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A Broken Promise for Gifted Learners: Re-Examining the National Strategy for Mathematical Sciences in South Africa Two Decades Later

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Abstract

The National Strategy for Mathematics, Science and Technology Education [NSMSTE] was promulgated two decades back with the aim of improving national excellence in mathematical sciences. Although the initiative has achieved several gains in participation, top-end performance which was targeted has remained alarmingly low at less than 5% annually. This study aimed at an in-depth understanding of how and why top-end performances targets were not achieved. I used an educational production function (EPF) to analyse the factors that were prioritized and those that were ignored in the 20-year implementation period of the strategy. I used a Secondary Qualitative Data Analysis design where I collected recommendations made in 20 sampled documents which had evaluated the strategy. An EPF places student ability as one key factor to be considered early in the primary school suggesting that gifted students should have been identified early before resources were provided. However, results show that the strategy prioritized the provision of external resources without considering the potential of the students. It also targeted low performance high schools instead of primary schools. This could partially explain why the program failed to make a significant impact. This study recommends that the Dinaledi School program focuses on gifted students at primary school level instead of average students at secondary level.

Keywords

Gifted Learners, Mathematical Sciences, Economics of Education, National Strategy

1. Introduction

Background and Context of the Study

In order for the reader to get a clearer picture of the South African education system let me start by explaining how it is structured. Basically, Primary Education covers Grades R - 7 and Secondary Education covers Grades 8 - 12 after which there is Higher Education & Training. Prior to 2009 all these three levels were under the jurisdiction of one Department of Education. However, in 2009 the Department of Education was divided into two i.e., the Department of Basic Education (responsible for primary and secondary) and the Department of Higher Education and Training (responsible for post-secondary education). Given that this paper covers secondary education in the period 2001 to date, I will talk about the Department of Education (DoE) with reference to the period 2001-2009 and the Department of Basic Education (DBE) with reference to the period beyond 2009. In both cases I will be referring to the same government department overseeing primary and secondary education nationally.

In 2001 the DoE through its National Strategy for Mathematics, Science and Technology Education (NSMSTE) committed itself to addressing problems that retarded provision of a high-quality education at secondary school level in mathematics, science and technology education (popularly known as STEM but herein referred to as mathematical sciences). The department's concern arose from an observation where the number of learners who participated and successfully passed mathematics and science in Grade 12 had persistently been very low and those who took these subjects in the Higher Grade (HG) had remained very few. The strategy stated that an adequate supply of Grade 12 graduates with mathematical sciences could be better assured by focusing on learners with potential in dedicated schools, rather than through a dilution of effort across the whole schooling system (DoE, 2001). In pursuance of that goal, the Council of Education Ministers (CEM) approved the establishment of the "hundred dedicated high schools" program. The schools later grew in number from 102 in 2001 to 500 by year 2008 and became known as the Dinaledi Schools—which means stars in at least three local languages. Admittedly there was some increase in participation resulting from this program, but an analysis by CDE (2013) showed that most of the HG passes in Dinaledi schools were being achieved by a few high-performing schools while the performance of most other schools had remained the same or even worsened. For example, in 2006, 65 Dinaledi schools (16 per cent) produced the same number of passes as before, while 155 (39 per cent) produced fewer. This prompted critics to describe the NSMSTE intervention as depicting a tree with only a few low hanging fruits in an extremely underperforming system. This constitutes a broken promise to gifted learners in mathematical sciences and if this brain drain is not harnessed soon South Africa will continue to blow away a huge amount of its human capital, particularly high-ability learners from previously disadvantaged backgrounds.

One of the reasons why many countries find themselves in such a crisis is that fewer stakeholders have approached education from an economics of gifted education and an investment in human capital perspective (Kottmeyer, 2011). Booij et al. (2017) point to an emerging economics literature on the causal impact of gifted and talented education on student skills and on economic development. Similarly, Kettler (2016) asserts that economists have become more interested in gifted education than educators themselves in the wake of current research suggesting that resource-based interventions are failing to make positive change on student achievement not because such resources don't matter but primarily because administrators are not optimizing the use of their resources in the production of scholastic achievement. The economic policy argument for optimization asserts that resources ought to be allocated to those programs with demonstrated effectiveness in terms of student achievement. In this regard stakeholders ought to ask questions about inputs which are important, and how such inputs can be manipulated to effect change in student performance. To give convincing answers to such questions would be among the most important tasks for evaluators of educational processes. Hanushek (2020) has argued that an educational production function (EPF) could be used for studying the relationship between inputs and outputs of schools. This paper is premised on the view that an EPF is a systematic and sensible framework which is essential for efficient resource allocation that could be used in South African education to judge the effectiveness and efficiency of the NSMSTE which in turn would guide stakeholders towards policy alternatives. Therefore, it is important to understand the relevance of this EPF, before the NSMSTE strategy is analysed using such a framework.

2. Literature Review

2.1. The Economics of Education as a Guiding Framework

Studies on the economics of education are premised on the view that education is a leading determinant of economic growth, employment, and earnings. However, the returns to education are not homogenous but rather heterogeneous across the population suggesting that different student abilities impact the economy differently. Similarly, differences in cognitive skills lead to economically significant differences in economic growth. According to Wößmann (2015) ignoring this economic dimension of education would not only endanger the prosperity of future generations, but it would also have extensive backlash for poverty, inequality, social exclusion, and sustainable development. Following this view in the wake of shrinking educational budgets, it has been suggested that the efficient allocation of schooling investments should therefore be guided by the rate of return on investment. This line of thought has led to attempts to screen educational inputs and outputs with a view to focus on variables that matter and their substantive significance in understanding consequential educational, occupational, or creative outcomes. A long-standing guiding principle in such screening efforts was made by Jenkins (1981: p. 224) as cited in Lubinski (2016) who suggested that:

> If you are concerned with improving the output of some complex system, you must study the component that produces the largest variance first. Adjusting or correcting smaller sources of variance has no appreciable effect on the output of the system as long as the major source of variance is uncontrolled.

This guiding principle has remained relevant to date and in the current debates on skills that matter in the 4IR, researchers have used it to screen diverse educational variables, some of which have concluded that the positive impact on a country's Gross Domestic Product (GDP) can be isolated mainly to mathematical science related achievements as opposed to achievements outside the fields, suggesting that STEM-related achievements are the main drivers of national affluence (Tanenbaum, 2016). Similarly, McCabe et al. (2020) concluded that innovations from occupations in the mathematical sciences fuel the engines of modern economies. There is a global consensus to this view which has driven curriculum reforms in many countries, including South Africa, to divert more educational resources towards mathematical sciences. Deeper analysis of STEM skills and their relevance in the 21st century knowledge-based economy have shown that the truly extra ordinary advances in STEM have not been the work of typical or average individuals in the STEM workforce. Rather, talented, and committed individuals within STEM have produced such advances (McCabe et al., 2020). These findings again have had some influence on STEM reforms with more emphasis being placed on top-end performance rather than general performance in mathematical sciences. Further refinements in these studies have been made in attempting to identify some important attributes of the STEM experts. For example, Super and Bachrach's committee report as cited in Lubinski (2016) concluded that, in addition to superior levels of general intelligence, promising engineers and physical scientists tend to 1) be highly adept in mathematical and spatial reasoning ability and 2) possess regnant scientific interests. Lubinski et al. (2014) found out that early manifestations of exceptional mathematical talent did lead to outstanding creative accomplishment and professional leadership in science related endeavors. This confirms an important characteristic of mathematics namely that mathematics operates at the interface of multiple disciplines of Science, Technology, Engineering and Mathematics (STEM) subjects, hence the National Science Foundation suggested the inclusive term of Mathematical Sciences.

All these studies suggest that mathematically precocious youth became the critical human capital needed for driving modern-day, conceptual economies. Yet according to the UNESCO (2012) report, in many countries government and other stakeholders are still some way from aligning their efforts with such findings, resulting in wastage of resources and a proliferation of initiatives that are too small to have meaningful impact.

According to Hanushek (2020) much of the analysis from an economics of education perspective flows from a simple model of an industrial manufacturing unit as a production function. Schools can be regarded as manufacturing units that provide service instead of tangible products and the fundamental idea of an educational production function (EPF) is that the output of the educational process i.e. the achievement of individual students, is directly related to inputs that are manipulated by policymakers as well as those that are not so controlled (Hanushek, 2020). Bowles (1970: p. 13) conceptualized an EPF as follows:

$$A = f(X_1, \ldots, X_m, X_n, \ldots, X_v, X_w, \ldots, X_z)$$

where A = some measure of school output e.g., a score on a scholastic achievement

$X_1, \ldots, X_m$ = variables measuring the school environment e.g., amount and quality of teaching services, the physical facilities of the school, and the length of time the student is exposed to these inputs

$X_n, \ldots, X_v$ = variables representing environmental influences on learning outside the school e.g. the parents' educational attainment; and

$X_w, \ldots, X_z$ = variables representing the student's ability and the initial levels of learning attained by the student prior to entry into the type of schooling in question.

Despite this relationship appearing simple and straight forward at face value, it should be noted that both the school inputs and outputs are multidimensional, and the relative valuation of different outputs differs among different education systems. For this reason, the school production function can be represented by a number of equations, each relating the school inputs to a different dimension of output. Optimum conditions for resource allocation could be conceptualized simply as the gain per marginal dollar expended or the maximum output compared with a given set of inputs. This could mean producing same outputs with less inputs, producing same outputs faster, producing better quality at less cost or producing same outputs cheaper. The choice of an optimal input structure depends on the relative valuation of the different school outputs and on the rates of transformation among these outputs implicit in the system of production equations. According to Bowles (1970) policy-makers' job is to determine the highest ratio for any variable over which they have control and to expend all available funds in that direction. Given the complexity of education systems many countries have tried different combinations of these educational inputs with varying success rates. In failed attempts, a general observation by economists was that school administrators were likely to have followed no systematic optimizing behavior.

In order to make judgement about the presence or absence of a systematic optimizing behavior, attempts should be made to determine what it is that school authorities are trying to accomplish, first, (the A in the EPF) then also recognize the educational typology within which the education system is operating. Educational typologies are described as the mechanisms by which educational opportunities and privileges are distributed among individuals within the system (Mandelman et al., 2010). In terms of what needs to be achieved in South Africa, it is not so much about access to basic literacy and numeracy anymore, but it is about top-end skills in mathematical sciences required for effective functioning in the 21st knowledge-based economy. In terms of typology, although there are many variants of typologies or distribution schemes, only two are central to educational debates in South Africa i.e., egalitarianism and meritocracy, sometimes referred to as equity and excellence respectively. Within each of these typologies there are specific economic and political pressures that further shape the educational systems allowing evaluators to also make judgment as to whether or not resource allocation was optimized or wasted.

For example, within the doctrine of egalitarianism, the assumption is that all children have abilities, hence the economic pressure on government is for all learners to have equal access to the educational opportunities that would be available. The egalitarian typology is characterized by a one-size-fit all resource-based provision where the core curricula expect all pupils to learn the same things, at the same time and by the same means and methods despite pupils having different abilities and needs. Proponents for this "average" practice argue that such an approach increases access and participation but from an EPF perspective critics moan that it is wasteful in terms of achieving excellence as it perpetuates mediocracy and defeats the whole purpose of human capital development. For example, Hanushek and Wößmann (2020) have apprised that in developing countries the discussions on development policy often simplifies and distorts this truth by focusing most attention on ensuring school enrollment for everyone and losing sight of the importance of the quality of education. In South Africa, there is evidence to show that setting of low targets both nationally and internationally, limited time on task, poor curriculum coverage, lack of progression in abstraction and cognitive demand, failure to improve the top-end of performance scores in mathematical sciences are all rooted in the egalitarian desire to move with "everyone" at the pace and cognitive levels of at worst the slowest but at best the average students.

On the other hand, the meritocracy typology is premised on the view that returns to education are not homogenous but rather heterogeneous across the population implying that different student abilities impact the economy differently. Consequently, the economic policy argument for optimisation asserts that resources ought to be allocated on merit to those programs which demonstrate effectiveness in terms of student achievement. Admittedly attempts to measure the relative importance of these inputs have occupied the attention of a number of educational researchers over the last half-century. Results show the difficulty in estimating an education production function independent of the socio-economic context of the pupils studied but the evidence seems strong enough to reject the use of innate abilities or IQ score as the measure of the student raw material or input into the production process (Hanushek & Wößmann, 2020). According to Lubinski (2016), although other things clearly matter, ability is the most important personal attribute for predicting work performance in complex settings hence evaluating responsiveness to interventions and opportunities is best accomplished by incorporating the assessment of individual differences. Terman (1954) as cited in Lubinski (2016), reflected on what he had learned by studying intellectually precocious youth for over three decades and his conclusion was that both interest patterns and special aptitudes play important roles in the making of an expert scientist or mathematician. Other researchers have shown that if our goal is to estimate the relationship between school inputs and net output, or value added, then we need a measure of the raw material inputs, i.e., student ability, or, alternatively, the level of learning upon entry to the school in question (Bowles, 1970). Without discovering and emphasizing genuine genetic differences our efforts are not only iatrogenic, but they also lack the basis for measuring improvements. Such efforts are like attempting to measure the effectiveness of a beauty parlor without knowing what the clientele looked like to begin with. Similarly, Gagné (2015) cited many studies which have shown that innate cognitive ability or intelligence has emerged as probably the single most important determinant of scholastic achievement. This suggests that it might not be possible to optimize educational resources without considering the innate cognitive abilities of students. This conclusion is not only less controversial in research, but it is also appealing to both common sense as well as to other disciplines such as sports where it is the foundational logic which is applied in programs for talent development. In sports for example, if the aim is to prepare top athletes for competing at say the Olympics, then potential is identified first through talent searches before such athletes are put in top of the range facilities for the purposes of honing their skills. Thus, even in an otherwise perfectly specified and perfectly measured EPF model, unless researchers are able to account for genetic differences in learners, they are unlikely to account for all of the variances of scholastic achievement.

Besides accounting for the role played by genetic endowment in the educational process, the EPF also suggests when it is best to develop such potential talent. According to Grant (2017) the achievement levels of students at an earlier age appears to provide an index of the aggregate skills of the students at the end of their schooling when each level of schooling builds on earlier knowledge. In education, there is an undoubted presumption that the right time for identifying learners' potential and structuring their support is when they are still in the primary school. Early childhood researchers have taken a strong and sustained approach to demonstrate the economic and social benefits of investing in young children. For example, Hanushek (2020) cited some research done with 67 explanatory variables in growth regressions on a sample of 88 countries whose results show that primary schooling was the most robust influence factor on growth in GDP per capita in 1960-1996. Similarly, Wößmann (2008) studied Euro spending at different stages of education and demonstrated that the rate of return declines with the age of a person of any background. The logic is quite clear from an economic standpoint, as Heckman (2011) argued, society can invest early to close disparities and prevent achievement gaps, or it can pay to remediate disparities, when they are harder and more expensive to close. Either way society is going to pay but there is an important difference between the two approaches in terms of optimization of resources. Investing early allows society to shape children's future; investing later chains society to fixing the missed opportunities of the past (Heckman, 2011). The question at stake now is the extent to which the NSMSTE took such matters into consideration.

2.2. Statement of the Problem

Although the Dinaledi Schools project was designed to improve the top 10% performance in mathematical sciences, international tests that South Africa participates in indicate that the top 10% of learners in South Africa do worse than the top 10% of learners in other developing countries (DBE, 2011). In order to achieve this, government admits there is need to do more work is in giving exceptional learners better access to focus schools hence the challenge is to improve the Dinaledi approach further. The fact that on one hand efforts are being made to close the skills gap in mathematical sciences while on the other hand the gap remains static or even widens, has been described as a conundrum that demands analysis, explanation and justification. Hence from an economics of education perspective I raised the following three research questions:

1) What was targeted by the National Strategy for Mathematics and Science over the last two decades?

2) Which educational inputs were prioritized?

3) What evidence do we have in the evaluation reports that student potential matters?

3. Methods

3.1. Research Design

The paper draws from a Qualitative Secondary Analysis of data (Irwin, 2013), which refers to the (re)using of previously generated data to obtain new social scientific and/or methodological understandings. This involves prioritizing a concept or issue that was present in the original data but was not the analytical focus at that time.

3.2. Sampling

This study employed purposive sampling in selecting the 20 documents in which texts were the focus for analysis. By the time 20 documents were analysed, a point of saturation was reached which in research occurs when no additional data are found that advance, modify, qualify, extend or add to the theory developed. The sample comprised of research reports, evaluation reports and task team reports that had something to do with either the National Strategy for Mathematical Sciences or the Dinaledi Schools. Table 1 shows some of the documents that were sampled in no particular order.

Table 1. Documents that were sampled for this study.

Name of document and its hyperlink
National Strategy for Mathematics Science & Technology https://www.westerncape.gov.za/text/2003/strategy_math_science_fet.pdf
Abt Associates Final Report: Support to Tertiary Education Prog https://pdf.usaid.gov/pdf_docs/pdaca559.pdf
Dinaledi schools presentation to the Portfolio Committee on 09 May 2012 https://static.pmg.org.za/docs/120509dinaledi.pdf
Investigation into Maths & Science implementation https://www.gov.za/sites/default/files/gcis_document/201409/maths-and-science-investigation-implementationa.pdf
The state of mathematics, science and technology in our schools https://www.education.gov.za/Portals/0/Documents/Reports/Research%20Repository/Curriculum/State%20of%20MST%20in%20schools.pdf?ver=2019-09-09-104855-510&timestamp=1570176022898
Revised National Strategy for Mathematics, Science and Technology MST Education in GET & FET (2019-2030) http://www.nstf.org.za/wp-content/uploads/2018/07/2-AUGUST-NSTF-STEM-EDUCATION-FORUM.MsKhembopptx.pdf
Action Plan to 2014 https://edulibpretoria.files.wordpress.com/2013/05/action-plan-to-2014-popular-version_1.pdf
Action Plan to 2019 https://nect.org.za/publications/nect-and-sector-documents/action-plan-to-2019-towards-the-realisation-of-schooling-2030/@@download/file/Action%20Plan%202019.pdf
Action Plan to 2024 https://static.pmg.org.za/DBE_Strategic_Plan_2020_-2024.pdf
Dinaledi Schools Report for the World Bank (2010) https://openknowledge.worldbank.org/bitstream/handle/10986/19009/884950WP0Dinal0Box385225B000PUBLIC0.pdf?sequence=1&isAllowed=y
Centre for Development & Enterprise: Doubling for growth: https://www.cde.org.za/wp-content/uploads/2019/03/Doubling-for-growth-Full-Report.pdf
Centre for Development & Enterprise: From Laggard to World Cla https://media.africaportal.org/documents/From_laggard_to_world_class_-_full1.pdf
Centre for Development & Enterprise: Math outcomes in S.A https://www.cde.org.za/wp-content/uploads/2018/07/Mathematics-outcomes-in-South-African-schools-what-are-the-facts-what-should-be-done-

3.3. Data Collection Instruments and Procedures

This study collected data through a software called WordStat. The software allows the researcher to search for words of interest in a particular PDF or word document. For example after opening the document entitled: National Strategy for Mathematics, Science and Technology Education in the General and Further Education and Training; I typed the word "ability" in the search window, and Figure 1 shows what I got.

- Firstly, good mathematics and science teaching is expensive and the necessary resources (qualified and competent educators, well-resourced laboratories and libraries) are scarce;
- secondly, an adequate supply of Grade 12 graduates with mathematics and science is needed to enter higher education. This could be better assured by focusing on mathematics and science learners with potential in dedicated schools, rather than through a dilution of effort across the whole schooling system;
- thirdly, dedicated schools may have policies to increase the participation of disadvantaged learners in science and technology-based education; and
- fourthly, these schools will promote innovative learning and teaching strategies for mathematics and science that are usually not found in mainstream schools.

The policy of dedicated schools is therefore the most cost-effective way of deploying scarce resources in the teaching of these subjects. In the context of competing priorities and limited resources, it is better to, at least in the short term, provide sufficient and adequate learning and teaching facilities to fewer schools with the aim of going full scale over a longer period of time. Secondly, this policy will respond better to a range of abilities and interests that learner display. It will allow those with the most ability to study intensively and learner preference in mathematics and science to be catered for. However, such a policy should not exclude other learners from studying basic mathematics, science and technology.

In pursuit of this policy, the Council of Education Ministers (CEM) has approved the establishment of a hundred dedicated high schools for mathematics and science. These schools will be distributed pro rata across the nine provinces and will be clustered mainly in districts for easy co-ordination, connectivity and sharing.

Figure 1. An example of a search for the word "ability" and its context.

Given that the word "ability" may be part of other words such as "reliability" or "availability", WordStat software has a built-in mechanism called key-word-in context (KWIC) for validating the context in which the word is being used. The highlighted word in "**Figure 1**" clearly shows that the dedicated schools policy would allow those with most ability to study intensively in mathematics and science. Similarly, the word potential in the second bullet point shows that the strategy focused on learners with potential in dedicated schools. These and many other statements support the researcher's claim that the dedicated school project was meant for most ability learners or gifted learners in mathematical sciences. Similarly, other words such as "dedicated schools", "Dinaledi schools", "NSMSTE", "gifted", "talented" and "potential" were searched for in this and all the other sampled documents. Data collection took four weeks given that some documents were long and that I had to meticulously search for the statements of interest.

3.4. Data Analysis

Being a qualitative research, data are the statements that referred to National Strategy or dedicated schools or Dinaledi schools (coded NS) as well as learner potential such as talented/gifted learners, learners with potential, motivated, enthusiastic or high achieving (Coded as T). In Figure 1 for example, the reader can possibly see examples of statements such as "dedicated schools" (coded NS), learners with potential, and "most ability" (both coded T). In each document the code NS was counted only once (even if it appears more than once) just to confirm the documents' relevance to the study. However, the actual number of statements coded T were counted because this was the main focus of the analysis. Essentially, I wanted to establish the extent to which gifted learners were recommended in the evaluation reports.

3.5. Validity and Reliability

A number of steps were taken to enhance the trustworthiness of the data. Firstly, WordStat software has a built-in mechanism called key-word-in context (KWIC) for validating any claims that the researcher might want to make. This is easily verifiable by a second researcher thereby ensuring the validity and reliability of data. Secondly the reports covered the period from 2001, the inception of the National Strategy for Mathematics and Science, to 2019 when a revised NSMSTE (2019-2030) was born. This gives a complete longitudinal perspective of the project enabling a reader to see the consistency with which recommendations were made over time. Data trustworthiness is also enhanced by the cross-section of the reports given that the reports were sampled from department of education reports, world bank reports, task team reports, commissioned reports as well as independent research reports

4. Results and Discussion

The first research question concerned what was targeted by the National Strategy for mathematical sciences. From an EPF perspective we really need to know the relationship between our output measure A and the educational inputs so that we can infer optimisation of resources.

Table 2 shows that the NSMSTE strategy targeted secondary schools i.e. learners from grade eight to twelve. The criterion for inclusion on the Dinaledi Schools project was that schools had to be well performing and this was described more precisely as having achieved 1) at least 35 Senior Certificate mathematics passes by African candidates, either at higher grade (50%) or standard grade (40%) level 2) 20% of the annual national target of learners passing at high-grade level.

In order to make the discussion more robust, let me go back to restate the EPF that shaped the investigation. It says: $A = f(X_1, \ldots, X_m, X_n, \ldots, X_v, X_w, \ldots, X_z)$ where on the left hand side A is the target or the expected output and on the right hand is a combination of inputs that would be consistent with the expected output. Admittedly A is multidimensional but, in this case, the discussion will focus on this target in terms of level of schooling as well as level of performance. From Table 2 it should be clear that secondary schools (grades eight to twelve)

Table 2. Summary of the composition of the Dinaledi Schools in 2001-2002.

Aims and Requirements for the Dinaledi Schools	
Focus of the NSMSTE	▪ 102 dedicated high schools in 2001 ▪ Later called Dinaledi Schools ▪ Increased to 500 by 2008 ▪ Schooling level Grades 8, 9, 10, 11, 12
Aims	▪ Create centers of excellence for Math & Science ▪ Focus on those mathematical science learners with potential in dedicated schools rather than a dilution across the whole system ▪ Enroll talented learners from neighboring schools that would not otherwise get access elsewhere ▪ Allow those with more ability to study extensively ▪ Promote innovative teaching and learning in math & science
Criterion for selection	▪ Located in Presidential nodal area i.e., those targeted for urban renewal and rural development ▪ Under resourced well-performing schools ▪ Display basic levels of functionality ▪ Offer both math & science at HG level ▪ Have satisfactory class sizes of a minimum of 20 learners ▪ Have competent educators in both math & science ▪ Have had at least 35 Grade 12 mathematics passes by African candidates, either at higher grade (50%) or standard grade (40%)
Performance Targets	▪ Increase the number of those registered for math and science at HG level by 10% annually ▪ Contribute to 20% of national targets in math & science

were targeted but from an EPF perspective herein lies the first problem that might have inhibited optimization of resources in the strategy. For example, Van der Westhuizen (2015) pointed out that the "Class of 2012" had 620,000 learners who had dropped out of the educational system since 2001, the year that this cohort of students entered formal schooling which also coincides with the inception of the NSMSTE. From an economics of education perspective, this suggests that intervention attempts that target grade eight are not optimizing resource allocation because by then close to 50% learners have been lost from a terribly leaky system. Other statistics show the same pattern that 50% of learners in any one cohort drop out in South African schools before reaching grade 12 (Spaull & Kotze, 2015). Even if children had stayed in school, other international studies have also shown that South African primary school learners are way behind in terms of mathematical concept formation and that these difficulties are clear by grade six and have become acute by grades eight and nine (Reddy et al, 2021). Hence Booij et al. (2017) recommended that interventions be focused at the primary level because the impact of expenditure is twice as high in primary education as it is in secondary education. The DBE (2019) report acknowledges this when it says that for continued improvements, it would be necessary to reap the benefits of better schooling in the lower grades because there is a limit to what can be fixed in the final two or three grades of the system.

Besides late targeting of the NSMSTE, the problem of inefficient resource allocation is further compounded by setting of what I would describe as very loose and low performance targets for such a heavily funded project. For example, Dinaledi schools were expected to achieve 20% of national targets annually and in 2008 they were expected to achieve 20% (10,000) of the national target of 50,000 learners passing at high-grade level. Yet to be included on the Dinaledi project, schools needed 35 mathematics passes at higher grade (50%) or standard grade (40%) level. Given that in 2008 there were 500 Dinaledi schools; all things being equal, the schools would be having a total of 17,500 learners passing at standard grade or better to start off with. This would enable them to meet the target of 10,000 without even putting a single muscle of extra effort hence my argument that it is low targeting. It is also important to note that the problem of dismally low top-end performances (>79%) is what gave birth to the NSMSTE strategy. Hence it can also be argued from an economics of education perspective that any discussion of the NSMSTE performance that includes passes at 30% or 40% level or anything else below 79% is missing the point. I argue that those are targets for the general education system and not a dedicated project like the Dinaledi program. So in the context of these dedicated schools, setting low targets or reporting success through such low targets is not only inconsistent with the whole notion of developing future "stars" but it also encourages a penumbra of vagueness in reporting which in turn conceals under-performance

It can also be argued that measuring performance of stars by a 50% pass mark and labelling it as higher grade does not even reflect current acceptable entry requirements at local South African universities or internationally. For example, Van der Westhuizen (2015) argued that commissioning of the National Benchmark Tests (NBTs) was an indication of the universities' lack of confidence in the Grade 12 final examination results. All these studies confirm the argument that a 50% pass would be too low for a dedicated schools project such as the Dinaledi project.

The second research question was about inputs that were prioritized. In **Table 3**, the ticks in the external resources column show that material resources or exogenous inputs were provided and specifically the school principals, heads of departments and teachers were trained, all with the aim of improving performance in mathematics and science

An EPF postulates that if a person has the potential to develop an ability, they must have both appropriate internal and external resources to develop the ability. Yet the results of this analysis are clear that the NSMSTE strategy was focused on the provision of external resources while totally ignoring the innate abilities of students. This again could be one potential reason why the project did not achieve any significant improvement on learner performance in mathematical science. From a similar study, Nussbaum (2011) lamented that resource-based

Table 3. Summary of educational resources provided to the Dinaledi schools.

Learning Materials provided	Internal	External
2002 • Materials for the first Autumn clinic	X	✔
2004 • Provision of micro-science kits • Related training by Somerset Educational Pty Ltd. • Provision of math teaching aids • Related training by Phambili Education projects • Interim syllabus for teachers for grades 11 - 12	X	✔
2007 • The budget for Denaledi schools was R4.5 million	X	✔
2008 • 5700 scientific calculators were distributed • 14,000 copies of the mathematics 911 workbooks were distributed to Dinaledi schools • Each Dinaledi school received two copies of the DoE/Old Mutual Grade 10 - 12 Exemplar papers for mathematics and mathematical literacy • 0.2 million textbooks for Grade 12 for math, science, English additional language	X	✔
2009-2010 • 398 mathematics teachers received training • 370 physical science teachers received training • 370 of the 500 Dinaledi schools received support from companies, higher education institutions and other organizations	X	✔
2011 • R70 million granted to the Dinaledi schools	X	✔
2012 • R100 million budgeted for Dinaledi schools • Teacher laptop project for all teachers in the Dinaledi schools • R811 million for the expansion of workbooks to grade 9 learners • 4.4 million textbooks to Grades 10 to 12 in partnership with the Shuttleworth Foundation • 0.9 million grades 1 - 12 mathematics workbooks • 1.2 million grades 10 - 12 • 0.9 million physical science textbooks	X	✔
2013 • R105 million budgeted for Dinaledi Schools	X	✔

approaches following an egalitarian typology focus on the equal distribution of resources but overlook say a gifted child's need for realizing full potential. From an economics of education perspective, yes external inputs such as teachers and material resources matter but they are insufficient in predicting achievements if learners' endogenous factors are ignored. Therefore, this paper argues that the egalitarian typology as a single justification for distribution of resources is now a worn-out approach for South Africa and has outlived its time especially in areas such as mathematical sciences whose skills are needed in the technological era. Counsel from OECD (2012) is that certain educational policies can make education systems more efficient, without having a negative impact on equity or excellence and in recent years many countries have managed to raise both excellence and equity. In South Africa there is therefore need for ruthless pragmatism to balance the egalitarian typology with a meritocracy one.

The third research question was about evidence in the evaluation reports that high ability students should have been selected into the dedicated schools. The summary results in **Table 4**, show that code T appeared 43 times in the 20 documents that were sampled giving an average frequency of twice in each document.

Table 4. Summary of recommendations about talent identification.

Category of reports	Number sampled	Code NS (Freq.)	Code T (Freq.)
Department of Education	6	6	8
Independent Reports	8	8	21
Research Reports	6	6	14
Total	20	20	43

Results from this analysis it can be shown that from as early as 2001 up to 2019 various reports consistently chant in unison that talented learners should have been selected and nurtured in the dedicated schools. For example, in the Action Plan to 2014 the DBE (2011: p. 15) clearly admits that: "One area where government needs to do more work is in giving exceptional learners better access to focus schools". Similarly, in 2005 the national strategy set itself the goal of doubling the number of learners passing HG mathematics and science to 50,000 by 2008 and the strategy aimed to achieve this by, among other things, "identifying and nurturing talent and potential" (DoE, 2009: p. 5). This would be consistent with an EPF which postulates that optimisation of resources is enhanced if student potential is prioritized in the development of mathematical skills. In their paper on the comparison of South African and Singapore's education systems, Milne and Mhlolo (2021) have shown that gifted education is what drives Singapore's success. Coincidentally, around the same time (2001) that South Africa initiated its NSMSTE, Singapore developed, in 2004, an initiative to develop specialized schools that would serve the top 5% of students in specific domains of talent including mathematical sciences. To date Singapore is envied by many countries globally because of its strategies leading to its success in such areas. Similarly, in their advice to the South African Department of Education, the Centre for Development and Enterprise (CDE, 2013) cited literature that makes it clear that systemic change does not work optimally by starting with improvements to the least effective components of the system. On the contrary, economic wisdom suggests that an optimisation behavior would be typified by investing in programs that help identify and nurture talented learners because they constitute the component that has a higher impact on the economy.

5. Conclusion

From these results the take home message is that student ability is none negotiable in South Africa's attempts to improve educational achievement in mathematical sciences. From an EPF perspective economic wisdom suggests that an optimisation behavior would be typified by investing in programs that help identify and nurture talented learners because they constitute the component that has a higher impact on the economy. Identification of student ability must therefore be taken into consideration before providing other exogenous inputs. Secondly, the identification and nurturing of students' potential talent should start early in the primary school because late interventions have little or no impact at all. In order to avert the current crisis in mathematical sciences, the country should enhance the 2001 NSMSTE strategy by means of supporting gifted learners in dedicated schools and this according to Shaughnessy et al. (2012) would depict an ideal model of the Dinaledi schools.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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