

MOTIVATING MATHEMATICS AND SCIENCE TEACHERS: REFLECTIONS FROM A MATHEMATICS AND SCIENCE INDABA

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Abstract

This reflective paper sketches out the challenges that have led to the continuing poor results in Mathematics and Science in the North West province (South Africa). To unpack these challenges, a series of two-day maths and science indabas took place in the different regions of the North West province. The aim with these indabas was to identify the challenges and to suggest solutions to improve the poor mathematics and science results. Above all, the indabas were meant to give teachers motivation. Each indaba was attended by more than 450 participants, including retired teachers, motivational speakers, priests, university lecturers, maths and science teachers from primary and secondary schools, principals and head of maths and science departments in their respective schools. The challenges mentioned ranged from overcrowding, teacher's content knowledge, learner discipline, maths phobia to teaching using a multi-grade system. Many of the speakers painted a poor picture of mathematics and science and encouraged teachers to work harder to improve the results in these subjects. Participants suggested a number of possible solutions such as the establishment of "mega schools" and continuous in-service training of teachers.

Key words: **Mathematics, Science, Indaba, performance, challenges**

Introduction

South Africa faces a huge shortage of skills in fields that list mathematics, science and technology as prerequisites for tertiary training. The shortage severely affects both the private and the public sectors, and the economic growth of the country. However, the results in mathematics and science continue to be poor. Concern is mounting as to whether the education system is producing a sufficient number of graduates in the hard sciences to support South Africa's growth and development. Consequently, more needs to be done to understand why mathematics and science education is lagging behind. Plans should be devised to persuade more learners to pursue the subjects of mathematics and science. The alarming state of mathematics and science education in South Africa was revealed by the [Third International Mathematics and Science Study \(TIMSS\)](#) 2011, the largest and most ambitious international study of mathematics and science achievement ever undertaken.

Studies done by the Human Sciences Research Council (HSRC) (2001–2002) also indicate that the achievement scores in mathematics and science are very low compared with the other participating countries. According to the latest South Africa Survey, published by the

South African Institute of Race Relations (2011), only 20% of learners writing matric (Grade 12) mathematics and physical science achieve more than 50%. The results show the lowest overall increase in knowledge from Grade 7 to Grade 9. As far as subject knowledge is concerned, no significant difference in achievement is displayed between what students have been taught at school and what they have not been taught. Learners possess inadequate problem-solving skills and are unable to construct their own answers to questions. They also have substantially less contact time in classroom with teachers than do learners in the top performing countries in TIMSS. Moreover, there was evidence of language problems among learners generally, also among learners from South Africa. The current debate in South Africa about class size is not borne out by the findings of TIMSS. It is significant to note that in top performing countries, for example Korea, 89% of the students were in classes with more than 40 students. In Hong Kong, Japan and Singapore, 90% of the students were in classes of more than 30 students.

The controversial 30% threshold for a pass mark has been criticised for being too low. Shockingly, 50% of learners who write mathematics and physical science cannot even achieve this low threshold. This indicates that there are problems with the quality of teaching in these subjects, but also that learners have not grasped core concepts by the time they reach matric.

In a desperate attempt to search for the origins of the current state of affairs, a series of mathematics and science two-day indabas were held across the North West province of South Africa. The aim of these indabas was threefold: firstly, to ascertain the challenges faced in the classrooms from the teachers' perspective; secondly, to suggest alternative solutions and the way forward; and lastly, to motivate teachers so that they might try and change the situation when they return to their respective schools.

In these indabas, education officials, lectures, retired teachers, motivational speakers, mathematics and science teachers from Grades 1–12 gathered to discuss this state of affairs. Each gathering was allocated a theme and, in order to find detailed answers to the chosen theme, seven to eight commissions were formulated, with a sub-theme being allocated to each commission. Sub-themes to be discussed in these commissions ranged from attitude of learners and teachers towards mathematics and science, the role of primary school mathematics and science, the education system, the content knowledge of educators, to lesson preparation and presentation. Experienced officials (lectures) from universities were appointed as commission leaders. These commission leaders were tasked with facilitating discussions in the commissions. The discussions lasted for two hours and thereafter the commission leaders were requested to give feedback. In the two hours allocated, the participants were tasked with identifying the challenges related to the given sub-theme and to suggest alternative solutions. A variety of challenges were identified. This paper will reflect on the challenges related to the inability of schools to produce good mathematics and science results as pointed out by these indabas.

For the sake of this paper, the highlights of two of the mathematics and science indabas will be discussed.

Theoretical framework

For this study the reflective judgement model (RJM) was used because there is continued controversy and doubt about the success of mathematics and science learners in many schools. Reflection on the experiences of retired teachers, motivational speakers, priests, university lecturers, maths and science teachers from primary and secondary schools, principals and head of maths and science departments is seen as potentially transformative to everyone involved in the teaching and learning of science. In the context of this study reflective practice was viewed as specific to the application of experiential learning of the participants of the indabas. This experiential learning, with its emphasis on the improvement of practice through reflection on experience, involves the learner-teacher going through a sequence of actions indistinguishable from those of the action research spiral (King & Kitchener 2004). Following on Kolb's widely influential model of the experiential learning cycle, reflection on challenges facing poor mathematics and science results followed by generalisation and abstract conceptualisation (McMahon 2006).

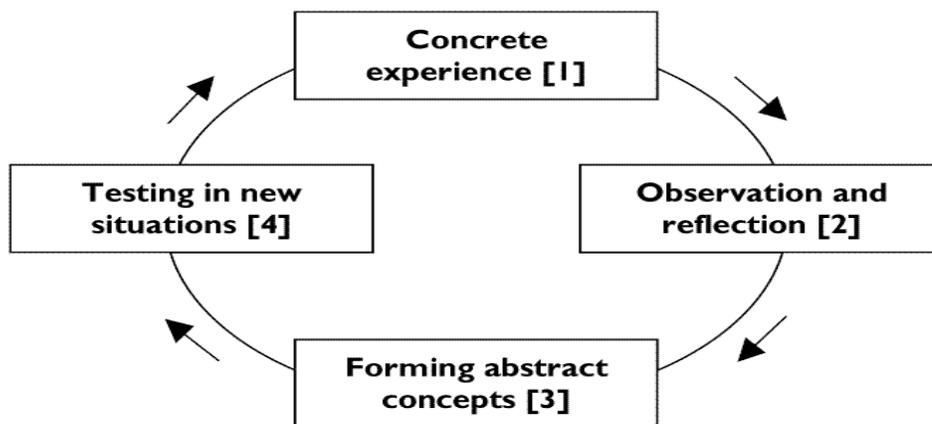


Figure 1 Kolb's experiential learning framework

Source: Knowles, Holton and Swanson (2005:198)

The major similarity between Kolb's learning cycle and the action research spiral is that they both emphasise the importance of reflection on action and experience. This reflection involves observation, discovery, and collaborative inquiry and discourse through shared experience. Life experience is seen as both a resource and a stimulus for learning. In both models the reflection is intended to be transformative. In the case of the learning cycle, this transformation can be mainly internal (i.e. concerned with knowledge or attitude) according to McMahon (2006). Greater emphasis is put on the externally observable results of transformation in terms of improvements to the teaching and learning of mathematics and science. However, in terms of the reflective practitioner model of teaching and learning, the strategic dimension is not only the most valid distinguishing feature, but also the key to an understanding of how the two can be usefully

related in practice. Reflective practice was thus used to identify challenges and alternative solutions

As a participant-observer I played an active role in the experience that was being studied (Nicholls 2009b:641; Merriam 1998:94/96). The physical setting in the indabas participants (the teachers as they share their experiences and challenges), interactions as well as conversations were observed (Merriam 1998:97). Field notes, as an additional method of recording observations, was also used.

Reflections on the first indaba

The purpose of the first indaba, involving schools from around Rustenburg, was put forward before the more than 450 participants and proved to be very interesting. The majority of the schools in this area are resourced since they are sponsored by the neighbouring mines. Although these mines invest a lot of money in the schools, performance in mathematics and science remains poor. Many sponsored interventions take place in these schools, including yearlong Saturday classes offered by dedicated mathematics and science teachers. However, only high schools participate in these interventions. The offices of the education officials are situated in town and many of the teachers are able to access the offices with ease. In turn, the education officials have easy access to the schools to offer support.

The indaba was held at a state-of-the-art college in the area, which boasts world-class laboratories and teaching facilities. This college's results are very good since it is an independent school and learners write Independent Examination Board (IEB) examinations. One of the teachers at this college gave a talk to offer moral support to the delegates.

More than 450 concerned delegates attended the event; a sign that all is not well with regard to the performance of learners in mathematics and science. With the aim of motivating the teachers, the first day of the two-day indaba consisted of speeches by invited motivational speakers, who included priests and high ranking officials of the department of education in the district. Speaker after speaker condemned the poor results in the mathematics and science and encouraged teachers to take precautionary measures to correct the state of affairs. One of the speakers highlighted the need for the department to move the passing percentage to at least 50%. He emphatically condemned the fact that 30% is regarded as a pass, as what this essentially means is that the learner knows only 30% of the work he/she is supposed to know. If we were to extrapolate this, we might in the future have engineers, health professionals and others qualifying in their respective professions while knowing only 30% of the work they are suppose to know – consequently affecting the quality of graduates we produce in our country. He gave a practical example of a doctor operating on a patient while knowing only 30% of the work – it would definitely be a disaster. In the same breath, the scenario can be equated to a mathematics and science teacher who knows only 30% of the work being entrusted with teaching learners. The question is, how much will the learner know? Critical questions like this need to be put on the table if we are to change the education system in our country.

By contrast, Basic Education Minister Angie Motshekga defended the controversial 30% matric pass mark, saying it is "reasonable", and that she was surprised at the criticism levelled by prominent academics such as Prof Jonathan Jansen and Dr Mamphela Ramphele (*Business Day* 2012). Motivating her stand, the Minister of Education said: "It is 30% of what is assessed. When you set up a question paper, you assess different levels of competency in terms of the skills required ... and when we say 30%, it means that person has been able to master the basic skills." Despite this, learners still perform lower than what is assessed. The implication of the minister's message is that those learners who by luck studied and mastered what has been assessed will make it in the examination. Conversely, the rest will fail the examinations. The standard of education in South African schools is very low because the ministry of education has set lower achievement standards. As proposed by one of the speakers at the indaba, the pass mark should be at least 50%. With the current state of affairs this means that we will have many learners getting lower than 50%. However, if we aim at a higher percentage pass we may get somewhere.

With regard to teachers' content knowledge, many teachers indicated that they require additional in-service training. According to these teachers, although they have the content knowledge, the challenge lies with the teaching methodology. As a result, every attempt geared to in-service training should address the teaching methodology for the two subjects (mathematics and science).

On the first day, teachers had an opportunity to listen and prepare for the second day, where they were supposed to reflect on the challenges they face in their respective schools. Thereafter, they were required to suggest practical solutions to correct the situation. Interestingly, many teachers in their respective commissions told the commission leaders that; schools are very overcrowded. This situation is caused by the fact that parents are now taking their kids to schools in the townships in the hope of better education. This overcrowding, results in behavioural problems, as some teachers mentioned. Many learners do not do their homework, thinking that, teachers will not monitor the work because they are so many of them. In response to this problem, teachers suggested the introduction of supervised homework, where teachers will monitor the completion of homework in the classroom. However, owing to limited teaching periods, this was mentioned as a challenge for many schools, as it would mean sacrificing one period a day to do supervised homework. Nevertheless, some teachers pointed out that with careful planning this could be achieved.

Late coming was regarded as troublesome in many schools. Many teachers were of the opinion that the reason for this is because punishment has been abolished in schools. Some teachers suggested alternative ways to punish learners, for instance locking them out of the school and calling parents to school to discuss the issue. However, these have all proved to be ineffective as learners enjoy being locked out of the school, and some subsequently go home, while others loiter around the streets in full school uniform. Moreover, although some parents come to school to discuss the problem with teachers the situation does not improve.

Those teachers who were determined to teach mentioned that the department allocated too few mathematics and science periods per week. When asked how many periods were allocated, they mentioned six 45-minute periods per week. It was suggested that they add a number of afternoon periods, but teachers were quick to say that learners always wanted to go home after school.

Many teachers complain that, although there are a number of interventions taking place in schools, these interventions affect the smooth running of the schools. Every week one or two teachers are absent in order to attend a workshop organised by the Department of Education. Ironically, these same workshops aimed at empowering the teachers to teach effectively in their respective classrooms actually end up causing problem because they take place during the time that learners are supposed to be taught.

Reflections on the second indaba

The second indaba involved schools from the rural areas around Rustenburg (Moses Kotane West). Similar to the first indaba, more than 450 delegates attended. The majority of the schools represented do not have the teaching facilities needed in order to teach mathematics and science effectively. They are situated in very remote areas where access to major services is a challenge. Moreover, during the rainy season it is difficult for education officials to travel to these schools for monitoring purposes. Most schools buildings are in a bad condition and only a few have a resourced laboratory for practical science work.

In contrast with urban schools (Indaba 1) where there is a problem with overcrowding, some schools in the rural areas have merged, and others have closed down because there are not enough learners. Despite these mergers, the education department has allocated them too few teachers and they are forced to operate using a multi-grade system; that is, a system that allows for one teacher to teach more than two grades in one classroom. The situation is such that, in some schools, Grades 1, 2, 3 and 4 are taught in the same classroom. This poses a major challenge in terms of effective teaching and learning.

Further, in many schools mathematics and science learners spend the entire year without a teacher, because teachers are unwilling to teach in these areas. In addition, the subject advisor has to monitor more than twenty schools in the district as well as helping those schools that do not have a teacher at all. Because of the shortage of teachers, in some schools teachers teach other subjects in addition to the mathematics and science they are required to teach. Teachers suggested to education officials that they should consider the establishment of mega schools. Although this might be a solution, there are challenges however. One of these challenges is that the mega school will have to be centrally situated in a place that is accessible to all learners as many areas are very remote. Another solution is to make accommodation available. This might also help to address the problem of late coming.

Some teachers highlighted lesson planning as very important in the teaching and learning of mathematics and science. However, they pointed out that many teachers no longer do lesson planning. As a result of this, teachers go into classrooms not knowing what they are going to

teach or how they are going to teach it. The implications of this are that there is no communication between the teacher and learners, resulting in delayed or no feedback from learners. The situation is such that teachers say that many teachers do not follow up on work given to learners.

Focusing on the learners, it was reported that many learners cannot read, write, count or calculate. This means that the basics should be attended to before pure mathematics and science can be taught. The role of primary education is important in this regard. However, as indicated, most primary schools use a multi-grade system and teaching learners basic skills like counting, reading and writing is a challenge.

A retired teacher and now motivational speaker emphasised “misdiagnosis” as a problem in our schools. Elaborating further, he argued that, in most schools, people do not know what the problem is, thus “prescribing” a wrong solution to the problem. That is why the problem continues to be there year in year out. He suggested a thorough introspection by each and everyone involved in education to search for the possible causes of this dilemma. He advocates that the poor mathematics and science results are a lack of passion in teachers in particular. According to him, the teachers of today are not motivated to teach mathematics and science for a number of reasons, one being the lack of support provided by education officials to underperforming schools. Moreover, some teachers are tasked with teaching a number of subjects including mathematics and science because the situation in the schools forces teachers to do this even though they are not qualified in these subjects. Some of the schools consist of only two staff members, one of them being the principal. Together they are supposed to teach, attend workshops and do all the administrative work for the school. Such a situation would therefore warrant the school being regarded as dysfunctional. Moreover, if one of them is absent from school, either attending a workshop or due to ill health, then the other will have to teach all grades and all subjects. This is practically impossible, but teachers find themselves in these situations.

Some of the teachers reported that learners have a “maths phobia”, resulting in many learners switching to mathematical literacy. Hence many of the schools have fewer numbers of learners doing mathematics. Teachers maintained that even with those who do mathematics are given fewer mathematics exercises per week, hence they do not have enough practice in the subject. With the purpose of mathematical literacy being to grasp the basics in terms of mathematics, learners prefer to do that rather than doing mathematics. However, universities do not accept learners with mathematical literacy into degree courses where mathematics is a requirement. This means that learners cannot participate in any of the maths and science related careers. Subject choices for many schools are a challenge as teachers cannot force learners to choose a specific subject.

Offering advice to the delegates, the invited guest speaker, the director general in the national Department of Education, emphasised the need for everyone to command authority in their field of expertise. He said that those employed by the department to manage schools must manage schools and they must do it effectively and those employed to teach mathematics and

science must teach the two subjects effectively. All those employed to monitor and support the schools, including the teachers and the learners, must show that they are experts in that field. Commanding authority in your field of expertise means that you must always be ahead of your subordinates. If you are teaching mathematics, you must know more mathematics than the learners you teach. In this way you will be able to command authority in the classroom. A school principal whose job is to manage the school should command authority in the school so that whoever visits the school can see just by entering the school that there is order in the school.

Another education official stated that teachers are not commanding authority in their subjects, namely, mathematics and science, because they further their studies in the subjects they are not teaching at school. She indicated that many teachers further their studies in educational management with the intention of being promoted to management positions like school principals. It was emphasised that everyone involved in education should continuously undergo in-service training to upgrade their skills in their field of expertise.

Way forward and resolutions of the indabas

The indaba resolved that the following measures should be adhered to if we are to improve the results in mathematics and science:

Teachers suggested that there should be ongoing in-service training for teachers. A positive attitude, good relations with learners and love for mathematics was encouraged. In the classroom, teachers were advised to vary tasks so that learners can actively participate in and be challenged by the subject. This means that teachers must go the extra mile and prepare their lessons thoroughly. Teacher accountability and a focus on curriculum coverage were recommended. By means of team work and regular subject meetings to share success stories teachers can be motivated to improve the way they teach both mathematics and science. In terms of making sure that all content is taught to learners a curriculum monitoring tool was proposed, the purpose being to monitor what was supposed to have been taught against what is taught, and what has been assessed against what was supposed to have been assessed.

Educational implications of the Indabas

The whole purpose of the indabas was to ultimately energise and motivate the teachers. The forces that lie beneath motivation can be biological, social, emotional or cognitive in nature. Researchers have developed a number of different theories to explain motivation but each individual theory tends to be rather limited in scope. However, by looking at the key ideas behind each theory, this reflective piece was located within the concept of choice, efficacy, and social cognitive theory as proposed by Bandura (1997).

The empirical findings concerning the benefits of choice are equivocal and confusing; however Flowerday and Schraw (2000) believe that choice promotes motivation. The concept of choice appears in several motivational frameworks. For instance, the expectancy-value model of achievement motivation (Wigfield & Eccles, 1992; 2000) focuses on the social-psychological

influences on choice and persistence. According to this theory, people's choices are influenced by the perceived positive and negative task characteristics that are associated with benefits and costs respectively. The cost associated with choice is thought to stem from the fact that when a choice is made, other options are often eliminated. Choice, according to this model, is an outcome of the motivational process and depends on the peoples' task-value beliefs and expectations of success.

Arguably, however, the theoretical perspective that best allows for a conceptualisation of choice – not as a motivational outcome but as a motivating experience in and of itself – is the self-determination theory (SDT) (Deci & Ryan, 1985; 2000). Central to SDT is the concept of basic psychological needs that are assumed to be innate and universal. These needs are the need for *competence*, the need for *autonomy*, and the need for *relatedness*. According to Ryan and Deci (2002), motivation is a process in which a person's way of thinking plays an important role. Motivated behaviour may be *self-determined* or *controlled*. These two types of motivated behaviour involve different reasons for behaving. By self-determined or autonomous behaviour, Deci and Ryan (1985) meant freely chosen behaviour which arises from one's self. To be autonomous means to study with a full sense of volition because the studying itself is interesting or personally important.

In his social cognitive theory, Bandura (1997) proposes that individuals' self-efficacy is similarly the major determinant of goal-setting, choice of activity, willingness to expend effort, and persistence. Choosing to engage in an activity and choosing a mode of engagement are conceptualised as being affected by three factors: the person's traits, the person's behaviour, and the environment. For example, teachers' feedback in the indabas (an environmental factor) may influence how education officials design policies. In turn, choosing to employ more complex strategies promotes acquisition of skills and can lead learners to feel more efficacious, thus inducing them to choose strategies and tasks in the future with even greater complexity (Pintrich & Schunk, 2002).

Because individuals are largely the products of their environments, Bandura writes, "[b]elief of personal efficacy can shape the course lives take by influencing the types of activities and environments people choose" (1997, p. 75). Significantly, he notes, "[p]eople avoid activities and situations they believe exceed their coping capabilities. But they readily undertake challenging activities and select situations they judge themselves capable of handling" (1997, p. 75). He concludes, "[b]y the choices they make, people cultivate different competencies, interests and social networks that determine life choices".

Bandura argues that people could be persuaded to believe that they have the skills and capabilities to succeed. Getting verbal encouragement from others helps people overcome self-doubt and instead focus on giving their best efforts to the task at hand. His theory added a social element, arguing that people can learn new information and behaviours by watching other people, for instance, modelling what best maths and science teachers do to achieve good results. Known as observational learning (or modelling), this type of learning can be used to explain a wide variety of behaviours.

There are three core concepts at the heart of social learning theory. First is the idea that people can learn through observation. In practice this means teachers can visit schools with good results and make observations. Next is the idea that the internal mental states of the teachers are an essential part of this process. Finally, this theory recognises that just because something has been learnt, it does not mean that it will result in a change in behaviour.

Bandura noted that external, environmental reinforcement is not the only factor to influence learning and behaviour. He described intrinsic reinforcement as a form of internal reward, such as pride, satisfaction and a sense of accomplishment. This emphasis on internal thoughts and cognitions helps connect learning theories to cognitive developmental theories. While many textbooks place social learning theory with behavioural theories, Bandura himself describes his approach as a "social cognitive theory".

Bandura writes, "[t]eachers operate collectively within an interactive social system rather than as isolates. Therefore, educational development through efficacy enhancement must address the social and organizational structure of educational systems". Collective efficacy is an overriding quality that influences different elements of a social system. Schools with high levels of collective efficacy create an atmosphere that empowers and vitalises stakeholders.

According to Bandura, "[s]chools in which staff members collectively judge themselves highly capable of promoting academic success are likely to imbue their schools with a positive atmosphere for sociocognitive development" (1997, p. 248).

He further clarifies that the belief systems of the staff also create an organisational culture that can have either vitalising or demoralising effects on the perceived efficacy of its members. Teachers who view intelligence as an acquirable attribute and believe they can attain academic successes despite learners' disadvantaged backgrounds promote a collective sense of efficacy, whereas teachers who believe that intelligence is an inherent aptitude and there is little they can do to overcome the negative influence of adverse social conditions are likely to undermine one another's sense of efficacy.

Bandura writes, "[t]eachers are producers and products of microenvironments within a larger school milieu" (1997, p. 249). When a faculty develops a strong collective sense of efficacy they believe they can promote the academic progress of learners, regardless of the challenges that may exist in a particular situation. In other words, Bandura (1997) found that collective teacher efficacy (CTE) had such a powerful effect on schools that it mediated such factors as learners' prior academic achievement and socioeconomic status.

Significant challenges regarding learners' socioeconomic status and prior academic achievement can create "a demoralizing descent of staff efficacy and learner efficacy and achievement, whereas positive bidirectional influences can produce mutual enhancement of efficacy and scholastic achievement" (Bandura, 1997, p. 250). Regarding leadership in schools, Bandura argues that, "[t]he quality of leadership is often an important contributor to the production and maintenance of organizational climates" (1997, p. 248). Strong, effective principals succeed in getting their teachers to work together, thereby building CTE.

Bandura's argument is that, "[t]he leadership of the principal plays a vital role in adoption and continuance of new educational practices" (1997, p. 258). Leaders in struggling schools often fail when they rely upon piecemeal remedies; rather, deep reform requires major restructuring of a school's climate (Bandura, 1997).

Conclusion

While teachers painted an unsatisfactory picture of the learning environments in their schools, they (teachers) continue to play a critical role in the creation of learning environments that nurture the effective teaching and learning of mathematics and science. The indabas created a platform where teachers could share best practices and learn from each other. The two indabas presented different challenges, hence different levels of interventions are required.

The significance of these indabas can be associated with the findings of Katz and Assor (2007), who argue that people can be motivated after being given a number of options (choices) to choose from. The options in this case refer to both negative and positive views elaborated upon in the two indabas. Through discussions, the indabas provided teachers with a platform to share their different classroom experiences. They were encouraged to work harder at improving the current state of mathematics and science. Teachers were encouraged to find ways to cultivate positive attitude amongst themselves and that of learners with the aim to improve their attitudes towards mathematics and science.

While acknowledging the challenges identified by the teachers at the two indabas, schools that do perform in both mathematics and science were encouraged to come to the fore and role-model the necessary initiatives for underperforming schools. In order for the underperforming schools to be successful, they have to be motivated to imitate the initiatives that have been modelled. In order to motivate teachers, rewards for extra work or outstanding mathematics and science results can be given out to deserving teachers. With the number of positive messages received during the indabas, one would just hope that teachers have been encouraged to achieve their goals.

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