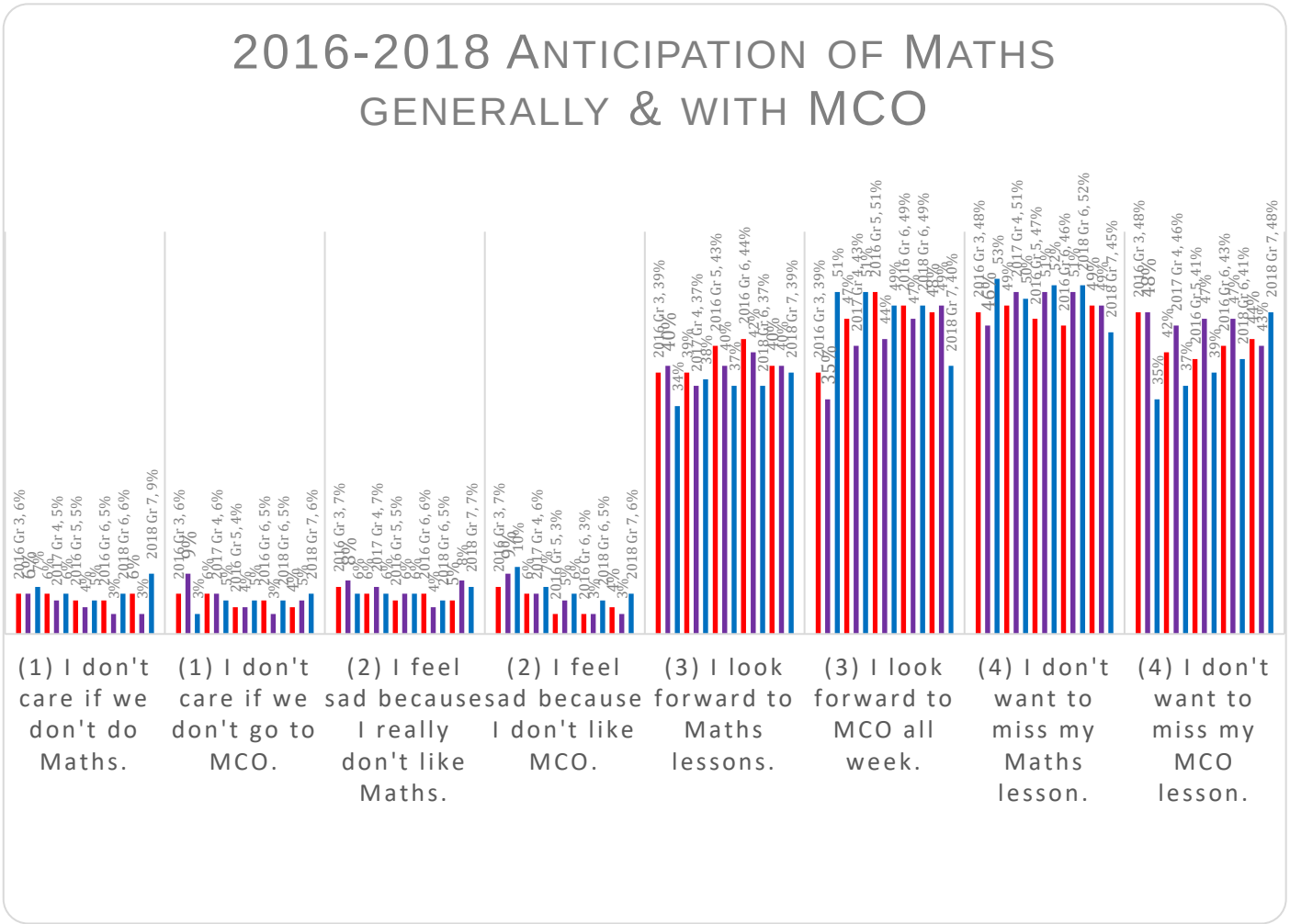


Figure 8 Learners anticipation of Maths generally and with MCO

general (and also with MCO), indicates a consistently positive improvement between 2016-2018 across grades.

Learners' survey results were triangulated with other data sources. Teachers' survey data for instance, indicated the changes teachers observed in their learners' engagement with and attitude towards Maths, the results of which are included in Figure 11. The data indicates that teachers observed a marked increase in learners' engagement with Maths between 2016-2018. Survey data also indicates that teachers noted an increase in learners' confidence to attempt new questions or concepts. Interview data with teachers at various schools however, differed slightly from survey data findings. Teachers completed the surveys anonymously and before the interviews. During the interviews, teachers repeatedly

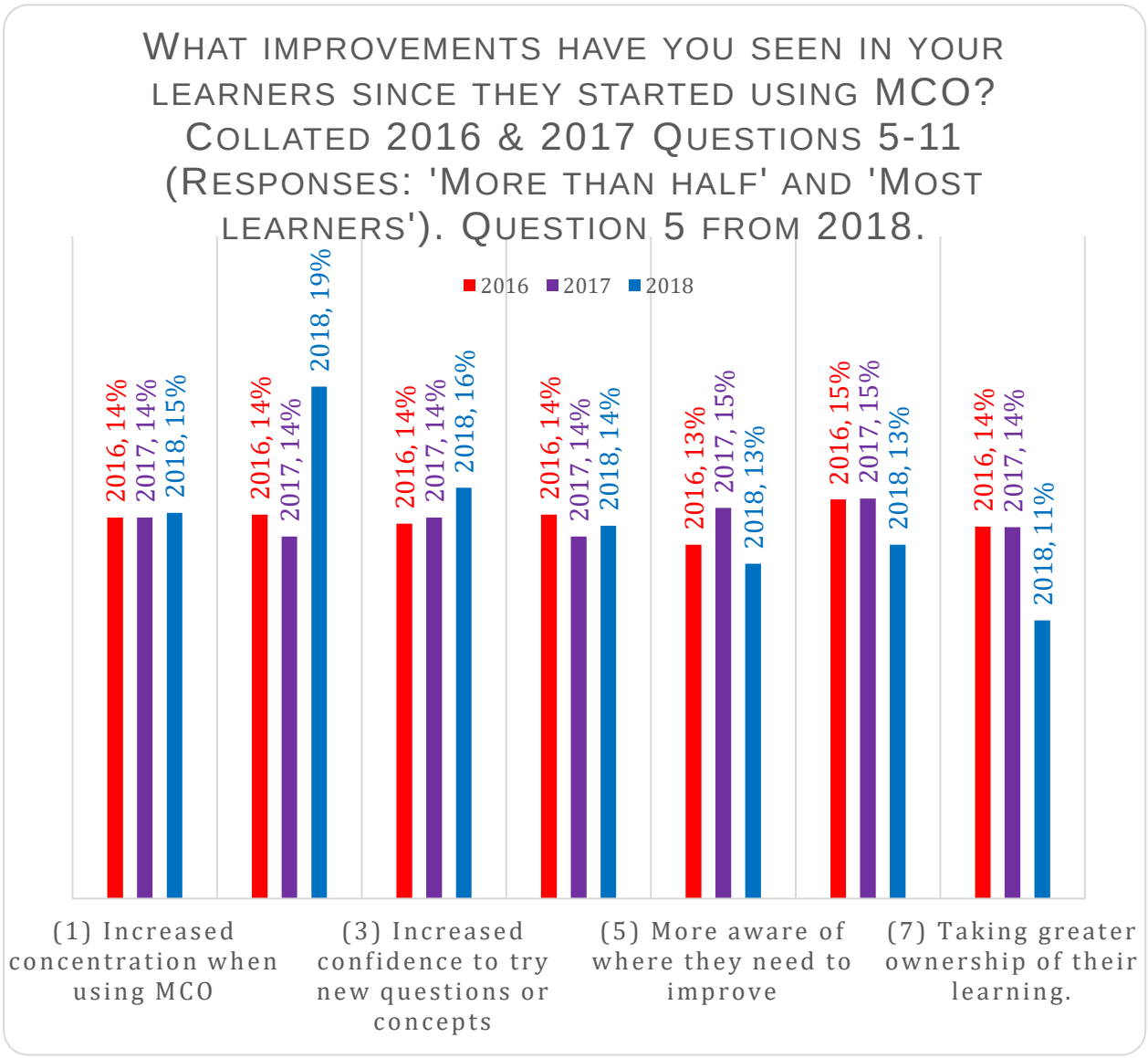


Figure 11 Teachers' observed improvements in learners' approach to Maths

indicated that learners displayed increased confidence in Maths. Teachers at two schools noticed a decline in the number of parents who complained about learners' low confidence in Maths. To the contrary, parents in these two schools as well as those in four other schools, asked for MCO afterschool programme as their children had asked to work on this to improve their Maths. The parents' and teachers' observations suggest that learners appear to take greater ownership of their Maths, are more engaged, and display a more positive attitude towards the subject. Teachers interview data further confirmed the observed positive impact MCO had on learners' attitude towards the subject and engagement therein. Mrs N. is a Maths teacher and Head of Department. Her comments summarise what many of the other teachers indicated during interviews across the three years:

> Teacher, Mrs N.: '*Our weaker learners do best on Maths online than in class so it also gives them courage and it also motivates them to do Maths online. Maybe in class the teacher, they don't listen actually and they are not to be on their own. You are mostly talking, now with computers they are working on their own and they feel great, you know, sitting there doing the thing, not you always you see. The teacher standing there, saying it, saying it, now this time the teacher only explains a little bit and then it is their turn. Yoh, they enjoy it! They feel that this is our thing, yah.*'

Although teachers and learners indicated that learners were more engaged and had a more positive attitude towards Maths, some of the learners' survey data appeared to be contradictory. The majority of learners surveyed between 2016 – 2018, were positive towards Maths, whether working in class or on MCO as can be seen in Figure 12. The chart in Figure 12 indicates longitudinal data for learners' survey responses to 'I HATE Maths!' (1) to 'I LOVE Maths!' (5). The potential impact of the novelty value is high in 2016 scores (indicated in red), with the majority of learners surveyed indicating a significantly higher score than in 2017. A second set of questions asked learners to judge whether Maths was 'VERY Difficult' (1) or 'VERY easy' (5) whether working with or without MCO – see Figure 13. Learners' responses in the second chart that gauges belief about Maths appears to be influenced more strongly by the novelty value, as scores appear to be higher in 2016 and then appear to decrease the longer learners are exposed to MCO.

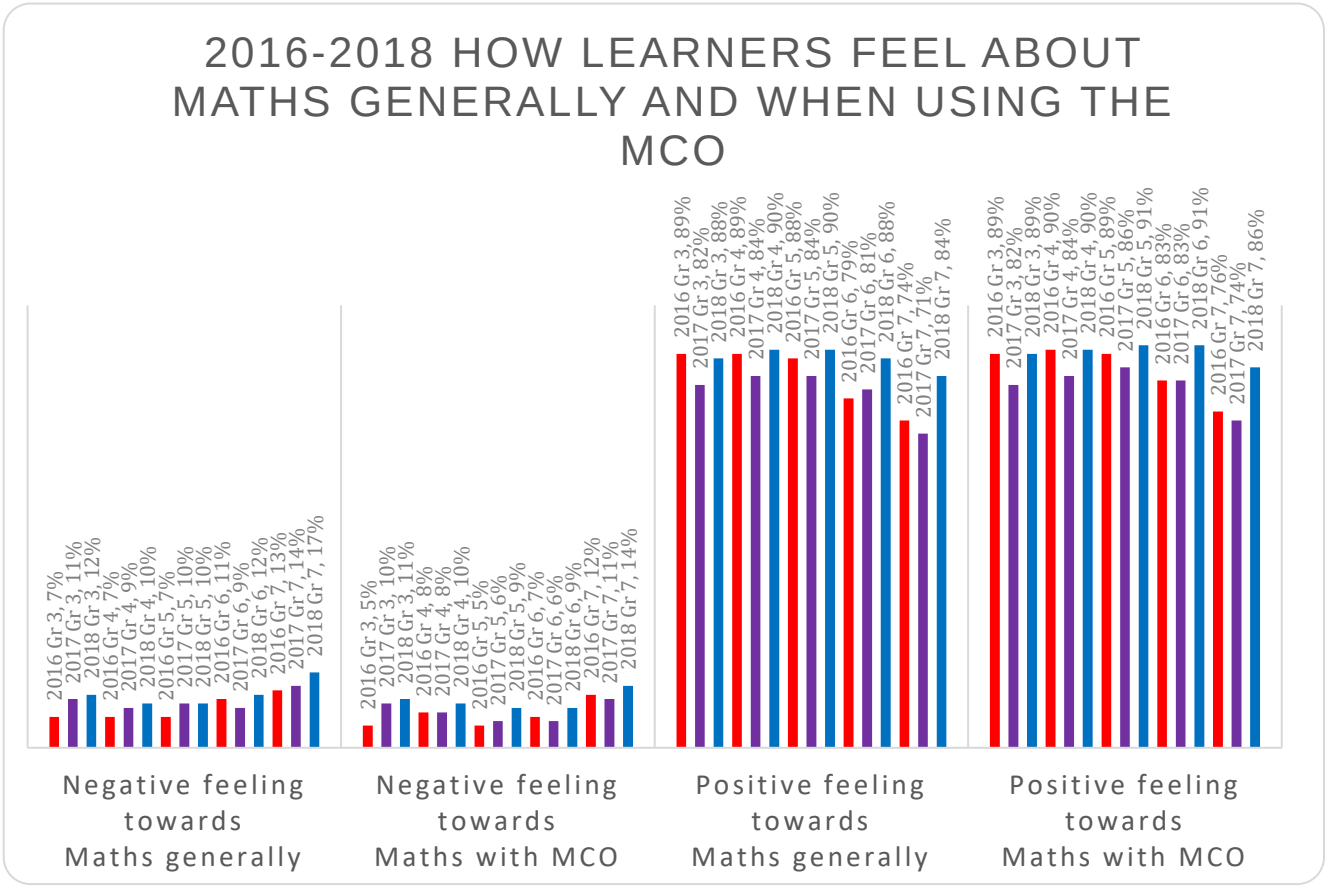


Figure 92 Learners' feelings towards Maths with/out MCO

Learners' perception of Maths in general and when working on MCO, also improved over the three years that they worked on MCO. When using MCO, more learners perceived Maths as 'easy' comparable to Maths in general. There is also an increase in Grade 6 & 7 across the three years in learners' positive perception of Maths. For example, in 2016 (after 1 year) 56% of Gr 7s felt Maths was easy, compared to 63% of the Gr 7s in 2017 (after 2 years) and 65% of Gr 7s in 2018 (after 3 years). Comparable results indicate that Grade 7 learners in general perceived Maths increasingly positive. In 2016 (after 1 year), 47% of Grade 7s felt Maths was generally easy, 55% in 2017 (after 2 years) and 56% in 2018 (after 3 years). Grade 6 results mirror this increase in both Maths in general and when doing MCO. The lower grades show some increases, but survey data fluctuates across the three years. For example, there appears to be a marked increase in learners who perceive Maths in general as difficult in 2018, with fewer learners who perceived Maths as difficult when using MCO and more learners perceiving it as easy when using MCO, yet fewer learners who feel confident about Maths across different years. These varying results are of particularly importance and bear further discussion.

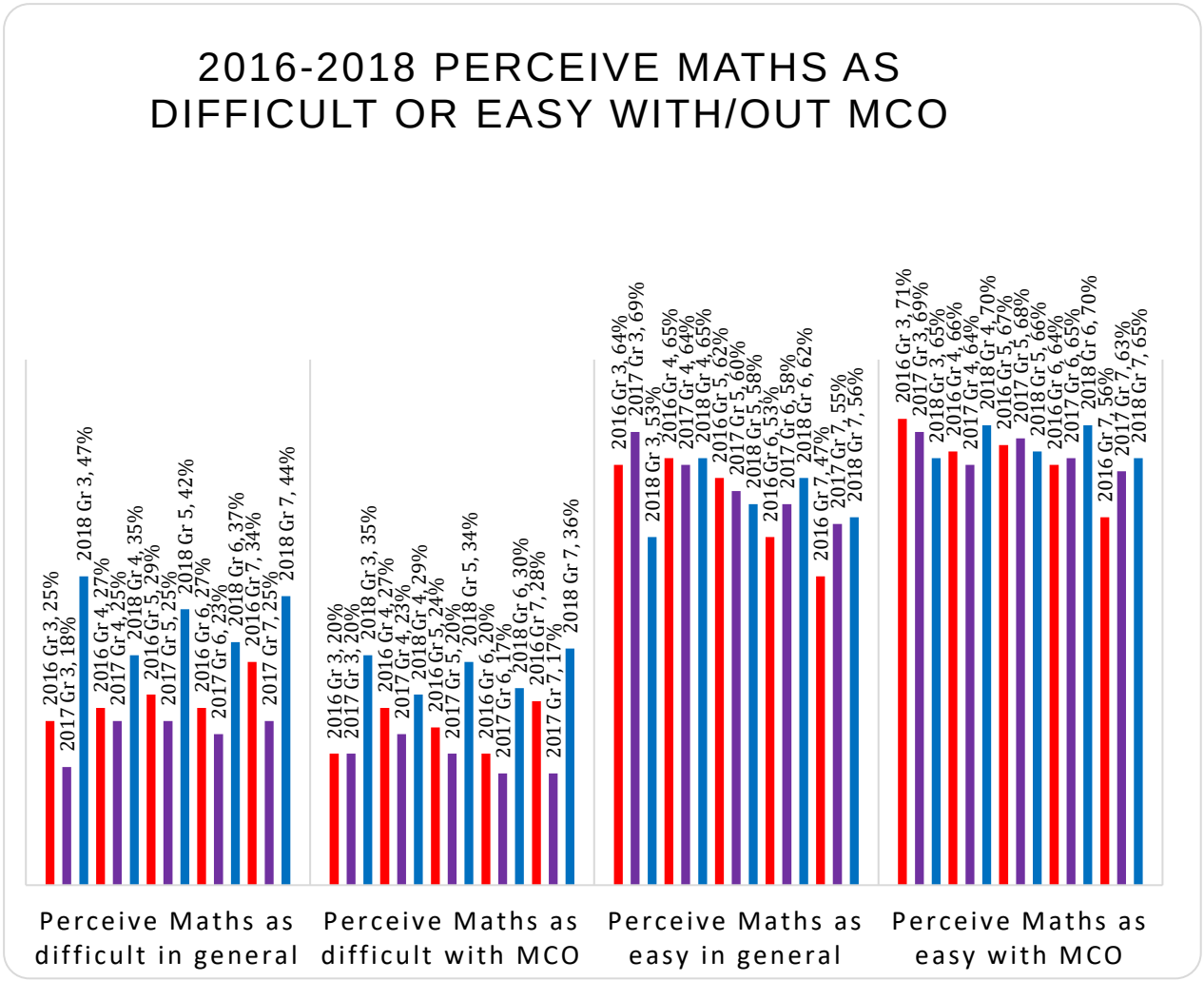


Figure 13 Learners' perception of Maths as difficult or easy

Learning theorists such as Piaget (1962), Ausubel (1968) and Bandura (1986) widely acknowledge the importance of learners' beliefs and confidence as a major precursor to learning. Hattie's (2009) meta-analysis of 800 factors that affect students' learning, identified student expectations and self-reported grades as the most critical. The accuracy of learners' expectations, confidence, judgements and beliefs, compared to their actual performance, is expressed as a degree of calibration. An accurate degree of calibration, aligns expectations, confidence and judgements about learning accurately with a students' actual performance. Over-confidence occurs when learners' expectations, perceptions and judgements about learning outweigh their actual performance, while under-confidence occurs when learners' expectations, perceptions and judgements are below their actual performance. Younger learners' calibration is typically poor because they have not yet developed the metacognitive processes to accurately calibrate. Between the ages of 9 – 12,

learners generally develop metacognitive processes that allow them to more accurately judge their potential learning, set confidence levels and align expectations and beliefs with actual performance.

The development of the ability to calibrate learning expectations and actual performance is of critical importance because it allows the learner to monitor the quality of their learning when studying (Hattie, 2013; Van Loon, de Bruin, van Gog, & van Merriënboer, 2013). Learners participating in the study were between the ages of 9 – 14 years, the period in which metacognitive processes such as judgement, expectation, belief and perception typically develop. In the first year of MCO, 2016, and impacted by the novelty value and potentially immature metacognitive processing, learners especially in Grades 3 and 4, tended to be overconfident in the estimations of their Maths ability. Compared to their teachers' and principals' evaluation of their confidence, and particularly their low actual scores (see section 5.3), the learners generally perceived Maths with/out MCO as easy and felt very confident in their abilities.

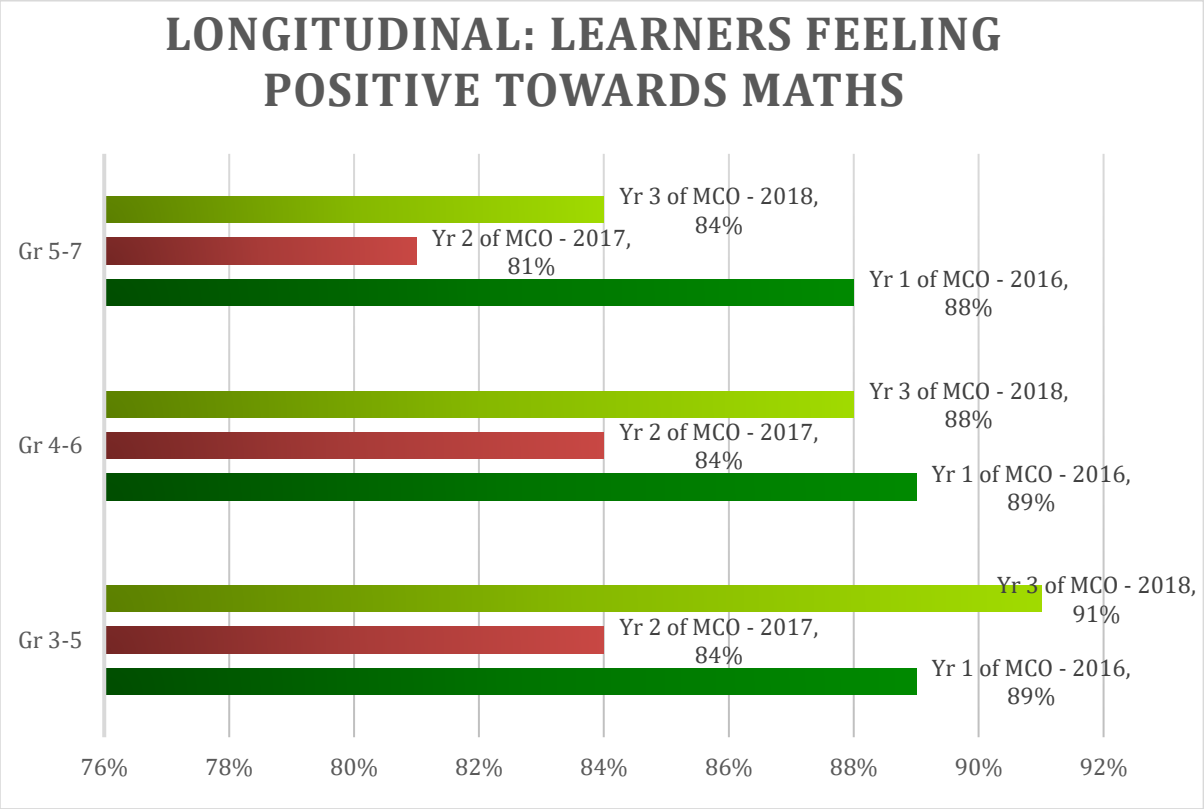


Figure 14 Longitudinally: Learners' developing positivity about Maths

In the second year of IMP, with their actual performance increasing, learners appear to become less confident. Survey data indicates that in their second year of engagement with MCO, learners' confidence levels and engagement in Maths for 2017 decreased, and learners viewed Maths in general and when doing MCO in a less positive light, as seen in Figure 14. However, comparative survey results from teachers and principals, suggest that learners were observed to be generally more positive about Maths, scores increasing from 29% in2016, to 60% in 2017 and 70% in 2018. Similarly, when asked what changes they noted in learners' approach to Maths (see Figure), teachers noted an increase in learners' confidence and engagement in Maths during the three-year period. As noted previously, during Year 2 (2017) and Year 3 (2018) of MCO, learners developed greater agency in their Maths learning, attempting incorrect sums or whole sections repeatedly until they had mastered it, and telling friends and family of their achievements in MCO. Although the decreased confidence appears to contradict learner's developing agency and increased SBA results, the decreased confidence is particularly encouraging as it suggests greater calibration between learners' perceived judgement of their learning and their actual performance.

The data collected between 2016 – 2018 indicates that MCO had a significant impact on learners' calibration of perceived learning and actual performance. During 2016 – 2018 learners had been repeatedly exposed to the feedback from Brain Quest attempts, given an opportunity to retry sections they struggled with to improve on this, and done several MCO SBAs. As can be seen in Figure 14, in their second year of participation in MCO, fewer learners felt positive about Maths compared to their third year of participation when up to 84% of Grade 7s going into high school, 88% of Grade 6s and 91% of Grade 5s felt positive about Maths. Data triangulated from interviews and surveys, confirms that learners' agency increased, and that they were observed to be more confident and engaged in Maths in the second and third years. Learners can be seen to be overconfident in their Maths learning in the first year, and underconfident in the second year, seeing as their actual performance was relatively low in the first year and slightly higher in the second. In the third year, learners' perceived judgement of their Maths learning and their actual performance showed a greater degree of calibration, aligning more closely. One could infer from these results that the three years of repeated use and exposure to the regular feedback from MCO Brain

Quests and SBAs, served to calibrate learners' judgement and expectation of Maths to more closely align with their actual performance. These findings offer a significant contribution to new knowledge in the field of learning sciences as there has not been similar studies that show longitudinally how learners' calibration can be improved. In this, Green Shoots MCO offers an unexpected and exciting avenue for further research.

5.3 Raise learners' Maths attainment

The Maths average attainment of learners using MCO as part of the IMP improved steadily between 2016 and 2018 as measured by the independent Western Cape Education Department (WCED) systemic Maths assessments. On average, the WCED schools increased in the same time period by 4.7% while schools participating in the IMP increased on average by 8.95%. This was corroborated by district officials who noted a '*definite improvement*' in learners' attainment specifically after the second year. Officials noted of this:

> District Official 1: '*Our WCED test results have improved with our participating schools showing an average of 11% to 15% improvement.*'
>
> District Official 11: '*The improvement in the results indicates that learners using MCO are progressing at a better rate than the learners at schools who do not have MCO.*'

Systemic Maths assessments are not written in the Northern Cape province, so a similar independent validation of improvement cannot be made. However, the Northern Cape learners completed the same MCO SBAs as learners in the Western Cape which are set in collaboration with the WCED district officials. Based on the MCO SBA results, the number of learners who passed these tests increased at five of the Northern Cape schools by an average of 17.48%. (Three Northern Cape schools are not included as they did not complete the MCO SBAs in 2018, and/or did not participate in the project from 2016-2018.) One school improved from 7% in 2016, to 18% in 2017 and achieved a 50% pass rate in 2018, an increase of 43% in the number of learners who passed between 2016 and 2018. As discussed in section 5.5, parents from the nearby town started bussing learners to this little farm school because of the marked increase in their children's Maths results. At the other schools where learners' MCO SBA results increased, the principals also noted an improvement in learners' paper-based exam results during the same period.

In the Western Cape, a departmental official noted an increase in learners' Maths results in her district between 2016 - 2017. She emphasized that during 2018, this improvement had been sustained and that they were hopeful that the systemic results published early in 2019 would confirm this. Citing Hattie's (2009) study of the factors that impact learners' attainment, she identified the regular and instant feedback learners receive after each Brain Quest as the single greatest contributing factor that increased learners' attainment. Another official attributed the learners' increased attainment to the positive impact MCO has on learners' perception of Maths, stating:

> District Official 2: '*Green Shoots MCO assists learners to overcome their fear of Maths, to interact with Maths concepts in a very relaxed manner and to love the subject. When learners love Maths and overcome their fear, they can progress.*'

Where learners' attainment did not improve, district officials identified school-based factors that contributed to this. Regular use of the Brain Quest is critical to improve learners' attainment. Teacher failure to use the Brain Quests regularly throughout the term, was repeatedly singled out as a significant impeding factor in learners' failure to improve. When MCO is not regularly used, learners are not exposed to the regular feedback, the varied levels of questioning and their mathematical literacy does not increase as intended. Failure to regularly use MCO could be related to device or connectivity challenges: in some instances, equipment or Telkom lines were stolen or damaged, or electricity supply to schools was interrupted making it impossible to use the devices. In other schools, the number of learners per class posed a challenge, forcing up to three learners to work on a device. When visiting schools, a large class in one school visited the computer lab and three learners were observed to share one chair, two sitting on the chair and one sitting on their laps.

Large classes with limited devices pose a challenge during Brain Quests but pose an even bigger challenge for MCO SBA twice a term. The SBA is completed individually and under exam conditions. Learners are given a defined time limit to complete the SBA (typically one hour) and may not communicate with other learners while completing this. An invigilator ensures compliance to these conditions. Larger classes have to be split when completing the SBAs with half the class typically completing the SBA in the computer lab, while the other

half are in their regular classroom. This poses challenges to the school's timetable, which very often runs on 30-minute periods, and special arrangements need to be made for learners to complete the SBAs. In some schools teachers let learners write the SBAs after school to compensate for this. It is therefore not surprising that not all schools working with MCO completed the SBAs as regularly as intended.

In other instances, district officials noted that teachers only used MCO SBAs without letting learners complete the Brain Quests. This posed a further challenge and detrimentally affected learners' achievement. When learners are used to working in a paper-based format during the term, the online format of the SBA is relatively unfamiliar, and learners do not do as well as expected. During their interviews, learners and teachers noted that the Brain Quests taught learners to write accurately, using the correct symbols, units or spellings. When learners are exposed to only the SBAs and not the Brain Quests, they don't have an opportunity to see where they made mistakes in spelling or when using the incorrect symbols for example, and therefore never get an opportunity to improve on this. District officials therefore repeatedly emphasized the need for learners to complete the Brain Quests regularly in preparation for the SBAs, as one official noted:

> District Official 2: '*Brain Quests are essential to prepare learners to do the SBAs. When they don't do the Brain Quests they aren't properly prepared to do the SBAs which detrimentally affects their performance in the SBAs.*'

5.4 Impact the Education Department and school's practice regarding ICT Integration & data analysis

The IMP has impacted and, in many ways, supported culture change within the schools and districts where it was implemented, '*becoming a part of the district DNA*' (District Official 4). This culture change was achieved in various ways, starting with the underlying philosophy of Green Shoots as an organisation, it's approach to change and resulting in districts and schools shaped by data informed learning.

Green Shoots as an organisation espouses a socially embedded approach to change. Avgerou (2010) defines a socially embedded approach to development and the use of

technology especially in developing contexts, as the construction of new techno-organisational arrangements within local contexts. A socially embedded approach emphasizes innovation as embedded and arising from local contexts. This stands in stark contrast to a transfer and diffusion approach that sees innovation as developed often in first-world contexts and applied as generic, universally transferrable skills, applications or behaviours to developing contexts. Technology developments from a socially embedded approach see technology innovations as arising from local problematizations. Technological innovation in this view, is thus shaped '*by the way local actors make sense of it and accommodate it in their lives*' (Avgerou, 2010, p. 5). The socially embedded approach to development and innovation espoused by Green Shoots, has achieved significant culture change through the development of different techno-organisational processes within local contexts.

The Green Shoots team approach socially embedded change in a holistic manner, supporting techno-organisational development at all levels. The Green Shoots team built a trusting, open relationship with provincial and district officials, as well as school communities. In various interviews, officials spoke of the trust and respect they held for the directors, and the various Green Shoots team members they worked with. They achieved this by creating opportunities for and maintaining open dialogue with all role players, from parents to subject advisers, teachers and principals. For example, one district team explained how the Green Shoots team worked closely with them to create the various SBAs placed on MCO. In this way, MCO SBAs became a locally developed innovation that arose from local contexts and addresses local problematizations, i.e. the need for a standardized assessment tool. The district team, having played a significant role in the development of MCO SBA, subsequently drove its use in the schools participating in the project, shaping how the tool was used by local actors and how they accommodated it in their classes.

Secondly, Green Shoots supported socially embedded change by problematizing the need for data to inform learning. Before MCO, districts had to rely on schools to provide data of learner progress. Typically, the data was only received after learners had written tests or exams, and some weeks if not months had passed. In some cases, officials indicate, that they did not have access to data unless they went to schools (especially in remote or rural locations). Where results were submitted via official channels, these became part of official

reports, but had little direct impact on the teaching and learning taking place in classrooms. MCO produces weekly Brain Quest usage results that is placed on a dashboard for easy access by all parties. Additionally, MCO SBAs are completed twice a term, typically in week 5 and 8, results of which are also instantly available.

The accessibility of data was problematized, and local actors accommodated this within their contexts in different ways. Districts use the data from the BQs and SBAs to track how schools and circuits perform, to identify general challenges and gaps in learning and to strategize how to address these. Districts would for instance, once they identify a learning area that needs attention, organise professional development sessions for teachers to strengthen pedagogical or content knowledge in this area. Schools may use the same data to identify learners who need specific forms of support or extension, or to identify gaps in teaching that can be addressed through local school-based systems.

Another problematization that grew from the use of MCO data, was the need to identify gaps in teachers' pedagogical content knowledge and develop targeted interventions to address teachers' professional development. Teachers and district officials widely celebrated the Green Shoots PLCs as having a significant impact on the quality of Maths teaching and learning. The PLCs, one official commented, provided a space where '*teachers can talk to other teachers*', share best practices, challenges and how they overcame these.

The PLCs also provided a means to strengthen teachers' methodology, or using Mishra and Koehler's (2006) framework, to develop Mathematics teachers' pedagogical and content knowledge. Following their engagement in the PLCs, district officials attest that teachers

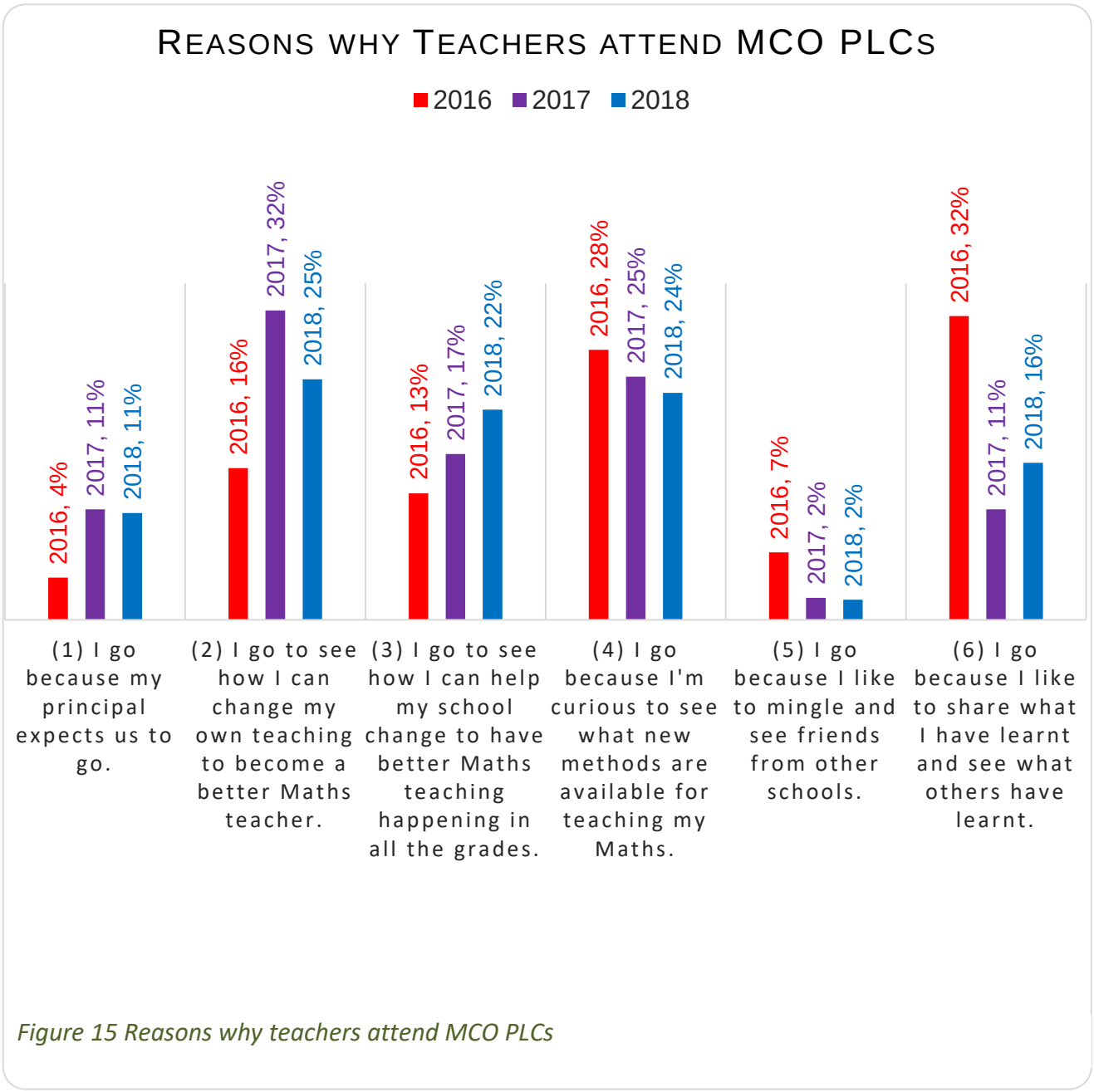


Figure 15 Reasons why teachers attend MCO PLCs

were more confident and knowledgeable about specific areas in Maths. This was confirmed by teachers who noted they felt more confident to teach Maths after their engagement in the PLCs. Survey data from 2016 – 2018, as presented in Figure 15 show that teachers attended these PLCs for different reasons. The socially embedded approach to change is reflected in the greater ownership teachers took for their participation in the PLCs, wanting to attend for example, to see how they can help their school change to have better Maths teaching happening in all grades.

The PLCs also provided a means to deepen teachers understanding of Maths learning. The subject advisers all felt that teachers needed to develop a deeper pedagogical content knowledge that would allow them to interrogate the methods learners applied. They felt that the PLCs provide a vehicle to achieve this. PLCs are structured to help teacher reflect on and analyse their learners' performance, developing their ability to make data informed decisions about teaching and learning. Using data from teachers' own MCO usage and how their learners performed, teachers can gain insight into areas where learners struggle, and in conversation with other teachers, identify ways to address this. One district official added that he particularly valued the PLCs to help teachers understand *why* learners made mistakes in their MCO and general Maths work. He valued the PLCs because it developed an inquiry mindset among teachers to question for example, whether learners' incorrect answers were a result of miscalculation, misconception or incorrect application of a method or process. In this way, the PLCs not only develop insight into students' learning, but also a means to problematize gaps in teachers' pedagogical content knowledge to address this.

Another role the PLCs played, was that of innovation embedding mechanism using a lead-teacher model. Teachers, principals and district officials repeatedly spoke of a general fear of technology, and specifically teachers' fear of using technology for Maths teaching and learning. Green Shoots, working with district officials, initiated a lead-teacher model that identified champion 'lead teachers' in different schools to become mentors and leaders for other teachers within their schools and the greater communities. Lead teachers share their experiences, best practices, and systems and processes they use to ensure regular, effective use of MCO. Principals and district officials were positive about the use of lead teachers, with one official's comment summarising the general opinion:

District Official 4: '*The lead teacher model is a strength as these experienced teachers can provide practical advice on what works in their own classes.*'

Apart from the PLCs, district officials also called on lead teachers to facilitate training or workshops with other teachers in the use of MCO or Maths in general. In some cases, district officials noted, schools even approached lead teachers (not based at their schools) directly for assistance. The use of the lead teacher model embedded change within local contexts, with the lead teacher being familiar with the challenges and opportunities within similar schooling contexts and offering relevant and meaningful advice on how to overcome these.

The PLCs provided a significant mechanism to achieve socially embedded change to the culture of schools and districts participating in this project. District officials and principals in one particular district, variously commented that the PLCs created synergy between districts, schools and classrooms, and contributed to a strong team-spirit. The use of data within the PLCs improved accountability at all levels, since teachers and officials each learnt to analyse their own schools or classroom result, compared these with their colleagues, and started seeing patterns. Based on a transparent use of data, the participants in the PLCs were able to develop a trusting relationship, which as one official noted, had a ripple effect on schools within her district. She observed that the data analysis done within the PLCs, impacted the way school principals treated teachers as professionals because they trusted the teachers more. Following their participation in the PLCs, teachers shared their experiences with colleagues, which in turn positively impacted the culture within their schools. District officials also explained that when non-Comic Relief schools in their districts heard about MCO, they applied to participate, so the district availed funds for up to twenty additional schools to receive MCO. Funding has since been secured to sustain and expand the roll-out of the Green Shoots MCO in 2019. In this way, MCO PLCs impacted not only schools participating in the IMP, but many beyond this.

The socially embedded approach to change followed by Green Shoots, is also evident in the increased use of data to inform district officials, school leaders and teachers' choices regarding teaching and learning. The use of data from MCO bears further discussion, since it

so widely impacted practices and achieved socially embedded techno-organisational change within schools and districts. This is hence discussed in relation to the last two indicators.

Indicator a) Extent to which Grade & Phase (grades 4-6) Maths teachers use data analysis to plan shared strategies/interventions to tackle common barriers to learning or support specific learner groupings

MCO data embedded new techno-organisational systems and structures in schools and districts, problematizing how choices are made and identifying the need for data-informed decisions. As previously discussed, teachers reported a year-on-year increase in their use of MCO data, see Figure 3. This finding was triangulated with observations by principals and district officials, who variously noted:

> District Official 2: '*…data is being used to inform classroom practice and inform improved future teaching and learning.*'
>
> District Official 4: '*Teachers are meeting regularly to discuss and analyse the data.*'
>
> District Official 8: '*The data has been used to guide some schools … to consolidate the topics where learners under perform.*'

New techno-organisational systems formed as a consequence of teachers using MCO data on a regular basis. Through the weekly analysis of MCO data, teachers can pin-point exactly where learners are struggling and can design interventions to address learning gaps. The number of teachers who self-reported that they did this, increased from 23% in 2016, to 77% in 2018, an increase of 54%. Triangulating teachers' self-reported data with district officials and principals' data, confirmed this substantial increase. Before using MCO, teachers typically identified learners who are struggling through informal assessment in the classroom, observing learners' body language and listening to individuals answer questions, or when marking workbooks. Formal classroom-based assessments twice a term provided a further means to identify learners who are struggling and to identify learning gaps. Both informal and formal assessment of this nature are problematic: informal assessment measures are not always accurate and are often based on teachers' perceptions and judgements, rather than irrefutable data. Similarly, formal assessments are done at key

points in the term once large sections of work had been completed, and do not frequently allow the teacher to drill down and identify specific misconceptions or tiny gaps in learning that may grow into large challenges later. MCO problematized this particular aspect of teaching and provided an innovation that teachers could embed in their practice to directly impact learning. By using and interpreting MCO data on a regular basis, most teachers (84% in 2018) could identify exactly which Maths concepts learners struggled with (compared to 23% in 2016) to address these gaps in learning.

Teachers' increased use of MCO data between 2016 – 2018 further developed techno-organisational communication systems. District officials and principals repeatedly noted in 2017 / 2018 interviews and surveys, that teachers started talking to each other about learners' Maths achievements and challenges. Foundation Phase and Intermediate Phase teachers within the same school typically remain apart, and communication between Grade 3 and 4 teachers in most schools is rare. It is therefore particularly important to note that district officials and principals, as well as teachers themselves, reported greater communication between teachers from different phases. One district team explained that MCO Data provides a trusted, standardized assessment of learners' Maths knowledge and skills. Therefore, Grade 3 end-of-year assessments are now regularly used by Grade 4 teachers for benchmarking learners. Teachers' also communicate more regularly between grades, with 62% of teachers in 2018 reporting that they regularly share their MCO results with their colleagues in grade and phase meetings compared to 15% in 2016, a 47% increase. One could infer from this that teachers developed a greater trust in their colleagues to share results with them, expectant that they would receive support to address learning gaps. The development of organisational communication systems, district officials and principals pointed out, built greater team spirit among teachers, schools and the district, which further motivates and drives excellence.

Indicator e) Extent to which Principals understand termly MCO SBA data analysis, can identify key trends and have used the data in supporting staff/whole school curriculum planning/managing the Maths Curriculum

Data from principals and district officials indicate that at school level, MCO data was increasingly used between 2016 – 2018 as means to identify trends and design interventions

to support teachers' pedagogical and content knowledge development. Two officials noted of this:

> District Official 1: '*…there is a definite improvement of how schools are engaging with the data available.*'
>
> District Official 3: '*Schools use the data to design learner intervention as well as teaching practices.*'

These two district officials' observations indicate that while most schools participating in the IMP increased their use of MCO data between 2016-2018, different techno-organisational systems and structures developed at an organisational level. Principals indicated that they use data from MCO in different ways, with two typical examples included here:

> Principal A: '*I find the data that shows comparisons between two grade classes useful as it urges us to find out why the one class is not performing as well as the other or why both are not performing as required. I also find data on usage useful as it shows which classes are keeping up with the pace of the Maths curriculum.*'
>
> Principal B: '*1) Teacher / Class completion rates - give me some idea of curriculum pacing and completion; 2) Performance per class and teachers' performance in teaching Mathematics - it gives me some indication on who needs possible professional development or inset; 3) The Data across the grades also give me an idea of gaps in the curriculum that learners are coming up with - this helps me with staff redeployment to get more competent staff teaching Maths; 4) I also use per class or grade data for teachers evaluating own practice and performance, encouraging them to do things differently to improve performance; 5) The itemized data shows focus areas for re-teaching or remedial work.*'

As indicated by these two principals, MCO data was used to develop an accurate, transparent and immediately available system to track usage of the innovation, i.e. MCO. Devices and internet connected has been supplied to many schools across South Africa, but invariably remains underutilised or completely unused (Bladergroen et al., 2012; Chigona, Chigona, Kayongo, & Kausa, 2010; Tarling, 2018). There are currently very few effective systems in place in schools and districts, to measure how teachers use devices or the

internet once this is supplied. MCO data, as principals indicate, problematizes this challenge and provides school leaders with a means to track usage by teachers and learners, and to address this.

MCO data also enables schools to develop techno-organisational systems that measure curriculum coverage and pacing. As the principals above indicated, correlating to the data from surveys and interviews with teachers, principals and district officials, MCO data is widely used to monitor curriculum delivery. Principals frequently noted in their interviews that they battle to find time to do regular classroom observations, often only getting to classes once a term if they are lucky. They rely on their Heads of Department (HODs) to monitor teachers' pacing and delivery of the curriculum. This may not always be the most reliable method, as HODs typically take teachers' planning in once or twice a term, or review assessment marks at the end of the term in order to give feedback to the principal. Once marks have been collated or planning books reviewed, teachers' challenges with curriculum pacing or delivery may be far greater, having compounded in the course of a term or two. Principals therefore celebrated the use of MCO data that led to the development of techno-organisational structures such as Maths committees and grade meetings once every two or three weeks. These new techno-organisational structures became necessary within the schools that used MCO data to determine teachers' pacing and delivery of the curriculum, to identify small challenges '*in time*' (timeously) and prevent these from becoming unsurmountable or compounded. In this way, the local socially embedded change that resulted from the increased MCO data usage not only impacted individual teachers but transformed whole schools to form or enhance cultures of teaching and learning.

Another techno-organisational system that developed across schools was a system to identify gaps in teachers' pedagogical content knowledge and design targeted strategies to address this as noted previously. Educational researchers have repeated noted that the leadership in many underperforming South Africa schools are often unable to manage the complexities of multiple deprivation in which they function (Maringe & Moletsane, 2015) and do not often have the skills or capacities to design targeted strategies (Christie, Sullivan, Duku, & Gallie, 2010; Taylor, 2008) to improve learning in their underperforming schools. MCO data and principal PLCs provided principals with a mechanism to problematize teachers' learning or pedagogical content knowledge gaps, and a means to address this. In

interviews, two principals, one from a township school and another from an urban, relatively well-resourced school, noted the immense value they gained from attending the meetings / PLCs with other principals in their district and particularly addressing this need. MCO data assisted these and other principals, to problematize teachers' learning gaps in order to develop innovations to address this, which was not previously possible.

Many schools by the end of the project, as observed by the district officials, were using the data to plan Maths teaching and learning. However, district officials also noted that by the end of 2018 most schools were using their MCO data to compare the school's Maths achievement with the district's improvement plan, and then set goals for the school to improve on this achievement.

Additional c) Extent to which district officials use data from MCO

In general, district officials themselves started using data from MCO more effectively during 2017, and optimally in 2018. The majority of officials use MCO Dashboard to identify schools, teachers and learners that underachieve in Maths, and design interventions to improve this. Relevant comments from officials include:

> District Official 4: '*The Circuit Managers are using the Dashboard to monitor usage and progress.*'
>
> District Official 5: '*We have used the data to inform our school visits.*'
>
> District Official 6: '*MCO data is used across the phases and in particular by the Maths Advisers to monitor the progress or challenges their schools per grade are experiencing. Maths Advisers and the GET Coordinator reviews schools' data and do comparisons to Term Performance and even Systemic results in terms of grade 3 and 6.*'
>
> District Official 11: '*The Subject Advisers for Mathematics use MCO data to identify areas of concern in terms of Conceptual understanding of Mathematics in teachers and learners. We use the data to identify learners at risk in our under-performing schools.*'

MCO Data in particular allows Districts to adopt a techno-organisational systemic approach. District officials use MCO data to gain a district-wide holistic overview (District Official 2) of the whole district's usage and achievement in Maths on daily and weekly basis. This overview allows the district to develop preventative techno-organisational systems to identify challenges before they turn into major concerns that may damage the district as a whole. It also allows a positive feed-back loop since gaps in learners' attainment can be identified across the district, and interventions designed to address this, and the effectiveness of this intervention can in turn be tracked by measuring learners' performance in subsequent activities.

Similar to the techno-organisational systems that MCO data enables at school-level, districts are also able to track usage and hold teachers accountable for under-usage of MCO. When MCO within a school is repeatedly not used, this provides the eLearning Advisers in a district with an early warning system that device or internet connectivity may be a problem in a school (District Official 4 and 7). Additionally, the general capacities of all district staff to analyse and interpret data, impacts all aspects of their work and as District Official 9 indicates, improves the skill set of the district as a whole.

5.5 Unplanned outcomes

The use of the IMP also contributed to different unscheduled aspects and achieved various unplanned outcomes. One district official's comment summarises a generally expressed feeling:

> District Official 1: '*This is an awesome programme which has many advantages for the learners, educators and District. … It is a dynamic programme offering enormous support in collecting, recording, analysing of data and implementing support programmes.*'

The various unplanned outcomes and advantages offered in addition to the set outcomes and indicators for the IMP are discussed in terms of curriculum pacing and delivery, assessment, saving teachers' time, learners' school attendance, the after-school Maths programme, and increasing professional collaboration.

Curriculum Pacing and Delivery

Data from MCO, as noted previously, provided a mechanism to measure and increase curriculum coverage within schools and districts, and to '*improve specific areas in the curriculum*' (District Official 9). It also improved the quality of teaching since teachers were better prepared for lessons. Two district officials noted in this regard:

> District Official 4: '*MCO is CAPS aligned and assists teachers to correctly pace their teaching and assessment. Teachers can now also get immediate feedback on learner performance which enables them to reteach when necessary. School Management teams can monitor progress and effective curriculum delivery.*'
>
> District Official 1: '*The educators who are using the programme well are more prepared for the next weeks Brain Quests; they have accessed it, worked through it, printed out the activities – so there shouldn't be any technical hitches…*'

Reteaching is often based on teachers' impressions or observations, which may not always be the most reliable measure of learners' performance. MCO data on the other hand, provides teachers with an accurate, immediate means to measure areas where learners struggle in order to reteach that specific area. Reteaching, as different district officials noted, is not a common occurrence in many classrooms as teachers feel under pressure to move forward and get through the curriculum. However, the data from MCO allows teachers and officials to make informed decisions, and teachers can reteach to close the gaps in learning (District Official 5).

Assessment

Another unplanned outcome has been the impact MCO had on Maths assessment processes. At the time of the interviews, the winter half-year exams were still fresh in memory and many teachers had submitted tests for their school-based assessments during that term. During moderation of the question papers in the past two to three years, principals and Maths HODs noted a significant improvement in the quality of Maths papers, and in the variety and levelling of questions types. Mr K. noted that teachers modelled their question papers on the different MCO question types. Before setting the question paper, they review the question types in MCO and fashion their questions to address the different types and levels therein. Mrs R., the Maths HOD in her school, explained the process:

> Interviewer: *Have you seen a difference in the way that teachers ask questions in their exam papers?*
>
> Mrs R, HOD: *Yes, there is a vast difference. … Before they set their task* [exam] *we sit down and engage per grade, and we go through the policy and discuss what should you do…. Then* [TTA at the school's name] *prints the questions from the Green Shoots. So individual teachers will go to her and she downloads the questions and they use the questions to set their exam papers.*

Although not an intended outcome, MCO had a positive impact on the assessment practices at the project schools. Teachers' ability to ask questions that are more varied and appropriately levelled, developed as a consequence of their engagement with MCO.

> District Official 6: '*Teachers are more aware of different types of questions. Teachers also notice that graphical images also helps to entice and capture learners' attention [during assessments].*'

Greater variation and levelling of questions in turn requires higher levels of mathematical literacy and a greater variety of strategies of learners. In this way, the improved assessment practices of teachers following their engagement with MCO, served as a tool for transformation within the schools.

Another unintended outcome has been the increase in learners' attainment based on the different format of assessments. Teachers, principals and district officials noted that many learners struggle to complete assessments in paper-based format, but do better when completing online assessments. One official notes for example:

> District Official 6: '*several teachers and principals have mentioned incidences where learners that are not performing very well with written assessments and exercises in the ordinary classes, are showing improvement in the Brain Quests and … the SBAs.*'

MCO activities and assessments, it was repeatedly noted by participants, make use of vivid and colourful visuals, that help learners to understand the question better and therefore improves their ability to answer exactly what is required. In this way the online format benefited learners attainment more so than paper-based formats that typically use black-and-white photocopied visuals.

Saving Teachers' Time

MCO provides teachers with fully prepared, CAPS aligned resources and assessments, and grades their learners' work providing immediate feedback (District Official 2). This saves teachers tremendous amounts of time as they do not have to create or find these resources or assessments, or mark and provide feedback. Two officials noted of this:

> District Official 1: '*It has definitely saved the educator time, which was previously used for marking and tedious analysis, where they now could do their analysis at the click of a button, and thus prepare and plan for the next level of support.*'
>
> District Official 5: '*Teachers are provided with more time to teach concepts instead of focusing on setting papers and marking scripts.*'
>
> District Official 7: '*The programme has made a good impact with the schools using it. The immediate feedback teachers receive and not having to mark the formal assessment tasks, yet they get a detailed report on each learners' performance.*'

These comments variously emphasize the positive impact MCO activities and feedback had to improve the quality of Maths teaching and learning, by removing aspects that teachers find tedious and laborious. Marking is often a challenge especially in large classes, as is administrative duties like preparing and interpreting data from learners' marks. MCO activities and data thus removes these tedious activities, leaving teachers with more time to engage with and plan higher quality Maths lessons.

Learners' School Attendance

Additionally, an unexpected outcome has been the increase in learners' school attendance. Learners' and teachers' attendance at underperforming schools are widely identified as a problematic (Christie, Butler, & Potterton, 2007; Christie et al., 2010; Spaull, 2013; Taylor, 2008; Weeks, 2012), as it hampers efforts to develop a culture of teaching and learning in schools. In several interviews with district officials, principals and teachers, it was noted that learners, even when ill, attended school on days when they could go to the computer labs to do MCO. Mrs M., a teacher at one of the schools, explains:

> Teacher, Mrs M.: '*Once a parent came to the school and said that the child was sick and the child want to come to school, who didn't want to stay home.* [The child] *was telling her about this Green Shoot. What is this about this Green Shoot? Then I started to explain to her Green Shoots is helping the learners and Green Shoots is online activities, it's computer-based, tablet. They become computer alert, it's like a cell phone, they like this technology. They say 'Wow, really?', then she said I see that my child's marks has improved, and I yes. They don't want to stay home with this computer lesson, they know every Tuesday and Thursday there is no way that I must be away from school because I'm gonna miss, so they started to see Oh this is really helpful.*'

As another principal noted, learners love working on the computers and particularly love achieving on MCO, and there is regularly 100% attendance for classes on days when learners have MCO in the computer labs.

One case is even more significant in this regard. School P is a deeply rural farming school that uses MCO in an offline manner. Since they started using MCO, parents have noticed an improvement in learners' attendance and attainment in their Maths. Children from this little farming school would typically go to high school in the nearby small town, where their teachers noted their improved Maths skills as well. As a result, parents started taking their children out of the town school and placing them in the farming school instead. In 2018, a bus was arranged to transport children from the town to the farming school, including all the orphans in the town's orphanage. The school's increased Maths results as a consequence of MCO, thus led to a greater intake of learners, and in turn, the provincial government made more money available to provide two more educators at the school. As a result, in 2018 the multi-grade classes previously observed at the school were replaced by single grade classes, an extremely positive step towards increasing the quality of teaching and learning for all learners. MCO thus had a far greater positive impact on this small school than was intended, and one can only hope this is sustained.

At another school, School I, a similar situation was reported. The principal noted that since parents heard that their children could work on MCO, the school received far more applications for children to join the school than in the past few years. The increased number of learners allowed the school to gain an extra teacher as well as an additional deputy

principal position. The school now has a waiting list of prospective parents, suggesting that further positive changes may be achieved in the next few years.

After-School Maths Programme

Another unintended outcome from the IMP has been an increase in the number of learners on the after-school Maths programme. As Mrs M. noted above, parents heard about MCO and in response to their children's pleas, enrolled them in the homebased after-school programme. This was a widespread experience, as Mrs N., an HOD at one of the schools, explains:

> Teacher, Mrs N.: '*The parents even interrupt the meeting because of MCO. The parents even ask can they be loaded on their computers so that the kids must do it at home. The way the kids relate to the story of MCO and the parents are very happy, they do get feedback because the learners show them the results every week and every assessment they show them and tell them what they do and parents say it in meetings how happy they are with MCO. This parent* [now] *wanted to know if the child finishes here with this MCO do they also have Maths online in high schools and if not where can she subscribe for MCO for his child when the child goes to high school because the programme is really good if possible she wanted the child to continue with MCO up until* [Matric/Grade 12].'

A higher proportion of parents of children who attend underperforming schools in challenging socio-economic contexts, are illiterate or innumerate, having never attended or dropped out of school at an early age. However, as any parent wishes, they want to provide better opportunities for their children. As Mrs N. explains above, and Mrs M. in the previous section, parents see the homebased after-school MCO as a means to provide their children with opportunities they never had. Even in the most dire economic conditions, they provide their children with devices and connectivity to achieve this, and in turn, improve their children's attainment in Maths.

Increased Professional Collaboration

Isolation and silo-teaching is a common occurrence in schools globally, as well as in South Africa. Although the strengths and value of professional collaboration are widely acknowledged (Darling-Hammond, 2010; Hargreaves, Earl, Moore, & Manning, 2001; Lortie, 1975; Talbert, 2010; Twining, Raffaghelli, Albion, & Knezek, 2013), deep-seated traditions of

teacher isolation (Fullan, 1995; Hargreaves et al., 2001; Lortie, 1975) limit collaboration between teachers (Hargreaves et al., 2001; Talbert, 2010; Twining et al., 2013). MCO problematizes the isolation between teachers and provides a means to create structures to support collaboration and communication. As Mrs N. explains:

> Teacher, Mrs N.: '*As a teacher before the Maths project I must tell you honestly there were things we really didn't know how to approach it. Now we used the teachers, like from grade 4 even to 7. So if we don't understand something we go to the other teacher, we can even ask the grade 4 teacher to come and introduce for you a certain topic, but with Maths online when you come to that topic there is always that teacher talk that it's easier. It helps me as teacher.*'

The increased collaboration and communication translated in district-wide team spirit that developed between classrooms, schools and circuit teams. District officials repeatedly noted and celebrated the synergy and team spirit that was not in the district before the IMP. They attribute this to the trusted, reliable and transparent use of data from MCO, the support from the Green Shoots team and the work of the whole district to develop a culture of teaching and learning.

5.6 Final insights

Green Shoots commissioned the monitoring and evaluation of the IMP to answer three key research questions.

1) What contextual factors impact the effectiveness with which the Green Shoots model is implemented, and/or which IMP elements are essential to the sustainability and successful integration of the programme when scaled?
2) Suggest an effective means to measure learners' progress and produce reliable and detailed evidence to communicate with key stake holders and decision makers.
3) What processes regarding data informed decision-making support change to district and school practices?

In this last section, these three research questions are answered separately.

1. What contextual factors impact the effectiveness with which the Green Shoots model is implemented?, and/or Which MCO elements are essential to the sustainability and successful integration of the programme when scaled?

Various contextual factors that impact the effectiveness with which the Green Shoots model is implemented, were identified from the different data sources. These factors are discussed in terms of critical success factors, as well as advantages, though not critical to the implementation of IMP.

Local actors

When evaluating a school or district for potential MCO implementation, the mindsets of local actors significantly influences the potential impact the programme may have on the context, and is identified as a critical success factor. Teachers and leaders within schools should be open and willing to work with the Green Shoots team. They should be willing to change and disrupt existing practices, processes and priorities to transform their current teaching and learning processes. School-based leaders and teachers should also be willing to learn and specifically learn how to manage, analyse and interpret data. In many instances it was noted that teachers and even school leaders, HODs and principals, lacked the skills to analyse and interpret data, and that they needed to be willing and open to learn how to do this in order for MCO to have a definite impact on learning in their schools. Teachers in particular should also be willing to change their paper-based routines and start working with technology to teach Maths. Many teachers noted that they had to first overcome their anxiety and fear of teaching with technology before they could effectively start using MCO.

Although not critical success factors, various other factors relating to local actors was identified in the data. Technical teacher assistants to work in the lab and support teachers and learners as they engage with MCO was widely celebrated as important, and in some cases even vital to the success of the programme's implementation (discussed in greater detail below). Another advantage is the presence of one or two champion teachers who can learn to use the programme, get enthusiastic about it and positively influence other teachers. It was noted that champion teachers influence others and build a critical mass to change the culture of schools. Although not a critical success factor, a champion teacher or

two is a huge advantage. Lastly, teachers' willingness to sacrifice their time was another advantage. In many schools, teachers would work after school, on Saturdays and in holidays to provide learners with additional time on MCO. Though not a critical success factor, this willingness was identified as a tremendous advantage in MCOs implementation.

Material and/or organisational arrangements

One of the biggest risk factors to the IMP's implementation is device and second to this, connectivity challenges. It is therefore a critical success factor that School Governing Bodies (SGBs) are willing and take ownership of providing devices and resources for maintenance and security of devices. This maintenance should where possible include resources to provide and maintain air-conditioning units especially in areas where summer and winter temperatures are extreme. Secondly, resources should be allocated, and responsibility taken for the provision and maintenance of internet connectivity to support the online component of MCO (where online is used).

Also, of critical importance, is a leadership team committed to plan and monitor MCO's implementation and hold teachers accountable for usage. The leadership team must prioritise and communicate usage goals with the staff, and develop techno-organisational systems to place pressure (though gentle) on teachers to adhere to this.

Although not critical success factors, other organisational factors were identified as advantages. Synergy between the SGB and school leadership is highly advantageous to MCOs implementation. When conflict arises between SGBs and principals/HODs this often has a detrimental impact on the climate within the school as whole, negatively impacting MCO implementation. Where possible, all role players within an organisation should be consulted and structures within the organisation used to do so, to achieve buy-in from all parties. This greatly enhances the implementation of MCO.

Timetabling within the organisational is a further important, yet not critical success factor. Timetabling and regulated use of MCO is critical to the successful implementation of the programme. Well-functioning schools are often characterised by regulated routines and timetables, while under-performing schools frequently lack scheduling or even basic timetables leading to high absenteeism and disorganisation. A well-established timetable

within an organisation is a huge advantage, but as was seen in 2017, not a critical success factor. One school for instance, had no functioning computer centre timetable when MCO was first introduced, and lacked basic ICT organisational structures. Due to these factors MCO was poorly implemented, as noted in 2016. However, a significant change was observed during the site visit in 2017. A new technical teaching assistant (TTA) had been employed a few weeks prior to our visit. Within the otherwise struggling school, she regulated use of MCO, fetching classes and supporting teachers to start using the programme. In this case, although an organisational timetable would have been advantageous, the critical success factor was the dynamic TTA that displayed tremendous leadership, agency and commitment to drive implementation of MCO.

Organisational structures

Different organisational structures proved to be advantageous to the successful implementation of MCO, but not critical to its success. A well-managed communication structure and clearly defined lines of communication is highly advantageous, but in many schools this was not available at first. The PLCs and ongoing support from the Green Shoots team, as well as school-based innovation processes led to the development of lines of communication and structures within the organisations to manage for example how data is used within the school. It can therefore not be assumed that such systems need to be in place before MCO can be implemented, but it is an advantage if they are.

Secondly, a system to identify and monitor learner performance is advantageous but not critical to the successful implementation of MCO. Again, as with communication systems, structures to identify where learners struggle and develop interventions to address this, can develop from the PLCs or MCO data usage during MCO's implementation. Additionally, a remedial support programme to address individual learners' gaps in learning is advantageous but not critical.

Green Shoots specific factors

As with organisational structures, Green Shoots specific factors were identified as potentially being advantageous to the successful implementation of MCO. The Green Shoot's gentle approach was widely acknowledge as playing a significant role in the success

with which the IMP was implemented at schools and in districts. This gentle approach, driven by the socially embedded perspective to change, was evident in the way the directors introduced the programme, never forcing but always suggesting positive ways in which the IMP can contribute to learning. Principals, teachers and district officials repeatedly noted that they never felt forced or manipulated, but valued the fact they felt they always had a choice whether to accept Green Shoot's offer or to walk away.

The Green Shoots team also instilled much trust, and all teachers, principals and officials repeatedly commented on this. They felt they could trust the team in every respect and felt safe as a result to change their practice. The district team particularly emphasized the trust they developed in the team because they were included in the development of the SBAs. Also, they felt the data produced by MCO could be trusted, but more so, that they could trust Green Shoots to protect and keep the data safe. Such trust is not achieved overnight and can therefore not be seen to be a critical success factor. Instead, trust develops through relationship building, and as Green Shoots built relationships and trust, this greatly impacted the successful implementation of MCO.

Another advantage in many of the schools was the use of the TTAs and pedagogical support teams. Teachers and schools repeatedly noted the positive impact of TTAs, especially in poorly functioning schools, to support and drive MCO's implementation. Equally, in more well-functioning schools, principals repeatedly mentioned the trust and respect they developed for Green Shoots team members. Without their pedagogical support, alongside technical assistants, principals felt the IMP would not have been as effective.

The Green Shoots PLCs were further identified as hugely advantageous to the successful implementation of MCO. Principals placed tremendous value in the principal PLCs as a space to share experiences and learn from other principals across contexts and distances. Teachers and district officials repeatedly noted the positive impact the PLCs had on the quality of Maths teaching and learning. In particular, principals, teachers and district officials valued the PLCs as they learnt how to analyse and interpret data. Although it is often assumed that all role players in education should be adept at managing, interpreting and analysing data, participants in this study did not generally possess these skills before the

introduction of MCO. They gained tremendously from MCO PLCs that taught them to analyse and interpret data, and celebrated their new-found skills in interviews and surveys.

2. Suggest an effective means to measure learners' progress and produce reliable and detailed evidence to communicate with key stake holders and decision makers.

The measurement of learners' progress should take various factors into account. It may be tempting to equate progress to attainment, and return on investment to learners' increased attainment in external, standardized assessment. However, multiple factors impact learners' attainment and extreme caution should be applied when measuring these factors especially in young children. The survey instruments developed in this study, grounded in the research of learning scientists as reported in section 5.2, took multiple factors into account when measuring learners' progress. Findings from the survey instruments were corroborated and examined through the lenses of learning theorists such as Piaget (1962), Ausubel (1968) and Bandura (1986), and conclusions validated through the work of learning scientists like Hattie (2009, 2013) and others.

The survey instruments were furthermore iteratively refined based on the utility-focused evaluation (Patton, 2010) methodological frame. Accordingly, as means to enhance the utility, feasibility, propriety and accuracy (Patton, 2010) of the evaluation, survey tools developed in the first year of study, were evaluated in subsequent years in collaboration with the Green Shoots team. These evaluations served to refine and redesign aspects of the survey tools to increase the utility, feasibility, propriety and accuracy of the measurements.

The survey tools developed to measure learners' progress in this study was therefore validated at three levels. The utility focused evaluation methodology ensured descriptive validity of the research instruments. Interpretive validity was achieved by firstly grounding the design of the measurement tools in learning theory and then refining analysis using state-of-the-art knowledge from the field of learning science. Theoretical validity could thus be achieved through the analysis process since the descriptive and interpretive validity measures ensured the survey instruments produced reliable and trustworthy data.

The survey instruments that were iteratively developed for this study are thus validated as effectively measuring learners' progress and providing detailed evidence that can be communicated with stakeholders. Findings from the increased calibration of learners' judgement of learning and actual performance, pose a significant contribution to new knowledge and will be included in future research opportunities to develop more refined tools to measure and track this through repeat use of MCO.

3. What processes regarding data informed decision-making support change to district and school practices?

The socially embedded approach to change espoused by Green Shoots, emphasizes the construction of new techno-organisational processes, systems and structures within local contexts to drive locally embedded innovation. As such, following local problematization of contextual challenges, various actors used MCO data to develop processes that make sense of and accommodate data informed decision-making to support change at district and organisational levels. These processes were developed within local contexts in response to various needs, and created different techno-organisational processes which embedded MCO into the social context and led to further innovations, systems and structures by the local actors.

Various processes regarding data informed decision-making that supported change at district and school level were identified from local problematizations, and led to culture change in districts and schools. A precursor to the widespread increase in the use of MCO data, was the development of MCO SBAs. The district officials particularly valued their involvement in the development of MCO SBAs, trusted the weighting and levelling of questions and subsequently trusted the data produced from these. Therefore, the district officials drove its implementation in the various IMP schools where MCO was used, and directly contributed to the widespread production of data that could be used to inform data analysis processes. Every effort should be made to increase and/or maintain this collaboration between Green Shoots and the district teams as this directly impacted the implementation and widespread use of data-informed decisions.

The PLCs also proved to be one of the most positive mechanisms to effect culture change. District officials, principals and teachers commented on the benefits of their involvement in the PLCs. The PLCs capacitated participants to manage and interpret data, to identify learning gaps for both learners or teachers, and as collaborative tool to develop targeted interventions to address these gaps. The PLCs are highly recommended as tools to drive data-informed decisions in the districts and schools.

Lastly, Green Shoots underlying philosophy towards change, following a socially embedded approach, had a significant impact on the implementation and widespread uptake of data-informed decision-making. Their socially embedded approach assisted schools and districts to problematize various challenges within their local contexts, before developing local techno-organisational systems, structures and processes to address this using MCO data. In this way, innovation became part of the character of the district and schools, and not an externally produced skill or application with limited buy-in.

6. Conclusions

The majority of South Africa's township, rural or farming schools, such as those served by the IMP, have limited access to facilities or resources (Maringe & Moletsane, 2015). Researchers (Christie, 1998; Heystek & Lethoko, 2001; Maringe & Moletsane, 2015; Spaull, 2013; Weeks, 2012) have noted a persistent failure in many such schools to develop a culture of teaching and learning, and frequently describe such under-performing schools as dysfunctional. Dysfunctional under-performing schools are characterised by loosely bounded timetabling, high absenteeism of teachers and learners, and low expectations that encourage mediocrity rather than excellence (Christie et al., 2007; Spaull, 2013; Taylor, 2008; Weeks, 2012).

Due to a lack of resources, dysfunctional schools often fail to attract and retain well-qualified and experienced teachers and leaders, who lack the skills to improve instruction through designed and targeted strategies (Taylor, 2008). This legacy of dysfunction is repeatedly evidenced in international benchmarking tests in which South African learners consistently underachieve. Learner challenges typically originates in the Foundation and Intermediate Phases (Grades R-6), creating barriers to learning that extend and become

insurmountable obstacles, serving to "*preclude pupils from following the curriculum at higher grades*" (Spaull, 2013, p. 57). Educational researchers (Christie et al., 2010; Hoadley, 2012; Spaull, 2013; Weeks, 2012) correlate learners' failure to achieve to ongoing institutional, leadership and teaching challenges, concluding that learning is severely compromised in the majority of South African schools.

Since the fall of Apartheid in 1994, various reform initiatives have been implemented to improve the quality of teaching and learning in South Africa's many dysfunctional schools (Tarling, 2018). This has included three complete curriculum changes, leading to the current Curriculum and Assessment Policy Statement (CAPS). CAPS is a strictly regulated, 'teacher proof' curriculum, intended to regulate instructional time and restrict teachers' pedagogic choices within rigid boundaries. An Integrated Quality Management System (IQMS) was introduced in 2003 to monitor and evaluate policy implementation. In addition, teachers' professional development and school improvement initiatives have been widely implemented to improve the quality of teaching and learning. Devices and internet connectivity has also been widely supplied to schools as a further means to improve teaching and learning, but widespread underutilisation or non-use of these devices and connectivity limits the impact of such devices.

Green Shoots as an organisation espouses what Avgerou (2010) describes as a socially embedded approach to educational change. Rather than seeing innovation as a generic, application neutral and universally transferrable set of skills, applications or behaviours, a socially embedded approach embeds innovation in local contexts. The MCO is thus framed as a technological tool that requires local actors and organisations to make sense of and accommodate it in their daily lives (Avgerou, 2010). Innovation was achieved within local contexts where culture change occurred as schools and districts developed different techno-organisational processes, structures and systems as they problematized local challenges and developed solutions to these.

Many of the challenges so prevalent in the resource-constrained under-performing schools across South Africa, were positively impacted by the IMP. The funding provided by the Green Shoots / Comic Relief partnership allowed the project to overcome many of the resource-related challenges that prevents schools from fully utilising technology solutions.

Old, outdated computer systems were revamped and maintained for the course of the project while unused tablets were utilised alongside desktops still running on Windows XP. Before the IMP, many schools had failed to develop a culture of teaching and learning, so typical in many schools across the country. As a consequence of problematizing challenges and identifying needs within local contexts, local actors were equipped to create timetabled use for MCO which in turn impacted the regulated scheduling of other learning events in the school. High absenteeism was significantly impacted with schools noting up to 100% attendance among learners on days when they had time in the lab for MCO.

Learners also developed greater agency for their learning. They learnt through MCO to set goals for their achievement, and importantly, refined the degree of calibration between their judged expectation of learning and their actual performance. Where under-performing schools are often characterized by low expectations and mediocrity, learners' increased calibration and agency set increasingly higher expectations towards achieving excellence. Similarly, as whole districts developed a team spirit and started analysing data together as a district, it motivated teachers and principals to not just strive for learners to pass, but as Mr P. noted, to set goals to improve the quality of passes.

Lastly, the Green Shoots PLCs provided a means to identify gaps in teachers' pedagogical content knowledge and develop targeted strategies to address this. Through the PLCs, district officials, principals and teachers learnt how to manage and interpret data. As a result, they learnt to identify gaps in learning from students' results, but also identified gaps in teachers' pedagogical content knowledge. The district teams then developed targeted strategies to address these gaps, equipping teachers with precise conceptual knowledge development that was transferred to classrooms where learners gained deeper conceptual understandings as a result.

Spaull found that learning challenges typically originate between Grades R-6, and compound to become insurmountable barriers to learning essentially precluding children from learning in higher grades. The Comic Relief Green Shoots project is situated in these critical years, working with Grades 3 – 7 learners. Schools as organisations developed techno-organisational structures, processes and systems, becoming in many instances functioning institutions. Learners developed greater agency and calibrated their judgement of learning

and actual performance. Teachers gained deep insights and developed conceptual understandings to increase their pedagogical content knowledge, increasing the quality of teaching in the project schools. District officials and principals were capacitated to monitor curriculum delivery and develop targeted strategies to improve this. The data thus indicates that the greatest contribution of this project has been to establish a sustained culture of teaching and learning in schools where this was often lacking before the introduction of the IMP. Since 1994, various largescale systemic initiatives have repeatedly aimed to achieve this, and largely failed as different educational researchers found. In contrast, this team of dedicated, passionate individuals inspired under-performing schools and achieved far beyond what they set out to do. This project should be used as an exemplar for all similar future projects.

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7. References

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