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An Evaluation of the Dinaledi Schools: Project Using a Framework of Enablers of Creativity

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Abstract

Creativity is an essential skill for the 21st century knowledge-based economy. Mathematically gifted individuals are often seen as "the hope of the future" especially in STEM fields because of the special creative attributes that they possess. The way schools and teachers interact with gifted learners has important implications for whether opportunities for nurturing their creativity will be supported or missed. For two decades now South Africa has been trying to cater for the needs of gifted learners in mathematics through the Dinaledi School project but without much success. Despite the initiative's "shortcomings", reports are unanimous that consideration should be given to expanding it. This paper aimed at understanding the shortcomings over the two decades of implementation. We used a framework of enablers of creativity to analyse the cognitive demand of the curriculum, the cognitive preparedness of the learners and the way they were assessed in the Dinaledi Schools. Results show that the cognitive demand of the curriculum objectives is very high suggesting that it had potential to support the creative potential of gifted learners. However, the way learners were selected and assessed suggests that the domain readiness of the learners was not considered. Yet this is one of the most important factors to be considered when nurturing the creative potential of gifted learners. In reconceptualizing the Dinaledi Schools project our recommendation is that issues of selecting learners with the potential to deliver as well as how they are assessed should be prioritized.

Keywords

Creativity, Giftedness, Dinaledi, Cognitive Demand, Knowledge Economy, Mathematics

1. Introduction

The debates on skills which are essential for competition in the 21st century knowledge-based economy have been at the center of key policy reports from the Organization for Economic Co-operation and Development (OECD) and the World Bank during the past decade. Creativity and innovation are among the listed skills which are becoming increasingly important because they contribute to economic prosperity as well as to social and individual well being. For example, the World Economic Forum published a report in 2016 showing that creativity had moved from a tenth place ranking in 2015 to the third most important work-related skill for 2020. Creativity is a distinguishing characteristic of giftedness, hence the way schools and teachers interact with gifted learners has important implications for whether opportunities for nurturing their creativity will be supported or missed. There is widespread consensus, however, that our education systems are failing to adequately prepare all students with these essential 21st century knowledge and skills. For two decades now South Africa has been trying to cater for the needs of gifted learners in mathematics without much success. This paper attempts to understand why?

Admittedly, there are various definitions of creativity which have been proffered by researchers in the field but given the focus of our paper, we took a position that aligns with Plucker et al. (2004) who define creativity as the interaction among aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context. In a similar way that society has been trying to figure out which skills matter in the 21st century KBE, researchers have also posed questions for education about which subject(s) matter in the development of skills needed in the fourth industrial revolution (4IR). There is a general consensus in the literature that connects creativity in schools to the cluster of subjects related to science, technology, engineering, and mathematics education (STEM) (Lubinski & Benbow, 2021). Empirical evidence has actually shown that the positive impact on a country's Gross Domestic Product (GDP) can be isolated mainly to STEM-related achievements as opposed to achievements outside the STEM fields, suggesting that STEM-related achievements are the main drivers of national affluence in terms of creativity and innovation (Tanenbaum, 2016). Similarly, in their more recent paper entitled "Intellectual Precocity: What Have We Learned Since Terman?" Lubinski & Benbow (2021) have synthesized numerous studies done over the past 50 years, which have reached some consensus that individuals who pursue STEM disciplines possess a different intellectual design space for problem solving and creative thought. Over a host of personal attributes, STEM graduates exhibited psychological profiles typical of outstanding engineers and physical scientists. In South Africa this view is also shared by the Department of Basic Education who state in the Action Plan to 2014, that poor performance in STEM has caused a shortage of people who are able to study for professions such as medicine, financial management and engineering. This also limits South Africa's capacity to come up with new technological innovations that can improve the global competitiveness of the country (DBE, 2011).

But do all STEM graduates make an equal contribution to economic development, one might ask. Deeper analyses 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 (such as Bill Gates, Mark Zuckerberg, Michael Dell just to name a few) have produced such advances (McCabe et al., 2020). Earlier Tanenbaum (2016) had argued that gifted children are the tiny minority we suspect may someday produce important new theories, inventions discoveries, artistic masterpieces and solutions to monumental' problems in order to enhance the human condition. These findings again have had some influence on STEM reforms with more emphasis being placed on top-end performance rather than general performance in the fields.

Still 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 be highly adept in mathematical and spatial reasoning ability. Earlier, Lubinski et al. (2014) had 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 (see **Figure 1**).

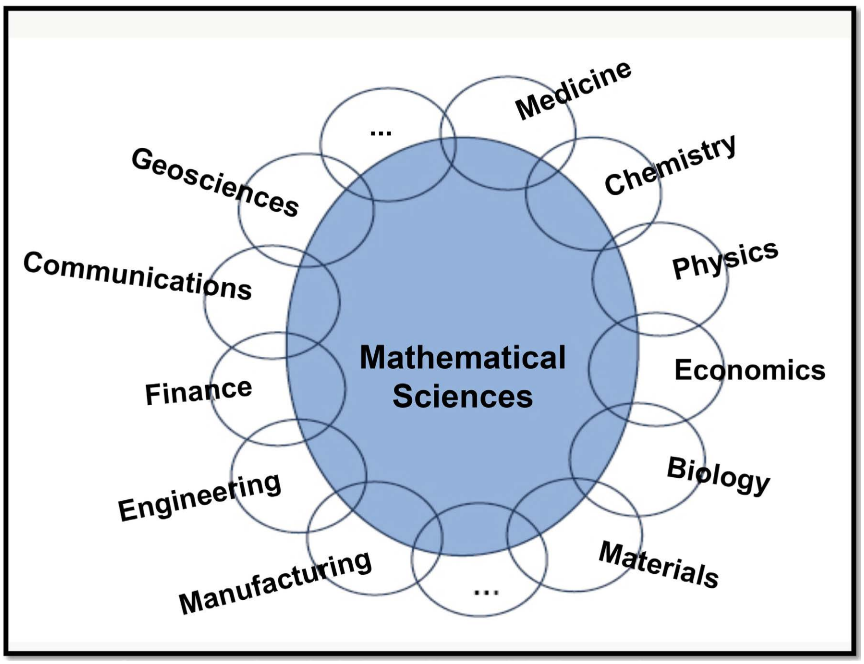

Figure 1. The mathematical sciences and their interfaces. (Source: National Research Council, 2013).

These studies confirm that, while STEM giftedness in general should be valued, the need for talent development of mathematically gifted students is even more pressing in the 21st century economy. In South Africa the National Strategy for Mathematics and Science (DoE, 2001) accentuates the role of mathematics arguing that the ability of all learners to succeed in today's technically orientated work environment is increasingly dependent on their understanding of mathematical and computational sciences and their application in practical situations. In fact, these sciences have become essential for all learners, including those preparing to become technicians, engineers, educators, leaders in business and government, and more generally, for developing scientifically, mathematically and technologically literate citizens. 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.

1.1. Education for the Mathematically Gifted in South Africa

In South Africa reports show that the plight of the gifted learner is seldom mentioned (Kokot, 2011) and that far too many of the gifted from poor backgrounds currently do not stand even the remotest chance of achieving up to near their potential (van der Westhuizen & Maree, 2006). Although there are such strong views about gifted learners, our view in this paper is that such views might be unkind to the system which is trying. There is ample evidence to show that South Africa has been making such attempts for two decades since 2001. For example, President Thabo Mbeki, in his State of the Nation addresses during the opening of Parliament in 2001, emphasized the centrality of mathematics and science as part of the country's human resource development strategy. Subsequent to that speech, when the National Strategy for Mathematics, Science & Technology Education (NSMSTE) was introduced in 2001, its vision was to empower individuals to participate in the emerging knowledge-based economy and sustainable development. According to the DoE (2001) this strategy to improve access to and participation and performance in mathematics, science and technology education represents a priority goal of our education and training system. NSMSTE's flagship program was the 100 dedicated schools which later became known as the Dinaledi Schools. Their mandate was very clear in that the Dinaledi Schools would focus on mathematics and science learners "with potential" in dedicated schools, rather than through a dilution of effort across the whole schooling system (DoE, 2001). Similarly, the National Planning Commission (NPC) 2012 report made it clear that opportunities for excellence be provided to the most talented students (NPC, 2012) and that consideration should be given to expanding the Dinaledi Schools Initiative, which increases access to Mathematics and Physical Sciences in underprivileged schools (NPC, 2012: p. 305). A Mathematics, Science & Technology Education (MSTE) task team that followed up the NPC also lamented that the education system tended to focus more on learners with learning difficulties while ignoring gifted children who could take the country forward in terms of scientific development. The team's recommendations were that MST talent development programs should be incorporated into the revised NSMSTE strategy and that at least one dedicated Mathematics and Science Academy or a special Mathematics, Science and Technology School should be established in each province (DBE, 2012: p. 48). In the five-year strategic Action Plan to 2014, the Department of Basic Education admits that one area where government needed to do more was to provide "exceptional learners" with greater access to focus schools. Focus schools are conceptualized here as schools that pay special attention to specific subjects such as mathematics, so that learners who do "very well" in these subjects can spend more time on them and be taught by teachers with additional training and skills in these subjects. The plan goes on to say that it is important for parents and teachers to recognize who is performing exceptionally well, or who has the potential to do this, and then to make sure that these learners are given the right support to develop their strong areas further. In the Department of Basic Education 2018/2019 annual report, the foreword by the Minister of Education reads:

> When talented children do not participate in school, or drop out before achieving their potential, this is a grossly inefficient use of a country's human capital (DBE, 2019: p. 16).

In an interview with Professor Maree this is what the late Archbishop Desmond Tutu had to say about gifted children in South Africa:

> …We should do all we can to make our children want to aim for the stars. Every child should seek to be the best that he/she can be. We cannot afford to play ducks and drakes. Where you have children who are particularly gifted, it would be criminal not to want to develop their potential to the highest possible extent. We are not looking for uniformity...we want to ensure that every child has a basic education, but we mustn't make a virtue of mediocrity. We must produce the best possible children in every possible sense (Maree, 2007: p. 6).

More recently government launched the three-stream model curriculum whose objectives are, inter alia, to implement a curriculum that will meet the diverse needs of South Africa's youth, to promote skills acquisition and empower creativity. The first thrust of its implementation would see participation and performance by historically disadvantaged learners, receiving most of the attention, with shortcomings in the dedicated schools strategy being a principal concern (DBE, 2018). The launch of the model on 8 May 2018, saw the Department of Basic Education committing itself to the NPC's recommendation that the Dinaledi Schools program should be expanded. These are just a few examples where the will to cater for the needs of gifted learners is very clearly articulated. Hence we argue that although implementation might have been problematic, since 2001 the will on the part of government to cater for the needs of exceptional learners in Mathematics and Science has been consistent.

1.2. Statement of the Problem

From the preceding paragraphs it is clear that STEM gifted education has been on the country's agenda for two decades now contrary to the view that nothing has been happening. So why has there been stagnation in terms of improving the top-end performance that was targeted by the national strategy for mathematics and science? A major problem cited by Blum et al. (2010) in their report for the World Bank on the Dinaledi Schools project, was lack of external validity. While the analysis for the World Bank report had been conducted using the best available methods given the time and data constraints, their recommendation was that the positive results presented should be taken with "restrained optimism". The Centre for Development & Enterprise (CDE) reports and other research reports pointed to a common weakness associated with internal evaluations—that evaluators tend to spruce performance and conceal the deficits often with the intention of securing further funding. In the same breadth Blum et al. (2010) recommended that, for future policy design for STEM, external evaluation of the Dinaledi Schools Program was necessary to complement the World Report's findings. Similarly, Kahn (2021) was of the view that the Dinaledi program continues to hold valuable potential to contribute to MST improvement but a review is necessary if the potential is to be exploited to optimal effect. The Department of Basic Education also wants to expand the project but with shortcomings in the dedicated schools strategy being a principal concern (DBE, 2018). It is against such recommendations that this study aimed at identifying possible barriers that might have worked against the successful implementation of the dedicated schools project for gifted learners in STEM.

1.3. Significance of the Study

Our analysis as outsiders is basically an external evaluation, hence one of the importance of this study is in the complementary role that external evaluations play vis-à-vis internal evaluations. For example, Newmann et al. (1997) studied the connection between internal and external types of educational accountability. They concluded that external accountability seems to strengthen the internal monitoring part of educational systems, and seems to encourage the search for success or failure in the educational practices. Another widespread form of interdependence between the two processes is the fact that external evaluation focuses on the safeguarding of standards of quality of education. In the case of the Dinaledi Schools project, the World Bank report specifically recommended that the project be subjected to further external evaluation (Blum et al., 2010).

From a practical point of view, at the time of initiating the NSMSTE, the department of education was clear, under section seven on research, that it would welcome research that tracks the success of interventions implemented as a result of this strategy (DoE, 2001). Our research does exactly that. Secondly, in our literature search we have not come across a single report in the two decades since 2001 which suggests that the Dinaledi Schools project should be terminated. Instead there is ample evidence from many reports that if the Dinaledi Project could be restructured it could be a case in point which could lead to the more wide-spread acceptance of specialist schools. But it is two decades after the introduction of the project now yet it has not achieved positive gains in the top-end performance for which it was intended. Our view in this paper is that, while we need to accept that systemic change takes time, there is need to understand that time and effort must be spent in the progressive direction. We must not spend time and effort doing the wrong thing, then having to go back to undo it and do the right thing all over again. Hence we also argue that if the idea of the dedicated schools for STEM needs to be expanded as per the NPC recommendation, with shortcomings in the dedicated schools strategy being a principal concern (DBE, 2018), then surely there is need to identify these shortcomings before further expansion.

From a theoretical point of view, creativity and innovation are becoming increasingly important for the development of the 21st century knowledge society because they contribute to economic prosperity as well as to social and individual well being. Creativity is seen as the source of innovation, and innovation in turn as the implementation of creativity. Creativity and gifted education are like fish and water in that it is expected that the gifted will accomplish more in terms of creative outputs than the non-gifted because they are better able to apply sophisticated thought processes to what is the same material (Tannenbaum, 1983). In this regard, mathematically gifted individuals are often seen as "the hope of the future" especially in STEM field because of the special creative attributes that they possess. Terman's Genetic Studies (Friedman & Martin, 2011) and the subsequent studies by Lubinski & Benbow (2021) are arguably among the most famous longitudinal studies in psychology to date that have tracked mathematically gifted youth for more than five decades with the aim of affirming this thought. Results from these studies have confirmed beyond any reasonable doubt that mathematically talented males and females indeed became the critical human capital needed for driving modern day, conceptual economies. Leikin (2011) therefore proposed that mathematics education must pay more attention to research of different kinds of mathematical activities, with a clear focus on students' creative thinking and giftedness. Consistent with these views, the justification for this paper is that it has potential to add to this research knowledge by investigating the extent to which the Dinaledi Schools enabled gifted learners to develop their creative potential.

2. Theoretical Framework

The Organization for Economic Co-operation and Development (OECD) developed a Framework for the Assessment of Creative Thinking in PISA 2021 which we found useful for our analysis. Although the framework was designed with classroom analysis in mind, in this paper we draw upon Csikszentmihalyi's (1997) view that we must consider how creativity arises from a dynamic interaction of systemic elements which might support or inhibit the development of creativity. Csikszentmihalyi's concern arose from an observation where much of the research on creativity has focused on individual creativity, or psychological, psychometric or personality approaches. Yet there has been comparatively little research on how the field of education could consider the extent to which educational policies and practices could foster creativity among the students, especially for the 21st century knowledge based economy. Csikszentmihalyi argued that although creative thinking is partially hereditary, the educational context in which individual students grow up and in which they learn, plays a major role in whether their latent potential will be maximally developed. Papadopoulos (2020) did an analysis of a total of 95 publications on gifted education, which is closely associated with creativity and the publications provide some evidence that the process of nurturing giftedness in children is determined by the dynamic interaction between individual strengths and an environment, which can stimulate or inhibit the full use of a child's creativity. The results suggest that a productive way of thinking about creativity is not only to consider the individual but also the elements within a system. Csikszentimihalyi & Csikszentmihalyi's (1988) argument was that creativity is likely to have a more significant impact on pupils' learning if the choices made to include creativity in national policy statements are coherent throughout different sections of the education system. Although Csikszentmihalyi's (1997) three systems model shares some similarities with the OECD (2019) model, we found the latter more appealing for two important reasons (a) that it is more recent and (b) that the model considers these systemic elements as enablers instead of just domains in which to study creative potential of children.

Figure 2 captures (in no specific order) the relationship between individual enablers, social enablers as well as achievement/assessment in terms of their role in supporting or inhibiting students' creativeness. Tannenbaum (1983) was clear that those who have the potential for creativeness require not only the personal attributes that are often mentioned in the various definitions of giftedness, but also some special encounters with the environment to facilitate the emergence of talent. Although this OECD framework was designed with a school as a focal unit, our view in this paper is that an education system or program such as the Dinaledi Schools project can also be analysed as a focal unit. The way the Dinaledi Schools project was designed and implemented had potential to influence several dimensions of students' internal resources which are captured in the model as "individual enablers" for engaging in creative thinking. As for the features of students' social environments that might incentivize or hinder creative thinking described henceforth as "social enablers", our view is that despite there being various social elements to consider, the curriculum could be singled out as the instrument that dictates the affairs of every educational system or the axle around which all the teaching and learning activities revolve. In South Africa the Action Plan to 2014 clearly states that the curriculum lies at the heart of the schooling process. It specifies the what and how knowledge should be taught as

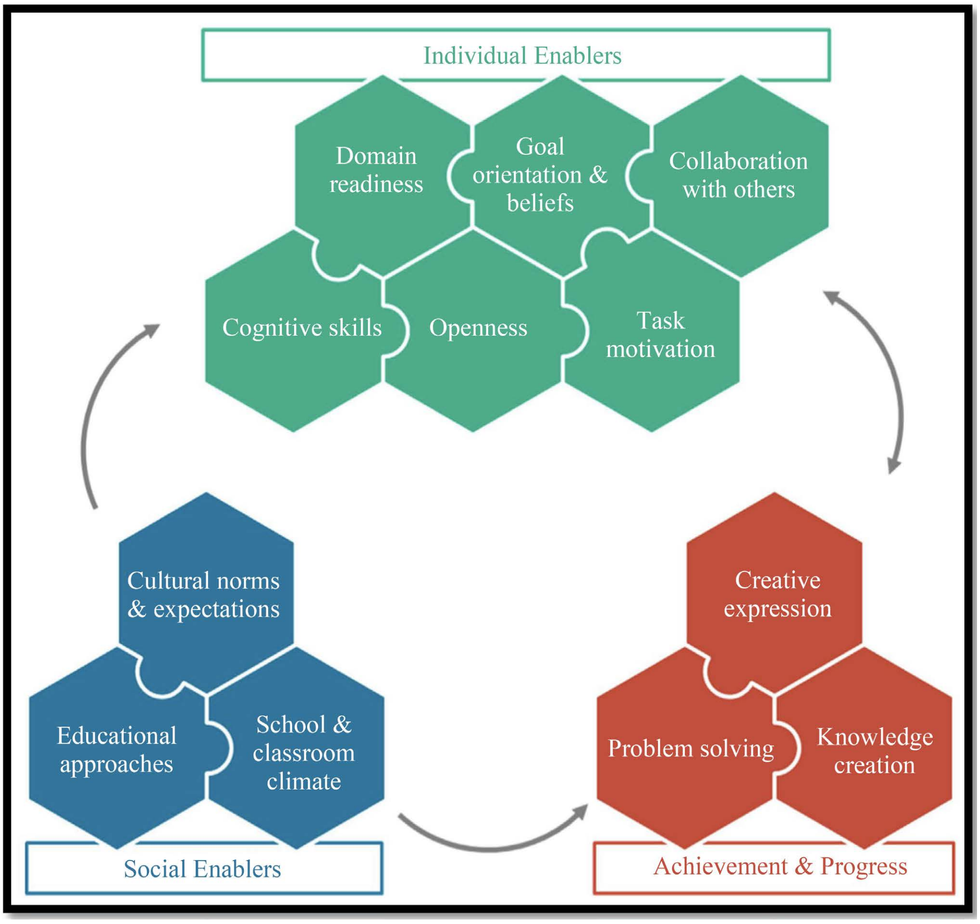

Figure 2. Enablers of creative thinking (OECD, 2019).

well as how learning in the classroom should proceed (DBE, 2011). In fact literature suggests that, in order to achieve the objectives of education, an instrument that serves as a vehicle of operation is required and that instrument is the curriculum (Aneke et al., 2016) which can provide students with incentives or obstacles for engaging in creative thinking. Finally, an education system or program is an arena in which students' manifestations of creative thinking can be observed and measured pointing to a critical relationship between the written and tested curriculum. Mhlolo (2011) showed how from a rational curriculum planning perspective, in stating the objectives of a curriculum, a claim is made about what the learners will do (e.g. to promote skills acquisition and empower creativity) and how this must be validated through assessment lest those claims remain rhetoric. Emphasizing this relationship, Knight (1995: p. 13) argued that:

> In writing a mission statement, a program plan or a validation document' (such as a curriculum), skilled drafting allows us to lay claims to a wonderland of concepts, skills, competences and the like, of which our students are to be made citizens. However, for those who want to know about the quality of a course, program or institution, the test is whether these goals are assessed and how well they are assessed. In a sense, the way students are as-

> sessed is the "DNA evidence" of their learning experiences. …if there is no evidence of appropriate assessment, then the DNA evidence belies the claim. At best, the absence of assessment suggests that our intentions have not been completely realized. At worst, it says that our intentions were rhetoric, for the benefit of auditors, not students.

In this sense we argue that assessment shapes the curriculum as it defines what students regard as important and how they spend their time. In other words students will learn for the assessment and according to Biggs (2003), they would be foolish if they didn't. Viewed in this way tests therefore act as "traps" into which both teachers and students find it difficult to escape. So what is assessed determines what is taught and what is learnt. Hence there is empirical evidence to suggest that there is a lot of teaching to the test with teachers focusing on topics and skills that are included in the examinations and devoting a lot of time to acclimatizing students to examination-type questions (Ottenvanger et al., 2007). This action by the teacher obviously can affect the achievement of the broad goals and objectives of the curriculum such as creativity. So, according to OECD (2019) these three distinct enablers (individual, social and achievement/progress) of creative thinking in the education system are strongly interconnected and our view in this paper is that in order to understand what went wrong with the Dinaledi School Project we could look through these three categories of enablers to creativity.

Research Questions

Our view in this paper is that a theoretical/conceptual framework "sets the stage" for the presentation of the specific research question(s) that drive(s) the investigation being reported. Having set the stage and consistent with our chosen framework we then raised the following three questions each linked to the three enablers as identified in the OECD model:

1) What is the level of cognitive demand in the mathematical concepts, processes and skills as articulated in the written CAPS documents at FET level?

2) To what extent did the Dinaledi Schools program consider the domain readiness of learners as well as their cognitive skills?

3) How was performance of learners measured in the Dinaledi Schools and to what extent did such assessment measure higher order cognitive skills of the learners?

3. Methods

3.1. Research Design

Our research was documentary research in which we focused mainly on the Curriculum, Assessment & Policy Statement (CAPS) for Mathematics at Further Education & Training (FET) level. The Dinaledi Schools project was for FET learners hence our interest in their curriculum. In South Africa FET level refers to Grades 10, 11 and 12, which is the exit level into Higher & Tertiary Education.

The FET curriculum breaks content into four Learning Outcomes (LOs) where LO1 is Number and Number Relations, LO2 is Functions and Algebra, LO3 is Space, Shape and Measurement and LO4 is Data Handling & Probability.

3.2. Sampling

Our sampling was purposive and we had a very specific interest in analyzing the following documents:

1) The Curriculum & Assessment Policy Statements (CAPS) Grades 10 - 12, Mathematics

2) The 2021 Annual Teaching Plan (ATP) for Mathematics Grade 11

3) The National Strategy for Mathematics, Science & Technology Education (NSMSTE) both old (2001) and revised (2019)

4) The Action Plans to 2014, to 2019, and to 2024

The relationship between 1 and 2 is that objectives are stated in the CAPS document while the ATP describes the objectives in more detail. The verbs used in the ATP allowed us to do an analysis of the cognitive demand levels of the objectives i.e. answering Research Question 1. The Dinaledi Schools project is articulated in the NSMSTE as the flagship program for the strategy and analyzing the NSMSTE enabled us to answer Research Question 2. The action plans are five-year strategic plans where assessment results are compared with the targets set and this enabled us to answer Research Question 3. All these documents are available at the Department of Basic Education's portal.

3.3. Data Collection Instruments

In developing the data collection and analytical tool for question 1 we borrowed from Porter et al. (2007) who argued that: "...to predict student achievement gains from knowledge of the content of instruction, a micro-level description of content that looks at cognitive demands by type of knowledge is the most useful approach considered to date" (p. 331). The procedure they developed is one of the few approaches to alignment analyses approved by both the Institute for Education Sciences (IES) and the National Science Foundation (NSF) (Webb, 2007). Porter et al. (2007) took over 20 years developing such a cognitive demand tool as shown in **Table 1**.

Although Porter's cognitive demand tools are more comprehensive, with clear descriptors or verbs associated with each level of cognitive demand, here we just present an abridged version in the interest of space.

Table 1. Language frequently associated with performance goals (Porter, 2002: p. 13).

Lower order skills/procedures		Higher order skills/procedures		
A	B	C	D	E
Memorize facts, Definitions, Formulas	Perform procedures/solve routine problem	Communication understanding of concepts	Solve non-routine problems/make connections	Conjecture, generalize, prove

3.4. Data Collection Procedures and Analysis

As explained earlier, the Annual Teaching Plan is the document in which more detailed objectives of the curriculum are articulated for each of the four learning outcomes. Table 2 shows how we used Porter's tool to code data.

Our interpretation to 1 and 2 for example was that "recognizing simplest perfect squares" required the learners to recall, recognize, identify—hence memorize (coded A) the definition and characteristic features of a perfect square or real numbers. In 3, 4, 5, 9 and 10 our interpretation was that these were examples where learners are required to compute or solve routine problems—hence perform procedures (coded B). Both 6 and 11 required the learners to use representations to model mathematical ideas or to describe—hence communicating understanding of concepts (coded C). In 12 this was a case of solving non-routine problems (coded D). Lastly in 7 and 8 the teaching plan required the learners to determine the truth of a mathematical pattern, make and investigate mathematical conjectures, provide proof of a conjecture—hence (coded E). All the four learning outcomes (LO1, LO2, LO3, and LO4) were coded in a similar way.

To answer research questions 2 and 3 we analysed the NSMSTE document in terms of criteria that was used for a school to qualify as a Dinaledi School. Domain readiness would come out clearly from this document. In terms of assessment, we then focused on the Action Plans, which clearly captured performances by Dinaledi Schools at certain periods.

Table 2. How coding was done during data collection.

Number	Objective	Code
We will know when the learner is able to		
1	Recognize the simplest perfect squares	A
2	Understand that real number can be rational numbers or irrational numbers	A
3	Simplify expressions and solve equations using the laws of exponents for rational exponents	B
4	Add, subtract multiply and divide simple surds	B
5	Solve simple equations involving surds.	B
6	Demonstrate an understanding of error margins	C
7	Investigate number patterns hence	E
8	Make conjectures and generations	E
9	Provide explanations and justifications and attempts to prove conjectures	B
10	Use simple compound growth formulae to solve problems	B
11	Demonstrate an understanding of different periods of compound growth and decay	C
12	Solve non-routine problems	D

3.5. Validity and Reliability

In order to enhance the trustworthiness of our data, we employed the services of an examiner and a moderator of mathematics papers to interpret and contextualize the cognitive demand tools. Inter-rather reliability (IRR) was very high at 0.88. Inter-rater reliability is deemed "acceptable" if the IRR score was ≥75%, following a rule of thumb for acceptable reliability. Coding of the ATP was relatively straight forward in view of the fact that, in the absence of content, objectives are stated mainly in the form of descriptors such as identify, simplify, investigate, and provide an explanation and justification for. These descriptors had an almost perfect match with the descriptors in Porter's cognitive demand tool, such that there was very little reinterpretation if any to be done by coders. This was consistent with the assumption in the critical paradigm that objective reality could be achievable through evaluation by a community of scholars (Silverman, 2001).

4. Results & Discussion

Research Question 1: What is the level of cognitive demand in the mathematical concepts, processes and skills as articulated in the written CAPS documents at FET level?

At the inception of the Dinaledi Schools project, there was no special curriculum developed for such schools. These schools were therefore expected to follow the general curriculum followed by all the other schools. We then became interested to see the extent to which the general curriculum would support or inhibit the higher order cognitive skills of these exceptional learners (**Table 3**).

So, the way the cognitive demand table above is interpreted is that columns A and B are the constituencies of lower order skills and processes while columns C, D and E constitute higher order skills and processes based on the definitions of higher/lower order thinking as discussed previously. There were 6 objectives for example, in the Annual Teaching Plan for (Number and Number Relationships) that we identified as higher order requiring learners either to communicate understanding, problem solve or conjecture, generalize and prove. If one were to take totals of columns C (11), D (19) and E (20) for example, it might be clear how this tool was useful in terms of answering the first research question for this

Table 3. Levels of cognitive demand in the annual teaching plan.

Lower order skills				Higher order skills			
Learning Outcome	**A**	**B**	**Total**	**C**	**D**	**E**	**Total**
Number & Relations	1	3	4	2	1	3	6
Functions & Algebra	3	4	7	5	5	5	15
Space, shape & measurement	0	1	1	0	10	9	19
Data handling	2	2	4	4	3	3	10
Total	**6**	**10**	**16**	**11**	**19**	**20**	**50**

study i.e. "What is the level of cognitive demand in the mathematical concepts, processes and skills as articulated in the written NCSM at FET level?"

Judged by these data counts one can argue that the CAPS documents' espousal of high order level skills and processes is evident within its Annual Teaching Plan. In our view, this provides prima facie evidence that the CAPS documents, though designed with average learners in mind, had the potential to support the creativeness of exceptional STEM learners. These results did not surprise us given that when the curriculum was revised from the old, which was described as content-based curricula, the department of education made it clear that in the revised curriculum the learning areas would have assessment standards focusing on the development of higher order skills (DoE, 2001). It was envisaged that the development of the National Curriculum Statement, if implemented accordingly, would equip learners with knowledge and skills that would help them to compete in a global economy and allow them to lead lives of satisfaction and integrity, both as individuals and as citizens. In South Africa, Umalusi, (derived from Nguni meaning shepherd or guardian of the family belongings, resources, and valuables) is the quality assurance and standards authority responsible for the schooling system. In their 2013 report they confirmed that the curriculum that was developed for the FET schools did adopt certain of the assumptions of the imagined future system (Umalusi, 2013). It went on to state that, what school completion means in terms of skills, knowledge, and aptitude is clearly spelt out in the curriculum. The report further argued that before one can make any meaningful judgement about relative standards, a comparison of quality across systems has to include curriculum load, cognitive demand, forms of assessment, and quality of examiners and markers. Similarly, Kahn (2021) does not doubt the quality in design of the curriculum but argues that what is missing from the body of research is consideration of the curriculum as a whole, meaning delivery in the classroom.

Research Question 2: To what extent did the Dinaledi Schools program consider the domain readiness of learners as well as their cognitive skills?

In order to put the discussion into context, we start by pointing out to the reader that there are other views expressed over the twenty year period that Dinaledi Schools were not for exceptional learners. Because of that view, there is limited data that compares the Dinaledi Schools performance with national performance. However, Spaull (2013) pointed to an existing culture of blame-shifting, impunity, patronage and obfuscation in South Africa, with the intention to cover up for ineptitude and incompetence. This is unsustainable and is arguably a binding constraint to systemic progress (Spaull, 2013). Our position is clear in this paper that Dinaledi Schools were meant to and are still going to be focusing on exceptional learners in mathematical science hence we discuss the results of our analysis from that position. Having given this background, let us now use **Table 4** & **Table 5** to discuss this question of domain readiness.

From **Table 4**, it is clear that to qualify for Dinaledi status, a school needed to have previously obtained at least 35 learners passing with a 40% or 50%. We find

Table 4. Criteria for selection of Dinaledi School.

Selection Criteria	❖ Located in Presidential model area i.e. those targeted for urban renewal and rural development ❖ Under resourced well-performing schools ❖ Display basic levels of functionality ❖ Offer both mathematics & science at HG level ❖ Have satisfactory class sizes of a minimum of 20 learners ❖ Have competent educators in both mathematics and science ❖ Have had at least 35 Grade 12 mathematics passes by African candidates, either at higher grade (50%) or standard grade (40%)

Table 5. Performance in mathematics 2008 examination (Source: DoE, 2009).

Province	Total number who wrote	Number passing with 50% and above	Total in Dinaledi	Number passing with 50% and above	Dinaledi passing as a % of national
Eastern Cape	37,069	5362	4921	1068	20%
Free State	14,719	3614	3366	922	255
Gauteng	50,885	15,298	13,635	4100	27%
KwaZulu Natal	81,780	14,929	10,517	3199	21%
Limpopo	49,643	7283	5906	1858	26%
Mpumalanga	23,822	4013	3921	844	21%
Northern Cape	3866	898	965	227	25%
North West	17,080	3607	5666	1415	39%
Western Cape	19,957	8031	4572	1418	18%
Total	**298,821**	**63,035**	**53,469**	**15,051**	**24%**

this to be problematic in two ways, especially when one considers that this project aimed at addressing top-end performance. Firstly, qualification is based on history, that is the school must have obtained 35 learners passing before. This clearly indicates to us that learner potential of the "current learners" was never considered. Secondly, the 40% and 50% mark is the one used for measuring performance in the general schooling system, surely this would be too low as a criteria for a school of excellence. We consolidate our argument using Table 5, where in 2008, (seven years into the project) 53,469 candidates in Dinaledi Schools wrote and only 15,051 passed. This is a mere 28% pass out of what should arguably be the cream of the crop! Never mind the 24% pass that the department used to "praise" the project when compared nationally, these results in terms of domain readiness actually confirm that the calibre of learners who went into the dedicated schools were far from ready. In fact a further disaggregation done by the department showed that 54 Dinaledi schools obtained between 0 and 20 learners passing mathematics in the 2008 National Senior Certificate examinations (DoE, 2009). This is an internal incoherence which the department has to tackle head-on if the project has to be expanded. The department cannot say on one end they want learners with exceptional ability to be identified and nurtured then go on to take any learner into a dedicated school. Our recommendation is in line with previous studies e.g. the Centre for Development and Enterprise who have consistently recommended that aptitude tests (or some other measure of domain readiness) be used to select learners onto this project. Domain readiness conveys the idea that an individual requires some degree of pre-existing knowledge and experience within a particular domain in order to successfully produce creative work (Baer, 2016). The argument is that the more knowledge one possesses and the better one understands the relationships between pieces of information within a domain, the greater the likelihood one has of generating a creative idea (Schwartz et al., 2005).

Research Question 3: How was performance of learners measured in the Dinaledi Schools and to what extent did such assessment measure higher order cognitive skills of the learners?

Table 5 shows clearly that what was considered a pass for the Dinaledi Schools was a 30% mark. Before we discuss this mark, we start by pointing out that comparing the 30% pass mark with other external systems, is a hotly contested issue in South Africa with some bodies vehemently defending it. For example, in their 2013 report, Umalusi argued that by increasing this mark to say 50%, this would increase the failure rate to (roughly either 55% or 89% in 2011) and this would be "politically and socially unacceptable", further heightening the belief that the system is in crisis. The report went further to say, aside the "symbolic" raising of the standard, there is little value to raising the overall pass mark in this manner (UMALUSI, 2013: p. 28). So we abandon the route of judging the mark against other external systems, because it won't take us anywhere. Instead we go back to the mark of 30% and its value internally through norm-referencing where we compare the cohort that wrote in a particular year.

In **Table 6**, Dinaledi Schools are presented as having registered 42,083 candidates of whom 22,877 passed with a 30% or better, translating to a 54% pass. This is 10 years after the inception of the project, and let us recall that the criteria for selection was a 40% or better but now the performance is being measured at 30% or better! Putting the 30% mark aside, a bell-curve theory as depicted in **Figure 3** would suggest that even using South Africa's own scale with a 30% as a pass mark; that 30% point would still be way below average, and wisdom lies somewhere much higher than that 30% mark.

Assuming there is sense in what we are arguing, we would remove all the 7791 learners who passed with a 30% and below because that was not the qualifying criterion for Dinaledi status. This would leave the pass rate at 35%, but hang on a minute; Dinaledi schools were expected to increase the number of learners passing with higher grade i.e. 50% pass. If we take away those 13 465 learners who passed below 50%, again this would reduce the pass rate to 22%. Finally, we need to consider that the department reiterated: "We need to improve results at the top end if South Africa is to have world class scientists, designers, analysts and so on". If we then agree that the dedicated schools project was initiated with top-end performance in mind, then only the 1174 learners who scored above

Table 6. Results for Dinaledi Schools 2011 (Source: DBE, 2012).

Total Number of learners writing and passing Mathematics in Dinaledi schools – 2011 NSC

Province Name	Total Wrote	Pass0-<10%	Pass10-<20%	Pass20-<30%	Pass30-399%	Pass40-499%	Pass50-599%	Pass60-699%	Pass70-799%	Pass80-100%	Total Pass	% Pass
EASTERN CAPE	6053	641	1520	1286	1047	707	383	240	128	101	2606	43%
FREE STATE	2538	68	368	551	606	394	242	143	103	63	1551	61%
GAUTENG	8472	428	1392	1477	1476	1200	1002	747	436	314	5175	61%
KWAZULU-NATAL	8936	822	2080	1787	1553	1035	670	455	322	212	4247	48%
LIMPOPO	4789	239	832	781	883	735	525	364	231	199	2937	61%
MPUMALANGA	3646	304	678	722	655	516	343	207	146	75	1942	53%
NORTH WEST	3519	114	613	728	788	507	321	226	139	83	2064	59%
NORTHERN CAPE	1008	89	219	210	210	103	78	45	31	23	490	49%
WESTERN CAPE	3122	126	524	607	573	477	330	218	163	104	1865	60%
Total	42083	2831	8226	8149	7791	5674	3894	2645	1699	1174	22877	54%

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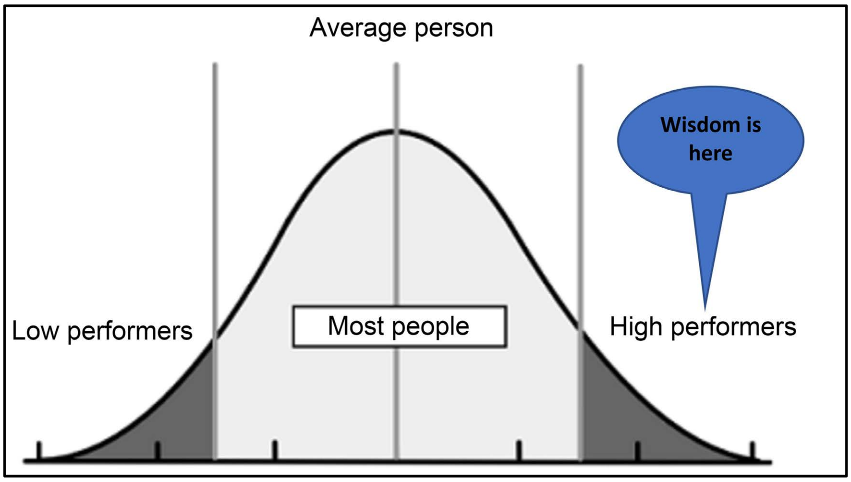

Figure 3. Where is the wisdom needed in the 21st century KBE.

79% should be considered and this again would reduce the pass rate to a mere 3%, ten years later! With such results, there is no way we could say assessment of learners in the Dinaledi project would be supportive of learners creative potential. In fact learners who pass with this very 79% mark, have been considered at risk by South Africa's own and not foreign universities. This is the reality that does not get to be told through the departmental reports. But let us remember that if we wish to discover the truth about an educational system, we must first look to its assessment procedures because that is the DNA evidence of the wonderland of claims of concepts, skills, competences that skilled drafting allows the curriculum to lay.

Our findings are further corroborated by CDE (2004) who dedicated two full pages (102-104) showing how in 2001 some Dinaledi Schools beat the system even though they did not qualify for the program. Unfortunately that trend continued to date with schools being removed and added almost annually when their results came out. Hence in some quarters, the Dinaledi Schools project is described as just a group of randomly selected ordinary schools and not schools of excellence. The CDE (2004) report concluded by lamenting that the selection of schools under the project was clearly a classic case of the power of local political interests which they described as self-defeating for the schools involved since success was hardly assured or even likely to occur for many of them.

5. Conclusion

This paper analysed the curriculum that was followed, the domain readiness of learners as well as how they were assessed on the Dinaledi Schools project. Results show that the curriculum was well designed in terms of cognitive demand however the schools never selected learners on the basis of their academic potential in STEM. The schools were never assessed differently from the general schooling system even though these were supposed to be schools of excellence. These in our view, are issues which need to be taken into consideration as the Dinaledi Schools project gets expanded. Our worry though is that these issues have been raised before but the department seems not to acknowledge them. As other studies have lamented, these recommendations appear to be unhelpful, in that a similar culling exercise took place in the early 2000s (Kahn, 2021). Similarly Spaull (2013) warned that without acknowledging the true severity of the problem, it is not possible to mobilize the resources and public support necessary to implement the uncomfortable and costly reforms that are necessary to make significant and sustained improvements in the quality of education.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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