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An introspection of High School Science Education from South Africa

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Abstract

This century, the twenty-first century, is a century of science and technology explosion. This is the period when the boon of science has arrived in almost every corner of the world. One such example is exposure to information (data) using a cell phone, bypassing a computer. This has made information available to the masses at a much cheaper rate and with less difficulty. This has become possible only because of the science, technology, engineering, and mathematics (STEM)-trained workforces developed by STEM education over the years. One more important aspect of the twenty-first century is the demand for more and more STEM workforces at all levels. As a result, every country is planning hard to achieve their goal of getting more and more STEM-trained workforces for the sustenance of social and economic growth using both the immigration channel and high school STEM education development programs. In order to keep pace, the South African education system is also undergoing changes. Significant adjustments are made in the high school education system to reflect the post-apartheid era's worldview and correct pre-apartheid era-induced mistakes. The 1996 South African Schools' Act is the beginning of changes in the South African school education system. The purpose of this study is to ascertain whether there has been any improvement in STEM education in general and physical science in particular after all these changes were implemented in the South African school system. The purpose of this study is to establish the empirical hallmark of changes in high school physical science teaching outcomes using a sample from rural South African schools for a period of 2008 to 2018. This study collected secondary data from the national senior certificate examination (NSCE) data base to analyse the teaching-learning outcomes of physical science *within a rural school district in the Mpumalanga Province of South Africa. A quantitative analytic method was used to analyse the set of secondary data thus collected. The study concludes that, during the observed period, there has been statistically insignificant improvement in learners' performance in physical science, and there exists a room for introspection regarding the state of high school science teaching processes in order to improve the quality of STEM education in the country.*

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INTRODUCTION:

The twenty-first century is the century of science and technology explosions. This is the period when the boon of science has arrived in almost every nook and cranny of the world. There are things happening that were unimaginable for ordinary citizens during the twentieth century or before. One such example is the use of mobile phones. Today, almost every ordinary citizen, including school kids, is able to make a call from wherever they are! Making a video call has become a daily chore of our lives without any hassle and at a feasible cost. We have plenty of options to communicate with each other while comparing people's lives around 1970 in Africa, Asia, or Europe. There used to be only one way of urgent communication. That was a post office with telegram sending and receiving facilities. If the villagers were lucky, they would have a rich man with a landline telephone open for neighbours' emergencies. Today, landline telephones have become almost obsolete. Remote sensing and artificial intelligence have occupied every sector of the life of a common citizen. Google Pay is a household name in every nook and cranny of the world. This has become possible only with a STEM-trained workforce created by STEM education over the years. The twenty-first century demands an increase in the STEM workforce at all levels. Every country is working hard to achieve their goal of getting a more and more STEM-trained workforce for the sustenance of social development (Camilli, 2019). Improving the quality of STEM education and increasing the quantity of the STEM workforce have been stressed by academicians (Maas et al., 2019; Chong, 2019). The incubation of the STEM workforce starts in high school classrooms. In order to prepare a STEM-trained workforce, colleges and universities need well-motivated and trained STEM graduates from high schools. Countries are tirelessly working on achieving this goal by bringing about changes in their high school systems (Stehle & Peters-Burton, 2019; Le, Tran, & Tran, 2021; Berglund et al., 2021). STEM education in particular and education in South Africa as a whole have been changing for a very long time. The South African high school education system changed how it operated once the country's regime transitioned from apartheid to a democratic, inclusive one. To reflect the mindset of the post-apartheid era, the South African educational system underwent considerable changes after 1994. A revamping of the educational system is also necessary to make it accessible to all South Africans.

The success of any school reform is measured by students' performances at school leaving examinations (Chowdhury & Rankhumise, 2022). This study intends to study the effectiveness of changes introduced in schools while comparing the performance of students in physical science in the Mpumalanga province of South Africa. This is done by performing a performance analysis of students at their national senior certificate examination (NSCE), which is the school exit point for South African high school students. Earlier studies have been conducted relating students performances to attitude (Chowdhury et al., 2020) and resources (Chowdhury & Rankhumise, 2022). This study intends to critically examine the impact of school reforms and correlate these with the performance outcomes at NSCE for rural South African schools. The purpose of this article is to analyse the rural population's response, followed by changes after a quarter century of independence from the apartheid era, in relation to NSCE results. The purpose of this study is to determine the effect of post-1994 modifications on contemporary stakeholders regarding high school graduates' performance in physical science. Physical science is one of the important STEM subjects taught in high schools in South Africa. South African education can be classified as either a pre-apartheid education system or a post-apartheid education system. Both the pre- and post-conditions have a bearing on South Africa's present education system. In other words, there is still a need to comprehend its past in order to make sense of its present. Periodization, it is believed, is crucial for comprehending the nature of changes, including structural transformations, discontinuities, tensions, and contradictions generated during the process of change (Wolpe, 1988; Chisholm, 2012).

Pre- and Post-Apartheid Education an overview

Prior to 1994, South Africa's education system was divided into eighteen severely segregated divisions. During the period 1994-1999, these were combined into a single national department and nine provincial departments (Chisholm, 2012). It is clear from the way the South African Department of Education, dubbed the Department of Basic Education, operates that it is the central authority for all policy formulation, monitoring, and evaluation. To address the curricular distinctions of the past, the first post-apartheid curriculum overhaul occurred in 1997 (Motshekga, 2011). The 1996 South African Schools' Act endowed school governing bodies with significant authority (Nicolaou, 2018). It is, though, very unfortunate; this shift of power in education too has failed to improve school education (Du-Pelssis & Mestry, 2019; Karlsson, Mcpherson, & Pampallis, 2020). It is observed that school administration (mainly the school principals) holds absolute freedom in shortlisting, interviewing, and selecting educators for appointments which in many cases allows the exclusion of a knowledgeable candidate over a preferred candidate. Nepotism and financial mismanagement are regular events in community-run government schools in rural South Africa (Ramothwala, 2022; Rangongo, Mohlakwana, & Beckmann, 2016). Offering absolute power with a lot of loopholes brings in more opportunities for corrupt school managers. A school principal has almost absolute freedom in financial management, decision-making regarding the school's language policy, and subject allotment to the teachers. It is observed that in many cases, this subject allocation causing conflict and performance debacles in schools in rural South Africa.

Flaws within democracy and proposed solutions

"The government has instigated wide-ranging initiatives to transform education from its apartheid past, including increased investment in school education, improved access to education, efforts to reinstate a culture of teaching and learning in schools, a new, more equitable basis for school finance, including an index of need, and efforts to rationalise and redeploy staff; and wide-ranging curriculum reform, including the introduction of outcome- based education (OBE)" (Ngcobo & Tikly, 2010). As time passed, OBE changed into the Curriculum and Assessment Policy Statement (CAPS) from 2014 (Musitha & Mafukata, 2018). This shows a continuous effort put forward by the government of South Africa towards the betterment of school education. "However, despite years of reform effort, South Africa continues to lag behind in international comparisons and has failed to significantly raise the performance of historically disadvantaged learners" (Taylor et al., 2003; Soudien, 2007; Ngcobo & Tikly, 2010) seems yet prevalent in South African schools.

Decentralisation has its own demerits and negative consequences; education does not remain untouched either. Irregular appointments in state education departments in South Africa are well documented (SA News 2015). The shortage of instructional materials in rural regions has also been documented (Thaba-Nkadimene, 2020). Conflicts in South African schools are also mentioned by scholars (Msila, 2012; Ngcobo & Tikly, 2010). Major reasons for conflict in schools were found to be personal vendettas, ambition, and jealousy between members within a school structure. It is due to the absence of any leak-proof school management system. If presenting personal experience could be considered evidence and not an anecdote, then the experiences of this author are worth mentioning. Three observed cases from three different schools are presented here.

Case one: a teacher producing a 100 percent pass result in physical science at NSCE and specialising (with a master's degree) was removed from grade twelve in order to accommodate the head of the department, who was not even an honours graduate, at the end of the academic year.

Case two: a teacher specialising in teaching accounting (a bachelor degree holder in accounting) was allocated mathematical literacy, avoiding a teacher with a mathematics major at bachelor's level.

Case three: a newly appointed deputy principal engaged in fierce fighting with the existing head of the department for taking life sciences at grade twelve.

A single teacher assigned more than two subjects to teach in a school is a common scenario in rural South African schools. There are those loose ends of democracy that create chaos in every possible manner to disrupt academic excellence in schools of South Africa. Is it so that teaching in a high school classroom requires no expertise? Or is it so that high school teachers are multi-talented? Reality is, neither high school teachers are multi-talented nor classroom teaching is an easy-come, easy-go job. It is a fact, that the study of teacher selection and its correlation with the academic performance of schools remains a neglected issue (Hanushek, 2014). In spite of this, this paper suggests a necessary reform in teacher selection for South African schools. One vital gap is found in the issuance of teacher registration certificates by the South African Council for Educators (SACE) to prospective educators. SACE registration certificates are issued without indicating the cognitive attributes of the concerned teacher. Cognitive attributes, also known as academic attributes, consists of subject area knowledge, reasoning abilities, and pedagogic knowledge (Klassen & Kim, 2019). One such SACE certificate from 2007 states that the candidate is registered with SACE. The said document never mentions the subject or grade the person is eligible or competent to teach. This small gap allows school principals to manipulate the teacher selection process towards a favourable candidate. In the South African context, SACE registration certificate is the most important document for an individual to be appointed as a school teacher because, without a SACE registration certificate, no one is eligible to teach in South African schools. The Department of Basic Education (DBE) needs to come up with a concrete solution to avoid chaotic situations at its high school arena. Even though most schools conduct a face-to-face interview for selecting a teacher, face-to-face interviews are considered unreliable and systematically biased (Kausewl, Culbertson, & Madrid, 2016). Some school managers prefer letters of reference brought by prospective teachers. Letters of reference are neither reliable nor valid in nature (Patterson et al., 2016). Even

though there is a lack of systematic studies on how to make decisions on appointing a teacher (Klassen & Kim, 2019), the following reforms are suggested for teacher appointment in South African schools:
Firstly, issuance of SACE registration certificates in South Africa, because the basic criteria to appoint a teacher in South Africa is a person having a SACE registration. Every SACE certificate must mention the academic attributes of the concerned teacher. Such as subject or subjects the teacher is able or allowed to teach. In grades in which the teacher is competent to teach, a teacher registered to teach a lower grade must not be allowed to teach at higher grades. On the other hand, a teacher eligible to teach a higher grade will be free to teach any grade below if the teacher is competent to handle the classroom, which could be decided by the school management team (SMT) in consultation with the concerned teacher.
Secondly, irrespective of the number of students a school must have a minimum of (x+1) teachers, one principal, and one deputy principal. Here 'x' denotes the number of classes (classrooms) present in a school. It is the most unscientific way of distributing teachers in a school only on the basis of the number of students on the roll. Similarly, distribution of teachers should also be based on the actual number of subjects to be taught in a school, not on actual number of students on the roll.
Finally, the appointment of competent teachers is the precondition for the academic excellence of a school. In order to select the best of the best, DBE needs to centralise its teacher appointment process through its provincial and district offices, along with a subject competency test for each aspiring teacher.

Purpose of the study

Improvement in STEM education is projected as the priority of the twenty-first century education system (Sahin, 2019). Due to technology development in leaps and bounds, twenty-first century will need a lot more STEM trained workers (Bland, 2019). The purpose of this study is to ascertain whether there has been any improvement in STEM education in South Africa. For this, a decade of performance of learners in one of the important STEM subjects called physical science is analysed after taking the data from a secondary source. The performance of students in the NSCE examination for physical science from 2008-2018 for three schools was selected at random from a selected school district (circuit) in rural South Africa. There are reports on problems associated with the teaching-learning process in South African schools. They are: methodology used to teach sciences (Chowdhury et al., 2022); socioeconomic factors influencing the learning environment (Bayat, Louw, and Rena, 2014); leadership and management challenges in rural schools (Van Jaarsvelds, 2021). Additionally, Howie (2003) addressed various impediments to mathematics learning for South African high school students. The South African government has taken a number of measures to strengthen the country's secondary education system. This study attempts to determine whether there has been a statistically significant improvement in science instruction in South African high schools using physical science as a base subject.

METHOD

The study used a secondary data analysis method for making its decision. A quantitative analytic method was used to analyse a set of secondary data pertaining to NSCE Physical Science examinations written by learners from 2008 to 2018. The study used the following sample size: Three schools were randomly chosen from a group of nine schools writing NSCE under a school district (circuit) in Mpumalanga province. Three schools under study were assigned the codes C, D, and N, respectively. Physical science results from the 2008-2018 NSCE examinations for the sampled schools were collected from the state office of the DBE and used as data for the study.

Aim

The purpose of this study was to establish the empirical hallmark of change in high school physical science teaching results using a sample of rural South Africa for a period of 2008-2018.

Research question

Is there any statistically significant difference in the learning outcomes for physical science when compared to students' performance over a period of 11 years?

DATA COLLECTION AND INTERPRETATION

For the period 2008-2018, data on learners' performance in physical science during their NSCE was collected from three schools in an Ehlanzeni rural school district. After that, the performance records of learners were classified into two categories. 2008–2013 was used as the initial reference period, followed by 2014–2018 as the secondary reference period. Three schools have been designated as C, D, and N. The percentage of students scoring less than 30%, 40%, and so forth are placed in order for every year in tabulated format (Tables 1, 2, 3, 4, 5, and 6).

Table 1: SCHOOL (C) - First Year Block (2008-2013)

YEAR	0-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%	Total Wrote
2008	7	7	2	1	1	-			18
2009	8	5	4	1	-				18
2010	20	2	2	1	-	-			25
2011	10	9	3	1	2	1			26
2012	2	4	10	4	2	-			22
2013	9	13	3	2	-	-			27
Total	56	40	24	10	5	1			136
% Status	41	29	18	7	4	1			

YEAR	0-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%	Total Wrote
2014	13	13	8	2	3	-	-		39
2015	13	7	3	1	1	-	-		25
2016	19	4	5	3	6	-	-		37
2017	14	11	3	3	3	2	2		38
2018	5	6	6	5	7	-	1		30
Total	64	41	25	14	20	2	3		169
% Status	38	24	15	8	12	1	2		

Table 2: SCHOOL (C) - Second Year Block (2014-2018)

Table 3: SCHOOL (D) - First Year Block (2008-2013)

YEAR	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%	Total Wrote
2008	28	9	4	3	1	-	-		45
2009	24	9	5	2	1	-	-		41
2010	19	16	4	1	1	-	1		42
2011	10	8	8	4	3	-	2		35
2012	4	10	15	5	5	4	4		47
2013	7	11	12	7	5	4	1		47
Total	92	63	48	22	16	8	8		257
% status	36	24	19	9	6	3	3		

Table 4: SCHOOL (D) - Second Year Block (2014-2018)

YEAR	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%	Total Wrote
2014	19	15	4	5	2	-	-		45
2015	6	15	4	6	2	1	-		34
2016	7	5	7	4	2	-	-		25
2017	20	13	5	4	2	1	2		47
2018	8	15	7	5	4	-	1		40
Total	60	63	27	24	12	2	3		191
% status	31	33	14	13	6	1	2		

Table 5: SCHOOL (N) - First Year Block (2008-2013)

YEAR	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%	Total Wrote
2008	0	8	7	4	-	-			19
2009	16	10	3	3	-	2			34
2010	14	16	9	5	2	-	2		48
2011	9	10	8	6	2	-			35
2012	2	6	9	6	6	6	2		37
2013	23	12	4	3	1	-			43

Total	64	62	40	27	11	8	2		216
% status	30	29	19	13	5	4			

Table 6: SCHOOL (N) - Second Year Block (2014-2018)

YEAR	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%	Total Wrote
2014	15	9	3	2	1	1	-		31
2015	6	8	9	4	2	2	-		31
2016	16	9	11	5	7	2	2		52
2017	4	6	6	4	4	1	-		25
2018	15	18	15	6	3	2	1		60
Total	56	50	44	21	17	8	3		199
% status	28	25	22	10	9	4	2		

Comparing learners who wrote physical science, we saw a roughly 20% rise in the number of students writing NSCE physical science from school C's second block year block (Table 1 and Table 2). On the other side, school D saw a reduction of about 26% in physical science enrollment (Tables 3 and 4). School N saw a 7.8% decline in enrolment in physical science classroom (Tables 5 and 6). The average over-all enrolment decline for physical science is 7.47%. While calculating the decrease in total enrolment (combining all three schools), we found that the strength of students in physical science classrooms decreased by 8.21%. It means that when there is a demand for STEM students at the university level to produce a STEM-trained workforce, registration in science is decreasing in South African high schools. At least within the considered sample. The average percentage of learners performing at different levels for each block year (first and second) is presented in table 7.

Table 7: Percentage of learners scoring in a specific percent level

Schools	20% First year block	20% Second year block	30% First year block	30% Second year block	40% First year block	40% Second year block	50% First year block	50% Second year block
School C	41	38	29	24	18	15	12	23
School D	36	31	24	33	19	14	21	22
School N	30	28	29	25	19	22	22	25

While taking the average of the three sample schools, there is a positive development in the performance of learners at the two extreme ends of the performance standard. Firstly, students performing below 30% have decreased by 3.5%, and secondly, students performing at 50% have increased by 5%. This is no doubt a positive achievement by schools towards STEM education. In spite of this, we cannot consider this change a discernible trend towards high school science education improvement. Figure 1 shows that there is no change in performance at level 2 (30%), and performance at level 3 (40%) has decreased by 1.67%. Apparently, if there is no decline in performance, the performance in physical science will remain stagnant.

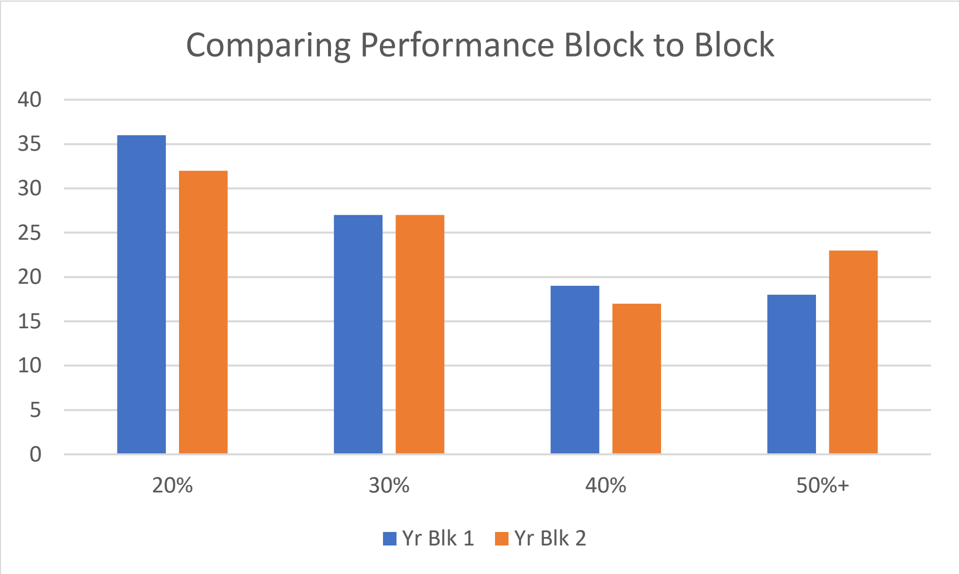

Figure 1: Comparing Performance Block to Block

When individual schools' performances are examined (Table 8), two of the schools had a close to 30% failure rate in physical science. In the case of the third one, the failure percentage increased from 27% to 28%. One interesting point is that despite the higher failure rate, pass rates at 50% and higher levels increased for all three schools.

Table 8: Mean of percentage level for three schools

	Below 30%			Below 40%			Below 50%			50% & above		
Year Block 1	40	36	27	29	24	29	18	19	20	12	18	24
Year Block 2	38	30	28	24	33	25	15	15	21	23	22	25

A regression examination of performance over two block years revealed $R^2 = 0.55$, implying that learners' performance patterns for both block years are at least 55% comparable.

Following that, an ANOVA test was run on each of the three sample schools (Tables 9, 10, and 11). For school C (Table 9), F = 8.32 and F critical = 9.28, i.e., F < F critical.

Table 9: ANOVA for School C

ANOVA SCHOOL C

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	0	1	0	0	1	10,12796
Columns	682	3	227,3333	8,317073	0,057733	9,276628
Error	82	3	27,33333			
Total	764	7				

Table 10: ANOVA for school D

ANOVA SCHOOL D

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	0	1	0	0	1	10,12796
Columns	338	3	112,6667	5,121212	0,106431	9,276628
Error	66	3	22			
Total	404	7				

F = 5.12 and F critical = 9.28 for school D (Table 10); i.e., F< F critical.
F = 4.47 and F critical = 9.28 for school N (Table 11), i.e., F < F critical.

Table 11: ANOVA for school N

ANOVA SCHOOL N

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	0	1	0	0	1	10,12796
Columns	85	3	28,33333	4,473684	0,125044	9,276628
Error	19	3	6,333333			
Total	104	7				

In each of the three examples, F < F critical indicates that there was no statistically significant difference in the performance of schools across two distinct block years.

OBSERVATION AND DISCUSSION:

This study detected modest improvements in the performance of high school learners in physical science for rural pupils in South Africa, namely a nominal decrease in failure rates (Below 30%) and another nominal increase in learners performing at or above level four (50 percent and above). Additionally, this study discovered statistically significant commonalities in high school students' physical science skills. The study concludes that, during the observed period of 2008-2018, there has been an improvement in learners' performance in physical science, which is statistically insignificant, and there is room for introspection regarding the state of high school physical science teaching processes in order to improve the quality of high school science education. Repeating the same behaviour with the hope of obtaining a different result is not a prudent course of action. The state of physical science education in South African high schools virtually always tells the same story. Barriers to learning (Chowdhury, 2014) are extremely prevalent and show no signs of abatement. Inadequate practical work (Chowdhury et al., 2020), one-way lecture method of teaching (conventional method) (Ramnarain and Hlatswayo, 2018; Bacay and Herrera, 2020), absence of effective class room dialogue (Sepeng, 2011), and finally, a poor learning environment at home (Juan and Visser, 2017) are destroying the future of science education in South Africa. The same is aggravated by the identified administrative anomalies occurring due to uncontrolled freedom handed over to the school manager.

CONCLUSION:

The author proposes two-point school reforms. Firstly, administrative reform, and then pedagogic reform. It is alleged that the appointment of educators is the basic source of manipulation and nepotism. Hence, all appointments are advised to be under the control of a central authority. While offering a job to a teacher, the subject offered by the teacher should be clearly indicated in the offer letter. No teacher should be allowed to teach a subject beyond their specialisation or training by the department. Include practical work in the school schedule (timetable) for both physics and chemistry. Incorporating dialogic discourse into all secondary classes (grades 9–11) in order to increase students' engagement and thus their performance, particularly in science and mathematics. Finally, before assigning a student to a scientific classroom for further education and training (FET, grades 10-12), consider his or her learning aptitude. This will contribute to the enhancement of science courses in rural high schools. Take one, take all is not a good policy for a science classroom environment. One cannot force a fish to walk on the bush or a donkey to sing a melody. Aptitude is more important than wishing to study science.

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