



SHAPING THE FUTURE OF PHYSICS IN SOUTH AFRICA – THE WAY TO GO?

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Introduction

In September 2002, the Physics community, under the auspices of the South African Institute of Physics and NRF, sounded the alarm regarding the state of Physics in South Africa and challenged the academic world to come up with tangible steps to revitalize the Physics field. Being a Fellow of the Institute, the author took up the challenge to investigate the state of Physics in South Africa, through this research.

Research Question

“Is the state of Physics in South Africa healthy?”

If not, how can it be saved and made to grow strongly?”

Methodology

It is a matter of common knowledge that if Physics is to be declared healthy, it should be supported on three pillars of strength namely, strong Physics at three tiers of the academic cascade – the school, higher education and research.

- Therefore, the methodology used is *cross-group analysis* (measurements/snapshots of opinions at one time with different stakeholders in physics) based on the data collected and analyzed from the consultation done with the stakeholders in the school, higher education and research arenas, with regards to the state of Physics.
- After analysing the inputs from the stakeholders, the strengths and weaknesses of the state of affairs are identified.
- Thereafter, the weaknesses are benchmarked against international trends in Physics.
- A comparative study between South African and international trends could provide some strong indicators which would be interpreted. This may lead to the recommendations as to the right steps to be taken to revitalize Physics in South Africa.

Data Collection

1. **An investigation into the state of Physics in the School system: How is the current system favouring the growth of Physics in South Africa?**
 - A comprehensive questionnaire, covering various aspects of Physics in the teaching and learning arena was surveyed among principals and Physical Science teachers at 200 secondary schools across the country.
 - Teachers' qualifications in Physics, school curricula, evaluation systems, quality assurance and resources at schools were the aspects investigated through the questionnaire.
 - The results of the survey (based on the sample received) are shown in the following table:

Table 1 : How qualified are the teachers to teach Physics?

First Degree with Physics as a major	First Degree with Chemistry and Mathematics as majors	First Degree with Chemistry, Biochemistry, Microbiology, etc.	Educational Degree/ Diploma HDE, UED, STD, etc.
0%	14%	21%	65%

- Majority (65%) of teachers have not majored in Physics or Physics and Mathematics. The Physics teachers at school mainly hold teaching qualifications rather than a major in Physics plus the teaching diploma.
- [This is in agreement with the opinion of 60% of teachers that they are compelled to teach Physical Science even though they have specialized in other fields].
- The norm over the years was that the Secondary School teachers require only secondary level subject knowledge to teach secondary school sciences. The Secondary Teachers Diploma (STD) had such a curriculum. This tradition has done a lot of damage to school level Physics in the past and still continues to do so.
- In many countries, the minimum requirement to teach at secondary level is a First Degree qualification in the specific field (i.e., Physics at third year level) coupled with a teaching qualification (E.g. BSc. in Physics + BEd. in Physical Science).

Table 2: Do the teachers feel the need for the Physics curriculum at school to be changed?



YES	NO
50%	50%

This 50-50 opinion may have to change if one compare the Physics curricula in various countries around the world.

Physics syllabus for Grade 12 only in Country A	Physics syllabus for FET (Grades 10 -12) in South Africa
<ol style="list-style-type: none"> 1. Electrostatics 2. Current Electricity 3. Magnetic Effect of Current and Magnetism 4. Electromagnetic Induction and alternating current 5. Electromagnetic waves 6. Optics 7. Dual Nature of Matter and Radiation 8. Atomic Nucleus 9. Solids and Semiconductor Devices 10. Principles of Communication 	<ol style="list-style-type: none"> 1. Motion and Force 2. Energy and transformation 3. Waves (Including light and sound) 4. Electricity and Magnetism 5. Structure of atoms 6. Structure and properties of Matter 7. Chemistry – chemical reactions ...
Physics syllabus for Grade 12 only in Country B	Syllabus prior to the introduction of FET in South Africa
<ol style="list-style-type: none"> 1. Fundamentals of mechanics 2. Structure and properties of matter 3. Kinetic theory of heat 4. Atomic and nuclear physics 5. Waves and electromagnetic spectrum 6. Electricity and electromagnetism 7. Electrodynamics and electronics 	<ol style="list-style-type: none"> 1. Newtonian Mechanics 2. Current Electricity

- The comparison clearly indicates that South African Physics curriculum at School is not internationally competitive.
- Making the curriculum-situation worse in South Africa is the non-existence of Physics practicals and Practical Examinations [Ref. nationally controlled practical examinations in GCE 'O' level, Pre-degree, etc]. In recent years more effective laboratory work and more intensive fieldwork (museums, science centres, etc.) are being developed/introduced in UK.
- Thinking along the lines of international competitiveness, the teachers were asked to respond to the idea of splitting Physics and Chemistry at School level.
- 70% were not in favour of splitting while 30% did want the splitting. This is in agreement with the 65% unqualified group of teachers who feel threatened due to lack of proper qualification in the relevant field.
- Board of Studies of the New South Wales recommended that the senior sciences should be offered as specialized courses such as Physics, Chemistry, Biology, etc.

Investigation of other factors contributing to students doing badly in Physics/Physical Science from international experience:

Findings from TIMSS study

- The International Association for the Evaluation of Educational Achievement undertook the Third International Mathematics and Science Study (TIMSS) in the 1990s and repeated studies in 1995, 1999 and 2003.
- This was the largest study ever undertaken of educational achievement. It involved nearly half a million grade 4, 8, and 12 students in nearly 50 countries and 15 000 schools.
- Its main objectives were to compare and analyse curricula, teaching practices and student achievement in science and mathematics.
- The findings from the study are as shown:

Table 3: Scores from the TIMSS (1990) Grade 8 test survey based on overall mean score for science assessment

Country	Overall mean score	All science content areas	Physics
Singapore	607	70	69
Czech Rep.	574	64	64
Japan	571	65	67
S. Korea	565	66	65
Bulgaria	565	62	60
Netherlands	560	62	63
Slovenia	560	62	61
Austria	558	61	62
Hungary	554	61	60
England	552	61	62
Belgium (Fl)	550	60	61
Australia	545	60	60
Slovak	544	59	61
Ireland	538	58	56
Russia	538	58	57
Sweden	535	59	57
USA	534	58	56
Canada	531	59	59
Germany	531	58	57
Norway	527	58	57
New Zealand	525	58	58

Country	Overall mean score	All science content areas	Physics
Thailand	525	57	54
Israel	524	57	57
Hong Kong	522	58	58
Switzerland	522	56	58
Spain	517	56	55
Scotland	517	55	57
France	498	54	54
Greece	497	52	53
Iceland	494	52	53
Romania	486	50	49
Latvia (LSS)	485	50	51
Portugal	480	50	48
Denmark	478	51	53
Lithuania	476	49	51
Belgium (Fr)	471	50	51
Iran	470	47	48
Cyprus	463	47	46
Kuwait	430	43	43
Colombia	411	39	37
South Africa (Lowest score)	326	27	27
International Average	516	56	55

Table 5: Scores from the TIMSS (1995), TIMSS (1999) and TIMSS (2003) Grade 8 test surveys based on overall mean score for science assessment

Country	Overall mean score (1995)	Overall mean score (1999)	Overall mean score (2003)
Singapore	580	568	578
Chinese Taipei	Not available	569	571
S. Korea	546	549	558
Hong Kong	510	530	556
Estonia	Not available	Not available	552
Japan	554	550	552
Hungary	537	552	543
Netherlands	541	545	536
United States	513	515	527
Australia	514	Not available	527
Sweden	553	Not available	524
Slovenia	514	Not available	520
New Zealand	511	510	520
Lithuania	464	488	519
Slovak Republic	532	535	517
Belgium-Flemish	533	535	516
Russian Federation	523	529	514
Latvia	476	503	513

Scotland	501	Not available	512
Malaysia	Not available	492	510
Norway	514	Not available	494
Italy	Not available	493	491
Israel	Not available	468	488
Bulgaria	545	518	479
Jordan	Not available	450	475
Moldova	Not available	459	472
Romania	471	472	470
Iran	463	448	453
Macedonia	Not available	458	449
Cyprus	452	460	441
Indonesia	Not available	435	420
Chile	Not available	420	413
Tunisia	Not available	430	404
Philippines	Not available	345	377
South Africa (lowest score)	Not available	243	244

If the mean score for science assessment at that time was 27 for South Africa has it improved over the years? A good indicator could be obtained from the matric results in recent years. For example:

Table 7: Comparison of matriculation examination results in physical science, 2002-2004.

Candidates National	2002 number	%	2003 number	%	2004	%
Total candidates	443 821	-	440 267	-	467 985	
Total writing science	153 855	35	151 7911	34	161 214	34
Total passing science	117 529	26	121 947	28	119 543	26
Pass with HG	24 888	6	26 067	6	26 975	6
Pass with SG	70 763	16	75 693	17	73 943	16
Pass with Lower Grade	21 878	5	20 187	5	18 625	4

Source: EduSource Data News No.47/April 2005.

The national pass rate for physical science remained in the range 26% to 28% for the period 2002-2004 with a mean value of 27. This is in agreement with the score of 27 for physics from TIMMS (1990) results. Can anyone be proud of these achievement levels? If not, what are the contributing factors to this state of affairs?

Some Facts from the Department of Education



Matriculation Examination Pass Rates for physical science in comparison to mathematics and biology and articulation benefit to science and technology programmes in 1999 and 2004

Physical Science (HG)	Mathematics (HG)	Biology (HG)	New undergraduate students entering science and technology programmes
36%	39%	52,2%	25%

Physical Science (HG)	Mathematics (HG)	Biology (HG)	New undergraduate students entering science and technology programmes
26%	34%	46%	25%

Sources: 1. DoE's Report on the 1999 and 2004 Senior Certificate Examination
2. CHE's Reports 2000 and 2005.

What do the teachers think as the reasons for South Africa's lowest scores in physics all over?



Factors contributing to poor achievement levels in Physics	Opinion	
	YES %	NO %
Absence of development strategy in the curriculum 1. Lack of continuous development of Physics from Grade 8 to 12 (learning Physics in bits & pieces)	60	40
2. Examination subject content is limited to Grade 12 and part of Grade 11 work only	40	60
3. Educators specialized in other fields are compelled to teach Physical Science due to lack of qualified teachers	60	40
4. Lack of sound mathematical skills hamper achievement	67	33

- Lack of resources at schools in order to do justice to the subject is a factor well-known to educators, educational managers and the public, which does not warrant more investigation. 56% of matriculates belong to rural schools with no electricity and sanitation and with few books and no other resources (Masehela, 2005).

The state of Physics in the Higher Education Sector : How is the current system favouring the growth of Physics in the Country ?



- There is a need to develop and popularize Applied Physics/Industrial Physics.
- Over the past decades, education in Physics was directed toward an academic career neglecting Applied Physics which makes great contributions to industrial and technological development.
- The universities for technology (formerly technikons) are the ideal ground for the development of Applied Physics. Instead physics is taken as a “service” or “support” subject giving access to other options and professions
- The existing Nated Credit weight for Physics in most engineering and medical courses at universities of technology is disastrous for the growth of physics as seen in the table below:

Table 5: Status of Physics in universities of technology

Qualification	Nated Credit for Physics
Chemical Engineering (heat & thermodynamics)	0,066 (66%)
Engineering Metallurgy	0,083
Extraction Metallurgy	0,083
Optometry (mainly optics)	0,132 (13.2%)
Radiation Science for Radiography (nuclear physics)	0,20
Architecture	0,083
Mining	0,10

- Physicists working in industry the world over have contributed enormously to innovation.
- To investigate the state of affairs regarding the success and failure in First Year Physics courses in Higher Education Institutions, the following responses were obtained:

Table 6

Question	Response		
	Yes %	No %	No response %
Do you think that you were good in Physics at school, but after joining the H.E institution, you have gone down in Physics?	7	86	7

- Other aspects investigated with regards to the state of Physics in H.E institutions through responses from academics at post-school institutions as regards to the student numbers in physics discipline and its status compared to other disciplines:
 1. Number of students taking Physics as a major subject **decreasing** year by year.
 2. In comparison to other majors in the Science Faculty, **less students** in Physics than some other major sciences.

**The pool of physicists available in South Africa:
Profile of applicants for a Physics Lecturer post at a
University**

Foreign Applicants	Female Applicants
57%	0%

Response from Industries

(Armcor, Denel, CSIR, etc. where fair number of physicists are employed)



- The industries are not marketing the skills and value added by Physicists correctly.
- There should be an early “branch” at university into Applied Physics and those students should spend time in industry to gain industry experience.
- University subject content not “applied” enough.
- School curriculum Maths and Science not providing right platform for learners to pursue other careers in Science and Applied Sciences.
- In industries, research is mainly limited to technology establishment but have no NRF support.
- Involve academia in industry so that the industry benefits from the exchange.
- Tax rebates on research is an easy way to achieve this.
- Very little collaboration between industry, universities and universities of technology :
 - (for example, DENEL (which is mainly Physicists’ world, has only collaboration between Stellenbosch and Free State Universities)

Shaping the Future of Physics in South Africa : The way to go

Revitalization and shaping of physics at school level

1. Address the shortage of qualified teachers and introduce a Science Inducement Allowance to keep knowledgeable teachers in the schools because there are relatively few physicists, who can handle physics courses that are compulsory for computer, medicine, chemistry and biology occupations.
2. Emphasize and incorporate the role of physics-based technology into teacher, counselor and administrative training.
3. Appoint teachers with degree in physics majors (recruit English-speaking foreign teachers to address shortage, if necessary). Allow Physics teachers to focus on their field rather than compelling them to teach other subjects such as Mathematics and Chemistry in addition to Physics. This dilutes their efforts.
4. Address the situation of lack of resources : Properly qualified teachers should be able to improvise teaching aids.
5. Specialization/grouping into Physics should start from Grade 10 onwards. Stop the combined Physical Science in Schools and split it into Physics and Chemistry and appoint teachers with degrees in Physics majors, to be in line with the practice in most countries in the world.
6. Secondary science teaching should be allocated more time and attention.
7. Follow the example set by Italian Physicists/Scientists. Fierce opposition by scientists has forced the Italian government to backtrack over a new curriculum that cuts the number of hours of science teaching for 11-14 year olds from 3 hours per week to 1, and which ditched many topics relating to physics (Physics World, June 2004).
8. Absence of physics practicals and practical examinations might have a damaging effect in developing an interest in physics. Hence the introduction of compulsory practicals is a matter of emergency.

Enhancing the status of physics in higher education Institutions

1. Improve the status of Physics by introducing Applied Physics as compulsory subject at universities of technology. How many of these institutions have a separate Physics Department? The merger-exercise in higher education provides a unique opportunity to improve the status and re-curriculation of pure and applied physics as well as the introduction of Industrial Physics for better collaborative partnership with industry.
2. Delete from the HE system the degrading title “service subject” for Physics because Physics is a co-requisite for almost all Engineering, Medical and Allied Medical courses.
3. Throughput rate vs Quality :

Government’s insistence on throughput rate (against quality) as a basis for subsidy calculation might result in the lowering of quality and standard of an all important “bottleneck” subject like physics. This is a matter to be raised by professional bodies such as the Institute of Physics.

Popularization of physics at all levels and publicizing and promoting careers in physics: the role of mass media

1. There is a need for popularization of Physics at all levels. Participation in Science popularization activities such as the National Expo for Young Scientists, introduction of compulsory annual science festivals at area level and provincial levels as well as establishment of science clubs at schools. Science Clubs could provide an arena for extracurricular science activities creating competitions in physics.
2. Publicize pockets of excellence in scientific achievements in the country, e.g. University of Johannesburg's achievement in producing cheaper and efficient solar panels, University of Cape town's excellence in cosmology research, etc.
3. Sports awards versus Science achievement awards

Conclusion

- Physics is the science that drives technology. Therefore it has become crucial on the part of academic and political organs to introduce measures for revitalizing the physics discipline at all levels.
- Repeatedly being the last among countries in the science achievement levels is not a healthy situation for South Africa.
- Limited resources, poor teacher education and lack of suitable learning materials should not stand in the way as limiting factors for educational transformation.
- School education is the incubator for future physicists. Hence, let the South African physics fraternity work together to shape-up the future of physics so that we would be able to produce some Nobel laureates in Physics in the next 20 years!
- Finally, let us look forward to hear from the top achievers in matriculation examination that they want to pursue a career in Physics!