The State of Physics in South Africa

A review commissioned by the South African Institute of Physics

August 2002

Maciej Soltynski

Institute for Futures Research

University of Stellenbosch

Contents

Introduction

From the second half of the 1990s the Council of the South African Institute of Physics (SAIP) has been investigating the role of the SAIP, and the role of the physics community in South Africa. Physics does not stand apart from the environment in which it is embedded and in which it operates. This social, political and economic environment continues to experience many changes and challenges. The transition to democracy that has taken place in South Africa over the past decade has had a significant effect on physics. This is particularly so as regards the restructuring and transformation of the national science and technology system. As well as an investigation on the influence of the changes on physics in South Africa, and on the SAIP and its members, the Council of the SAIP has also set up a Transformation Committee to investigate possible changes to the SAIP and the way in which it functions.

In any meaningful strategic planning process, such as that being undertaken by the SAIP, in which decisions about and affecting the future are to be made, it is vital that an understanding of the present environment exists. Such an understanding usually has three components, viz., the organisational, the transactional and the contextual. The organisational environment relates to that part over which the organisation has control; the transactional environment is that which the organisation interacts with, and has influence over, but little control; and the contextual environment over which the organisation has little influence and can only adapt or react to.

This review, ‘The State of Physics in South Africa’, provides the present environment of physics, and particularly that of the SAIP, in South Africa. It is part of an ongoing process undertaken by the SAIP, which includes two surveys carried out in 1999 and 2000, and of which the next step will be a ‘Review of Physics in South Africa’, to be conducted jointly by the SAIP and the NRF in the period 2002 to 2003. This review presents relevant aspects of the contextual, transactional and organisational environments. It starts with a broad perspective which examines the importance of science and technology for national competitiveness in the global marketplace. It then examines how South Africa rates with regard to various indicators of science and technology. A brief overview of key research directions in physics is followed by a look at the issues facing physics in some countries, with the emphasis on the United Kingdom, Australia and the United States. A key reason for examining these issues is to enable comparisons to be made with South Africa, so as to ascertain whether or not physics in South Africa exhibits the same, or different trends and influences.

The next chapters deal with the South African National System of Innovation, which affects physics directly; the situation regarding the teaching of and learner performance in science and mathematics at the secondary level, from which future physicists are drawn; and trends in science graduate numbers.

In 1999 and 2000 the SAIP conducted surveys of its members and of other physicists in South Africa. The next three chapters present a detailed analysis and comparison of these two surveys.

The final chapter summarises the key points of the review and briefly presents elements from the medium term expenditure framework strategic plan of the Department of Arts, Culture, Science and Technology (since August 2002 split into the Department of Arts and Culture, and the Department of Science and Technology) which will have a bearing on any decisions about the future of physics that the SAIP and other stakeholders may make. The review closes by making some suggestions for action for further consideration by the SAIP and the physics community in South Africa.

Executive Summary

The review begins by arguing that science and technology (S&T) has a profound effect on a nation's ability to compete in the global marketplace. The better placed a nation is with respect to science and technology, the greater is its economic growth and development, with consequent higher levels of national wealth and a better quality of life. Nations can be placed into three groups, those that rely on natural resources for income, those that focus on investment and largely buy-in technological know-how, and those that have a well developed system of innovation. This latter group relies far more on human capital for its competitive advantage, utilising education and the resulting intellectual potential to innovate. These innovation driven nations are without doubt the most successful in economic terms. While there is no complete economic theory of the relationship between economic growth, and science and technology achievement levels, an indicator based approach is used to convincingly illustrate that the nations that are better positioned with respect to S&T, are indeed more wealthy and enjoy a better quality of life. It is also noted that investment in research and development (R&D) is a form of savings for the future.

Having illustrated the national importance of S&T, the review examines the situation of S&T in South Africa by comparing South Africa with a number of other countries by means of selected indicators. South Africa fares poorly with respect to most of the indicators examined. South Africa does not spend enough on R&D, and this is particularly so in the business sector. The amount spent on R&D in South Africa, at 0.7 percent of GDP, is one-third or less than in developed (first-world) nations, where amounts in excess of 2 percent of GDP are spent on R&D. South Africa has a negative 'balance of payments' of about R1 billion between the royalties paid to overseas companies for 'bought-in' technologies, and the royalties received by South Africa for exported innovation. This gap is primarily the result of the reluctance by industry to carry out applied research and development (R&D) and rather to purchase proven technology from overseas. The number and proportion of students in tertiary education studying science and engineering is well below the levels in developed countries, and contributes to the low numbers of R&D and related personnel in South Africa. A minimum threefold increase in proportionate numbers would be required to meet the minimum levels found in first-world countries. It is quite clear that South Africa is not succeeding in increasing its technologically skilled human resource base to the levels existing in countries with which it needs to compete. R&D spend per researcher is low, even when compared to developing countries.

Turning more specifically to physics, it is argued that developments in physics underpin future developments in the four enabling technologies that are presently driving global economic growth, viz. information communications technologies, materials technologies (including nanoscale technologies), energy technologies and the emerging biotechnologies (especially genetics and proteomics). This makes physics a key science for the future. The National Research Council of the United States has concluded that physics has entered a new era of expanding opportunities and is having an increasing impact on science, technology and the economy. A list of six areas in physics of 'unprecedented scientific opportunity' are presented in support of this conclusion. It is noteworthy that, while US Federal funding for physics has generally decreased in the past 15 years, there has been an increase in funding for nanotechnology (which received funding of $1 billion in 2001) and for astronomy.

An examination of physics in some other countries, in particular Australia, the United Kingdom and the United States, shows that physics faces serious issues. All recognise that sufficient numbers of graduates in physics, mathematics, chemistry and engineering are essential for a country to compete globally in high-technology areas. However, interest in physics at the secondary level is dropping, and learners prefer more broadly based and less challenging courses. There is a shortage of science and mathematics teachers, mainly due to poor pay. The quality of science and mathematics teaching at the secondary level is poor. Entrants to physics tertiary education are not as well prepared as they should be. The number of physics graduates is dropping as physics is not seen as an attractive career. Funding for physics research and for tertiary education in physics is under pressure. The situation is clearly self-reinforcing, and it is recognised that the 'vicious circle' needs to broken.

South Africa has undertaken a long process of clarifying and rationalising its national S&T structure. While the restructuring and rationalisation process is ongoing, especially as regards the tertiary institutions, the focus is now shifting to truly new initiatives, and integrating policy with that of other government departments to achieve national objectives. Clear S&T objectives for the future have been formulated. Within the S&T structure, physics has a key role to play in supporting the new initiatives.

The situation regarding physical science and mathematics education at the secondary level in South Africa is similar to that in the other countries mentioned earlier. While South Africa spends a high proportion of its public budget (in excess of 20 percent) on education, the annual amount spent per learner is low compared with developed countries. The system can be categorised as being in crisis, especially with regard to physical science and mathematics. There is a shortage of teachers in these subjects, and those that do teach are in general un- or under-qualified. Fewer than 5 percent of the nearly half-a-million writing the final secondary-level examinations annually pass either of these two subjects on the higher grade, and this situation regarding pass rates is far worse when it comes to African learners, who constitute by far the majority of learners. The Department of Education has put in place a strategy to address these issues. This includes the selection of 102 schools to specially focus on the teaching of physical science and mathematics, the upgrading of teachers, and the re-recruitment of ex-teachers.

At the tertiary level in South Africa, the number of bachelor degree physical sciences graduates nearly doubled (a 98 percent increase) in the period 1987 to 1997, a growth rate higher that for any other disciplines in the natural sciences and engineering category, with the exception of the chemical sciences. However, this doubling was off a low base. This growth rate in physical sciences graduates was on a par with increases in other high growth categories such as nursing, education, law, libraries and the humanities. First degree graduates increasingly tended not to continue their studies. While the physical sciences were no exception, physical sciences graduates tended to continue their studies proportionately to a greater extent than did graduates in other disciplines. In general terms physical science as a course of study has not experienced any decline in the period 1987 to 1997, and it compares well in relative terms with most other disciplines.

The results of two South African Institute of Physics (SAIP) surveys, conducted in 1999 and 2000, are evaluated and presented in detail. To gain a complete picture of the survey results, the reader is encouraged to refer to chapters 8, 9 and 10. The surveys indicate that the South African physics community is predominantly white and has a low proportion of women involved (this latter situation also occurred in the other countries reported on earlier). Some key points made by respondents were that physics should make itself more relevant to industry and to South African society at large, and that universities should review their curricula with a view to providing a broader educational experience, more relevant to the needs of industry and business. A telling statistic was that some 10 to 16 percent of physics graduates had experienced some form of unemployment in the two year period prior to the surveys. As regards the SAIP, the main benefits from membership of the SAIP were seen as contacts, events and information. The most important additional benefits and features the SAIP could provide were to promote and represent physics, and more information.

In the concluding chapter the medium term expenditure framework strategic plan of the Department of Arts Culture Science and Technology (DACST), now the Department of Science and Technology (DST), is briefly outlined. The strategic plan notes that a number of key indicators relating to S&T need to be addressed in the medium term and sets out a number of objectives to achieved. These are the same or similar to those raised in this review, such as increasing the national spend on R&D, increasing the number of researchers as a percentage of the workforce, improving the situation with regard to secondary level science and mathematics education, having more science, engineering and technology students in tertiary education, both at undergraduate and postgraduate level, etc. The commitment by DACST is reflected by its budget for S&T which has has grown by 64 percent over the past four years to R685 million, and is projected to increased to R878 million in the next two years.

The situation for science in South Africa is more positive than it has been for some years, and the physics community is encouraged to pro-actively grasp the opportunities that developments in the national system of innovation are offering.

The importance of science and technology for national wellbeing

> ‘Technology is the application of science, engineering and industrial organisation to create a human-built world. It has led, in developed nations, to a standard of living inconceivable a hundred years ago. The process, however, is not free of stress; by its very nature, technology brings change in society and undermines convention. It affects virtually every aspect of human endeavour: private and public institutions, economics systems, communications networks, political structures, international affiliations, the organisation of societies and the condition of human lives. The effects are not one-way; just as technology changes society, so too do societal structures, attitudes and mores affect technology. But perhaps because technology is so rapidly and completely assimilated, the profound interplay of technology and other social endeavours in modern history has not been sufficiently recognised.’
>
> Preface to the Sloan Technology Series. Alfred P Sloan Foundation

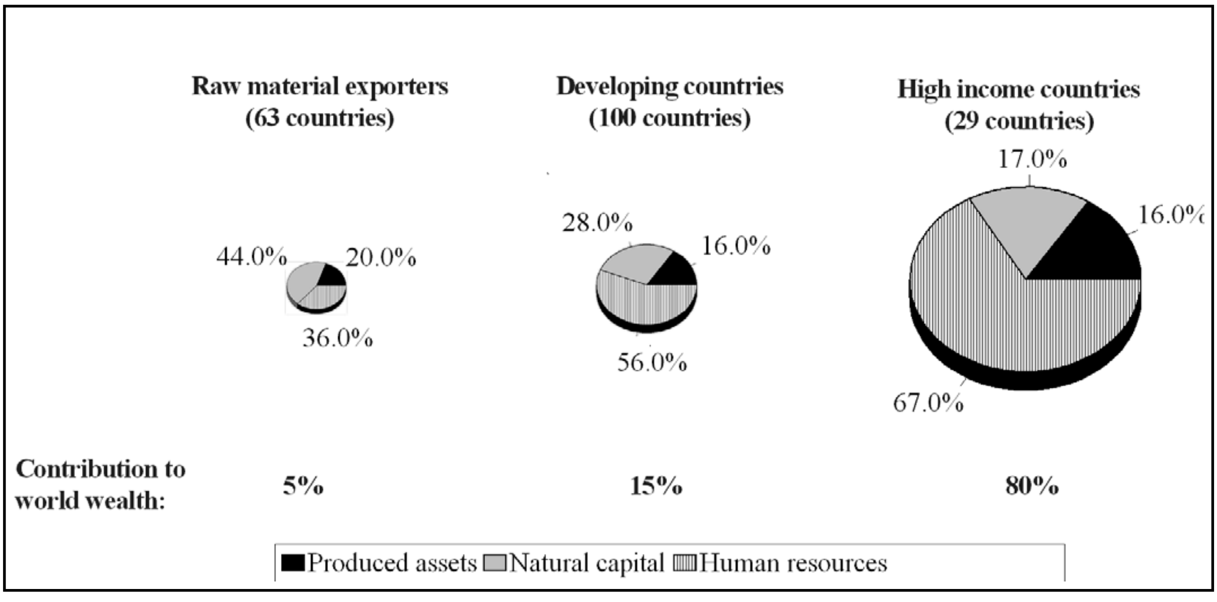
The statement that technology is a key driver of economic growth appears in various guises throughout the literature and elsewhere. For example, the current budget of the United States Government states that, ‘Technological innovation and scientific discovery generated much of the [US] Nation’s economic growth over the last 50 years, creating millions of jobs, and improving the quality of life. … This innovation and discovery was possible because of both public and private investment in research and development (R&D)’ (United States 2002:159).

This chapter presents a brief current understanding of the relationship and process involved between science and technology and global competitiveness, which it will be argued lead to national wealth and a high quality of life. It should be noted that there is at present no complete economic theory of the relationship between economic growth and science and technology (S&T).

The Competitive Advantage of Nations

A number of studies have informed that a country’s wealth in terms of natural resources, or even in terms of its ability to invest, is no longer sufficient to enable that country to raise its standard of living. The World Bank (1996) found that countries which contributed more to the world’s wealth (had a larger share of) had a much higher input of human capital than did poor countries. Of a total of 192 countries, 29 countries were classified as high income, they produced 80 percent of the world’s wealth and 67 percent of the inputs were in the form of human capital (the other inputs being natural capital or produced assets). At the other end of the scale 63 countries classified as raw material exporters produced just 5 percent of the world’s wealth and only 36 percent of their inputs were human capital. This is summarised in Figure 1-1, with the area of each pie chart representing the share of that country type of total global wealth as measured by GDP (gross domestic product).

Figure 1-1: Share of world wealth by type of country - illustrating the role of human resources and thus innovation in contributing to wealth (Source: World Bank 1996)



Porter (1990) argues that the competitive advantage of nations is rooted in innovation. Those countries where the emphasis is on an integrated approach to utilising the intellectual potential (read human capital) of the nation through education programmes and the application of advanced technology with a corresponding emphasis on investment, productivity and quality, are those that have global competitive advantage, and thus have higher economic growth rates than countries who do not systematically improve their stock of human capital. He calls these innovation driven, and cites the US and Japan as prime examples. Other types of countries in Porter's classification are factor driven countries and investment driven countries. Factor driven countries primarily depend on their natural resources to generate some degree of wealth for their citizens. The technology content in products or processes is low, there is a domestic focus with import substitution usually a driver, and overall there is low productivity growth. Third World, or less developed countries, fall into this category. Investment driven countries, tend to buy-in technological know-how so as to generate income. This technology is usually not the 'latest'. A strong domestic market with internal rivalry drives growth. The South East Asian region has a number of examples of this type of nation. South Africa has elements of both an investment-driven and factor-driven types.

Porter's argument is that unless a country makes a determined effort to become innovation-driven, it will not be able to compete effectively in the global market and will not be able to generate wealth and raise the standard of living of its citizens. Nations have realised this to an increasing extent, and in attempts to either enter this innovation driven high-technology global market place, or to protect their positions in it, governments have formulated national science and technology policies.

Sachs (2000), much in the same way as Porter and the World Bank, has divided the world into three technological regions (**Table 1-1**), only his classification is harsher, *viz*

- the technological innovators (10 patents or more per million of population);
- the technological adopters (high-technology exports of at least 2 percent of GDP) (including South Africa); and
- the technologically excluded.

Table 1-1. Innovators, adopters and the excluded nations

Type of nation		Percentage of world's		
		Population	GDP	Patents
Innovators	Top 5	10.4	41.3	87.2
Adopters	Next 5	2.7	8.4	7.7
	Others including SA	1.8	5.8	4.3
	Total: Innovators and adopters	**14.9**	**55.5**	**99.2**
Excluded	Former Soviet Union	5.2	3.0	
	Sub-Saharan Africa excluding SA	9.5	1.6	
	Andean nations	1.8	1.8	
	Other non-innovators	68.6	38.1	
	Total: Excluded	**85.1**	**44.5**	**0.8**

Source: Data from Sachs, 2000.

Innovation and Technology

It is appropriate to consider at this point the meanings or definitions of some of the terms in this document.

Science may be defined as any of various intellectual activities concerned with the physical world and its phenomena and entailing unbiased observations and systematic experimentation. In general, a science involves a pursuit of knowledge covering general truths or the operations of fundamental laws. (EB 96)

Research and development (R&D) is the collection of efforts directed towards gaining greater knowledge or understanding and applying knowledge to the production of useful materials, devices and methods (United States 2002:169). **Basic research** is defined as a systematic study directed towards greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind. **Applied research** is systematic study to gain knowledge or understanding necessary to determine the means by which a recognised and specific need may be met. **Development** is systematic application of knowledge towards the production of useful materials, devices, and systems of methods including design, development and improvement of prototypes and new processes to meet specific requirements.

A useful definition of **technology** is that technology is the systematic application of knowledge to resources to produce goods or services (from Stilwell 1994). Here resources may be physical resources such as raw material and land, and human resources such as management and labour, as well as capital. In addition, technology consists of three levels, *viz.* the physical technology or technological artefact, the skills to use the technology, i.e. human resources, and the infrastructure or organisation surrounding the technology.

Innovation may then be simply defined as **new** technology. That is, innovation is the systematic application of (new) knowledge to (new) resources to produce (new) goods or (new) services. At least one of the '(new)' needs to be present.

The Technology Achievement Index (TAI)

From the above discussion and definitions, it can be seen that there is a relationship between science, research and development, innovation and technology which underpin economic processes and activity. A key component of this undefined relationship is that of knowledge and its creation. It follows then that education has to be a key factor in the relationship between S&T and the degree of economic wealth of a country. Lacking an economic theory of technology, it is useful to take an indicator based approach to examining these relationships. The most recent, and very useful, is that of the TAI.

The United Nations, in the Human Development Report for 2001 (Human Development Report 2001), has attempted to measure how well a country is creating and diffusing technology, and building a human skill base, thus reflecting its capacity to participate in the technological innovations of what is called the 'network age', the combined result of the technological changes and globalisation that is integrating markets and linking people across previously traditional boundaries.

The TAI composite index measures actual achievements, and not inputs, effort or potential. It focuses on how well the country as a whole is participating in creating and using technology. It is not intended to be a measure of which country is leading in global technology development. The TAI is constructed using indicators, and not direct measures, of a country's achievements and provides a rough summary, and not a comprehensive measure, of a society's technological achievements.

The TAI focuses on four dimensions of technological capacity that are important for reaping the economic and other benefits of the network age. The indicators selected relate to important technology policy objectives for all countries, regardless of their level of development and all carry an equal weight in the TAI. The selection of the indicators was also restricted by the availability of data across countries. The dimensions and indicators are summarised in Table 1-2. Some comments regarding the dimensions are relevant:

Creation of technology. The global economy provides significant rewards to the leaders and owners of technological innovation. Although not all countries need to be at the leading edge of global technological development, the capacity to innovate is relevant for all and constitutes the highest level of technological capacity. The ability to innovate in the use of technology cannot be fully developed without the capacity to create, especially in adapting products and processes to local conditions.

Table 1-2. The dimensions and components of the Technology Achievement Index

Dimension	Indicator
Creation of technology	- Patents granted per capita - Receipts of royalty and license fees from abroad per capita
Diffusion of recent innovations	- High- and medium-technology exports as a share of all exports - Internet hosts per capita
Diffusion of old innovations	- Logarithm of telephones per capita (mainline and cellular combined) - Logarithm of electricity consumption per capita
Human skills	- Mean years of schooling - Gross enrolment ratio at tertiary level in science, mathematics and engineering

Source: Human Development Report 2001

Diffusion of recent innovations. All countries must adopt innovations to benefit from the opportunities of the network age.

Diffusion of old innovations. Although leapfrogging is sometimes possible, technological advance is a cumulative process, and the widespread diffusion within a country of older innovations is necessary for adoption of later innovations. Because the indicators used here are important at the earlier stages of technological advance but not at the most advanced stage, both indicators are expressed as logarithms and capped at the average OECD (developed countries) level. Expressing the measure in logarithms ensures that as the level increases, it does not contributes proportionally as much to the index as it does at a low level.

Human skills. A critical mass of skills is indispensable to technological dynamism. Both creators and users of new technology need skills. Effective use of technology requires adaptability i.e. the skills to master the constant flow of new innovations. The foundations of such ability are basic education to develop cognitive skills and skills in science and mathematics.

Weighting all indicators equally, the TAI is calculated as a number in the range 0 to 1, where 1 represents the zenith of technological achievement, and zero means no achievement at all. The calculation was carried out for 72 countries for which comparative data was available. The report categorised countries, depending on the TAI, as Leaders (TAI above 0.5), Potential leaders (TAI 0.35–0.49), Dynamic adopters (TAI 0.20–0.34) and Marginalised (TAI below 0.20). Some selected results are shown in Table 1-3. Table 1-4 shows in more detail the indicators for a few countries including Finland, with the highest index, and South Africa.

Table 1-3. The TAI for selected countries

Rank	**Leaders**	TAI
1	Finland	0.744
2	United States	0.733
3	Sweden	0.703
4	Japan	0.698
5	South Korea	0.666
6	Netherlands	0.630
7	United Kingdom	0.606
8	Canada	0.589
9	Australia	0.587

Rank	**Potential leaders**	TAI
19	Spain	0.481
20	Italy	0.471
21	Czech Republic	0.465
22	Hungary	0.464
23	Slovenia	0.458
24	Hong Kong	0.455
25	Slovakia	0.447
26	Greece	0.437
27	Portugal	0.419

Rank	**Dynamic adopters**	TAI
38	Uruguay	0.343
39	**South Africa**	**0.340**
40	Thailand	0.337
41	Trinidad and Tobago	0.328
42	Panama	0.321
43	Brazil	0.311
44	Philippines	0.300
45	China	0.299
46	Bolivia	0.277

Rank	**Marginalised**	TAI
64	Nicaragua	0.185
65	Pakistan	0.167
66	Senegal	0.158
67	Ghana	0.139
68	Kenya	0.129
69	Nepal	0.081
70	Tanzania	0.080
71	Sudan	0.071
72	Mozambique	0.066

Source: Human Development Report 2001

Table 1-4. Details of the TAI for selected countries.

Indicator	**Finland**	**US**	**Chile**	***South Africa***	**Tunisia**	**Egypt**
TAI	0.744	0.733	0.357	**0.340**	0.255	0.236
Patents granted to residents (per million people)	187	289	-	**-**	-	-
Royalties and license fees received (US$ per 1.000 people)	125.6	130.0	6.6	**1.7**	1.1	0.7
Internet hosts (per 1.000 people)	200.2	179.1	6.2	**8.4**	-	0.1
High- and medium-technology exports (as % of total goods exports)	50.7	66.2	6.1	**30.2**	19.7	8.8
Telephones (mainline and cellular. per 1.000 people)	1203	993	358	**270**	96	77
Electricity consumption (kilowatt-hours per capita)	14129	11832	2082	**3832**	824	861
Mean years of schooling (for those in the population greater than age 14)	10.0	12.0	7.6	**6.1**	5.0	5.5
Gross tertiary science enrolment ratio (%)	27.4	13.9	13.2	**3.4**	3.8	2.9

Source: Human Development Report 2001

Does science and technology lead to national wealth and a high quality of life?

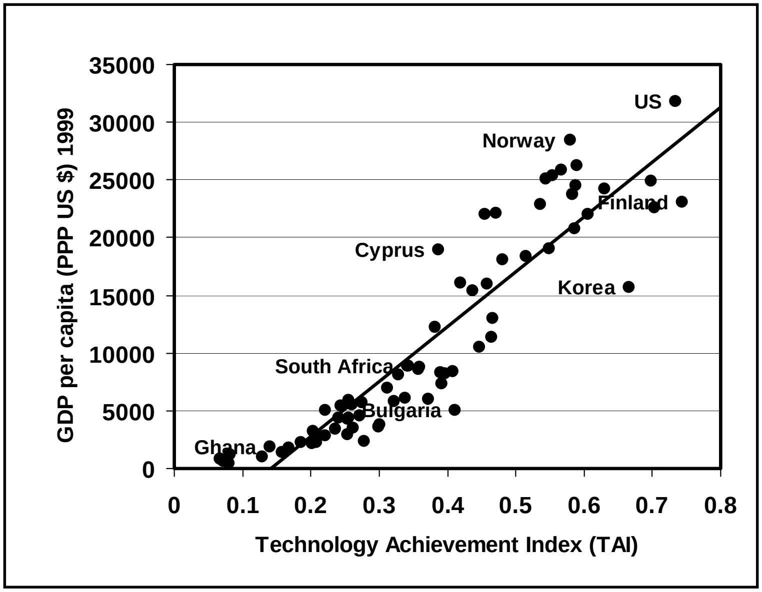
The TAI is particularly useful in investigating the claim made at the beginning of this chapter, namely that that the innovative use of science and technology lead to national wealth and a high quality of life.

Taking the per capita GDP as a measure of wealth of a nation, Figure 1-2 shows the relationship between wealth and the TAI. There is a linear relationship with a high measure of correlation and thus the claim made appears to be a valid one.

In similar fashion, the United Nations measures of the quality of life of a nation using the composite Human Development Index or HDI (Human Development Report 2001). The HDI is a summary measure of human development. It measures the average achievements in a country in three basic dimensions of human development: a long and healthy life, as measured by life expectancy at birth; knowledge, as measured by the adult literacy rate (with two-thirds weight) and the combined primary, secondary and tertiary gross enrolment ratio (with one-third weight); and a decent standard of living, as measured by GDP per capita (in purchasing power parity US$). The relationship between technology achievement and quality of life is shown in Figure 1-2, and there is a high measure of correlation between the two parameters.

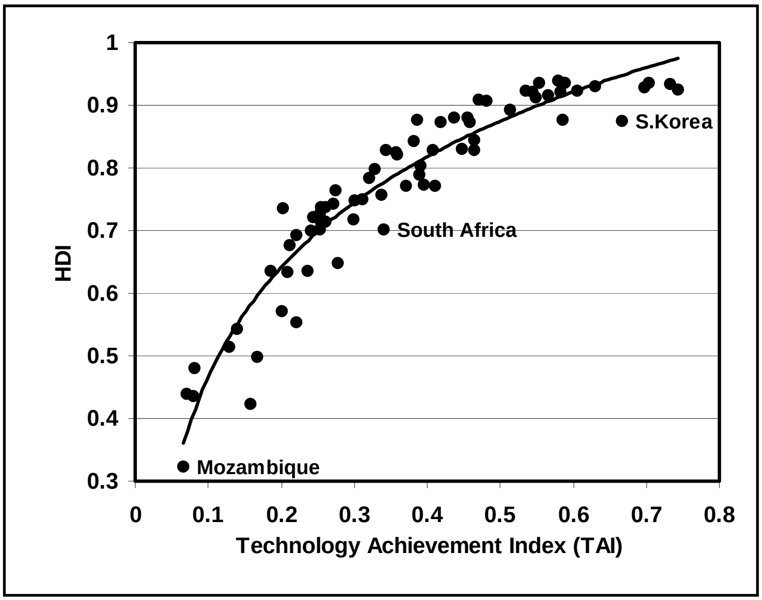
It is thus with a large measure of confidence that we can proceed further in the discussion of the situation as regards the importance and measure of science and technology.

Figure 1-2. The dependence of national wealth on technology achievement.



Compiled by the author from data presented in the Human Development Report 2001

Figure 1-3. The dependence of the national quality of life on technology achievement.

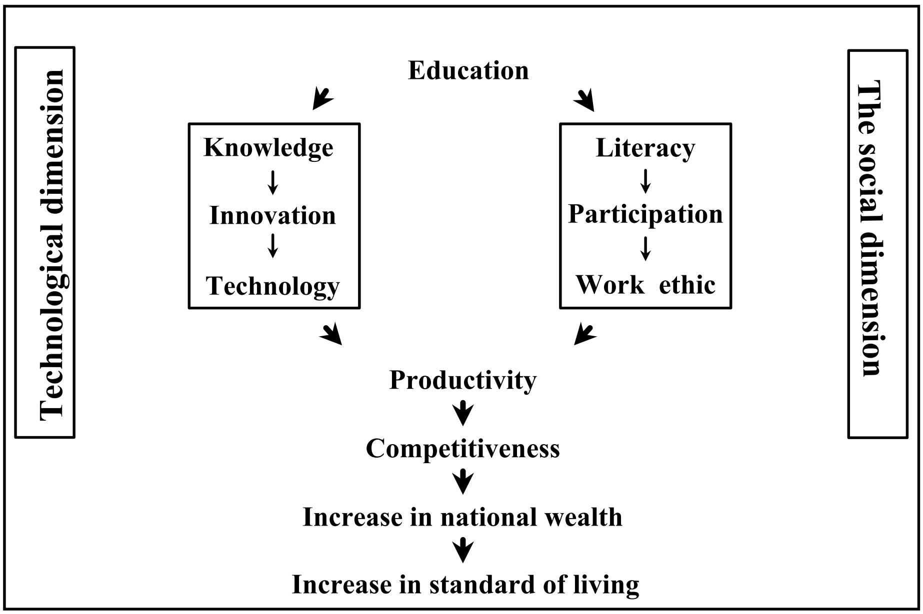


Compiled by the author from data presented in the Human Development Report 2001

The importance of education

It is not only the innovators that are necessary in ensuring national competitiveness, but it is also essential that consumers and labour should be able to participate in the exploitation of technology. For this to happen, they need to have a 'user' understanding of the technologies, i.e. the goods and services offered or utilised, and their ultimate purpose, i.e. the generation of wealth. In addition to the technological literacy among both workers and consumers, there needs to be a positive national attitude to technological innovation. These are all key factors in ensuring the competitiveness of a nation in the global market place. Education underpins the requirements outlined in this paragraph, both for the innovators, and for the workers and consumers. Thus the education levels in society are ultimately crucial in determining the competitiveness or otherwise of a nation. The relation of education to wealth creation and improved quality of life through technology is presented in **Figure 1-4**.

Figure 1-4. The importance of national education in applying technology for competitive advantage



Source: Compiled by the author

Other indicators of technological achievement and potential - the R&D dimension

The foregoing discussion has hinted at the importance of R&D in the whole process of innovation. It is thus appropriate to consider how one could measure the R&D position of a country. A number of available indicators are of use and these are:

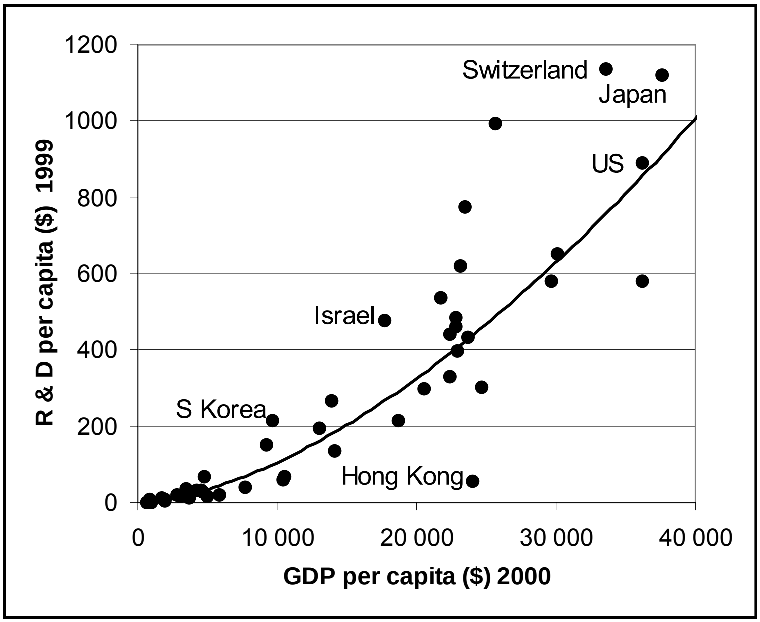
- R&D expenditure per capita
- R&D expenditure as a proportion of total national wealth
- The business sector financing of R&D
- Number of R&D personnel
- The proportion of R&D personnel in the business sector

R&D expenditure is obviously important as a long-term investment in a nation’s future. The US government states ‘R&D is critically important for keeping our Nation economically competitive’ (United States 2002:160), and goes on to point out that in subjecting investment decisions to transparent investment criteria, R&D requires special consideration in the context of performance assessment, as many R&D outcomes, especially those of basic research, may not be apparent for years or even decades. It is noteworthy that the more wealthy nations realise the importance of R&D and spend proportionately more on R&D (see Figure 1-5). In general terms the more ‘successful’ nations spend more than 2 percent of their GDP on R&D.

The contribution of the business sector to R&D, both in terms of amount spent and in terms of personnel involved in R&D is also seen to be important for national competitiveness, as government funded R&D has a lesser tendency to result in more immediate and tangible innovations.

The above-mentioned indicators are presented in the next chapter (S&T in South Africa - indicators and observations).

Figure 1-5. R&D investment and the wealth of a nation



Source: Complied from data presented in Garelli et al, 2001

Concluding remarks

It was earlier stated that there is no complete economic theory of the economic effects of technological change. Nevertheless, various recent attempts have been made to advance earlier essentially equilibrium economic models by including more realistic assumptions about the externalities associated with innovation, such as knowledge, R&D, education and skills. Consideration of such models also contributes to our understanding of the processes discussed in this chapter.

This approach is exemplified by Romer (1990), who presents a model which includes not only the usual inputs of labour and capital, but also human capital and a technological index. He distinguishes between non-rival and rival knowledge, where non-rival means it has the property that its use by one firm or person in no way limits its use by another. He argues that human capital measured in the form of the cumulative effect of formal education and on-the-job training and experience is rival, whereas other knowledge, such as the outputs of basic scientific research or designs, is non-rival. He also distinguishes between human capital employed in R&D, whose ‘job’ it is to generate new knowledge, and human capital employed in final output. Growth in Romer’s model is driven by technological change that arises from intentional investment decisions made by profit-maximising agents who exchange the current costs of research projects for a stream of benefits in the future. The model demonstrates that the stock of human capital determines the rate of economic growth, i.e. an economy with a larger stock of human capital will experience faster growth. It also finds that too little human capital is generally devoted to R&D. This fits in with the notion that R&D is a form of savings and that growth cannot occur until human capital can be spared away from the production of goods for immediate consumption. Romer also concludes from his model that having a large population is not on its own sufficient to generate growth, and that the integration of an economy into world markets will increase thart economy’s growth rates. Romer’s conclusions are much in line with observations of the real world as described above.

References

EB. 1996. Encyclopaedia Britannica Inc. CD version

Garelli, S et al (Eds). 2001. World Competitiveness Yearbook 2001. IMD.

Human Development Report 2001. United Nations Development Programme. 2001. Human Development Report 2001. Oxford University Press.

Romer PM. 1990. Endogenous technological change. Journal of Political Economy 98(5/2) pp.S71-S102

Porter, ME. 1990. The competitive advantage of nations. MacMillan.

Sachs, J. 2000. A new map of the world. The Economist. 24 Jun 2000, 355(8176):99-101.

Stilwell, WJ. 1994. Appropriate technology and appropriate management arrangements in irrigation development: A new paradigm for the 1990s. Invited Paper at the Biennial Congress of the South African Irrigation Institute, Mar 1994.

United States. 2002. Fiscal Year 2003. Analytical Perspectives. Budget of the United States Government. Washington DC.

Science and technology in South Africa: some indicators

Having argued in Chapter 1 that science and technology (S&T) is a key driver in national competitiveness, which leads to national wealth and a high quality of life, this chapter is concerned with presenting South Africa's position in S&T by means of a number of indicators.

These indicators are presented not only for their intrinsic interest, but also to show the S&T situation that physics in South Africa is embedded in, from a broad perspective.

While the Technology Achievement Index (TAI) discussed in Chapter 1 is useful for making a broad comparison of the technological situation between countries, experience shows that a number of parameters are important when assessing the S&T situation in a country. In this context it can be noted, by way of introduction, that the developed countries publish 84 percent of all scientific articles, they have 10 times as many R&D scientists and technicians as developing countries, they provide more than 97 percent of new patents and they spend an average of 2.36 percent of GDP on R&D compared to 0.5 percent or less in developing countries. A recent World Bank report (World Bank 2000) found that the North-South scientific gap is large and growing.

The indicators of interest include, among others, the following:

- Spending on research and development (R&D)
- Business sector spending on R&D as percentage of total R&D
- Number of research personnel
- High technology exports
- Royalties and licenses
- Levels of education
- Graduates in science and engineering
- The use of venture capital

The above indicators are all presented in more detail below. Also of relevance, but not discussed any further, are:

- The number of patents filed would, to some degree, indicate the innovation capacity of a country.
- Infrastructure development indicators such as telecommunications, computers per capita, energy consumption. To a small extent these have been dealt with in the discussion relating to the TAI in Chapter 1, and a detailed presentation of these is beyond the scope of this document. Interested readers are referred to Garelli (2002), or Roux (2001).

For particular disciplines or fields of study such as physics, more detailed indicators would be appropriate. These could include:

- Research output as measured by publications
- Number of practitioners as a proportion of the population
- Student numbers
- The proportion of total funding for R&D received by the discipline

Some of the above are addressed in this review.

Research and development expenditure

Details of R&D expenditure and numbers regarding research personnel for a number of countries are presented in Table 2-1. It may be noted that there is a strong relation between the wealth of a nation and the percentage of that wealth it is prepared to spend on investing in future innovation, i.e. R&D, and indeed, wealthy nations tend to spend proportionately more on R&D than the less wealthy, with the

Table 2-1: Selected indicators of S&T competitiveness potential, ranked by geographic region and R&D expenditure as a percentage of GDP within region (all data for 2000)

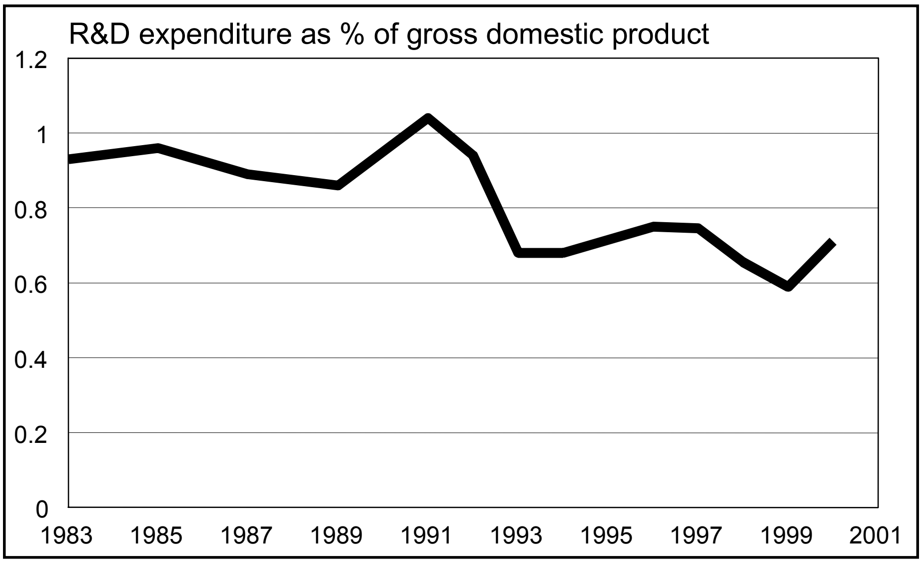
Country	R&D spend as % of GDP	Wealth GDP (PPP) per capita $	R&D expenditure $ mil	R&D expenditure per capita $	R&D personnel per 1000 people	Business financing of R&D %	R&D personnel in business % of total
South Africa	**0.71**	**8 791**	**896**	**11**	**0.45**	**52**	**47**
Israel	2.58	19 028	2 841	266	-	56	-
Turkey	0.58	6 694	1 167	7	0.37	38	23
USA	2.66	33 847	265 322	706	-	75	-
Canada	1.87	27 297	12 881	238	4.61	57	55
Brazil	0.78	7 286	4 623	11	0.46	38	36
Chile	0.60	8 996	426	6	0.48	22	7
Argentina	0.51	12 061	1 466	12	1.21	30	21
Colombia	0.40	5 806	334	4	-	48	-
Mexico	0.34	8 668	1 939	5	0.37	27	14
Venezuela	0.34	5 558	405	-	0.19	-	-
Sweden	4.02	23 509	9 176	778	7.53	75	66
Switzerland	3.36	28 040	8 083	808	7.11	71	69
Finland	3.30	24 308	4 013	551	9.79	71	55
Iceland	2.53	27 586	218	450	8.66	60	40
Germany	2.45	24 747	45 921	395	5.85	70	64
Denmark	2.26	26 525	3 627	432	6.69	63	59
Netherlands	2.22	25 131	8 060	287	5.50	56	52
Belgium	2.17	26 604	4 921	324	4.84	68	67
France	2.15	23 367	27 787	302	5.32	64	55
UK	1.90	22 654	26 964	293	1.61	65	66
Austria	1.80	25 402	3 399	297	3.88	71	65
Norway	1.61	29 129	2 606	327	5.70	56	52
Ireland	1.18	28 124	1 109	221	3.28	73	68
Italy	1.14	22 941	12 265	95	2.48	45	42
Spain	0.91	18 784	5 033	68	2.62	53	37
Portugal	0.83	16 750	868	20	2.10	23	16
Greece	0.76	15 728	848	23	2.50	29	18
Slovenia	1.50	16 619	274	63	4.27	46	48
Czech Rep	1.38	13 338	685	40	2.36	60	48
Russia	1.10	8 088	2 723	3	6.10	16	65
Hungary	0.81	12 068	373	16	2.34	44	34
Estonia	0.71	9 159	35	6	2.71	23	11
Slovakia	0.69	10 756	131	13	2.81	54	34
Poland	0.68	8 882	1 104	10	2.04	36	24
Japan	3.12	25 312	148 566	737	7.26	63	66
S. Korea	2.68	16 939	12 249	196	2.96	75	68
Taiwan	2.04	22 186	6 326	178	4.67	63	67
Singapore	1.89	22 437	1 746	269	4.82	62	53
Australia	1.43	25 285	5 617	138	4.89	46	29
New Zealand	1.47	19 674	734	45	3.43	23	26
China	1.00	3 832	10 844	5	0.70	60	54
India	0.52	2 371	2 303	1	0.20	28	50
Malaysia	0.51	8 708	440	11	0.43	58	34
Hong Kong	0.47	24 125	761	28	1.02	24	48
Thailand	0.25	6 184	317	2	0.23	46	38
Philippines	0.07	3 897	51	0	0.21	41	11

Source: Compiled and calculated from data in Garelli *et al,* 2002 and Garelli *et al,* 2001 result that their wealth increases faster and they then have even more resources to invest for the future. Those countries that are adjudged to be successful spend at least 2 percent of their GDP on R&D, and furthermore for these same countries the proportion of business expenditure on R&D is at least 60 percent of the total. This latter observation supports the view that it is primarily the role of the private sector and not government to drive innovation. Countries spending more than 3 percent of GDP on R&D in 2000 were Sweden, Switzerland, Finland and Japan, while those with 70 percent or more contribution to R&D spending by the business sector were USA, Sweden, Switzerland, Finland, Germany, Austria, Ireland and South Korea. Similar observations can be made for the R&D expenditure per capita (with the highest being Switzerland at $808) and the proportionate number of R&D personnel (with Finland having the highest, at 9.79 per 1 000 of population). The proportion of R&D personnel in the business sector to the total does not follow the previously noted patterns, most likely because while business may finance R&D, some of this R&D will be carried out in the non-business sector, i.e. by tertiary or by government-supported institutions. The converse is very infrequent.

In absolute terms, the United States and Japan dominate world R&D expenditures. The United States accounts for 41 percent of the total R&D expenditure of all the countries in Table 2-1, while Japan accounts for 23 percent of the total. Of the other countries, only Germany, at 7 percent, contributes more than 5 percent to the total.

Examination of Table 2-1 will show that South Africa is not well placed with respect to any of the indicators. Hovering around 1 percent of GDP for most of the 1980s and having dropped to about 0.7 percent of GDP in the 1990s (Figure 2-1), South Africa’s R&D expenditure is proportionately about a third of that of industrialised countries over the past decade. If one considers South Africa’s expenditure on R&D as a percentage of GDP and compares it with other countries having comparable economies, South Africa is positioned among the less industrialised economies.

Figure 2-1. The trend in R&D expenditure, South Africa



Sources: Department of Education. 1993; Garelli et al, 1996; 1998; 1999; 2000; 2001; 2002

On the other hand, South Africa’s expenditure on R&D is estimated to be 72 percent of the total spent on R&D in Africa and South Africa’s high-technology exports amounted to 79 percent of all of Africa’s high technology exports in 1999 (estimated from data in World Bank 2001).

The trend for business to finance a greater proportion of R&D, noticeable in industrialised countries, is not yet apparent in South Africa where business expenditure on R&D is about 50 percent of total R&D spending. To reach the suggested minimum guidelines of total R&D expenditure of 2 percent of GDP, and business’ contribution being 60 percent of the total, the business sector would have to increase its spending on R&D by more than three and a half times the 2000 levels.

In the United States the level of R&D spending by business is regularly reported in annual reports as a percent of sales turnover and averages 3.1 percent (DACST 1998). As can be seen from Table 2-2, all sectors in South Africa with the exception of medical and pharmaceutical fall considerably below 3.1 percent. The survey that yielded these results notes that, 'the sample size only provides an indication of the R&D investment in South Africa'. South Africa does not regularly collect R&D expenditure statistics from business, and business does not regularly report such expenditures, e.g. in company reports. This is sharp contrast with the common practice in innovative and successful countries. This situation indicates that South African business is not yet geared to thinking of technology as a investment area for the future, and is a cause for concern.

Table 2-2. R&D expenditure as a percentage of sales by business sector in South Africa

Sector	**R&D spend**
US average	**3.1%**
Medical & pharmaceutical	10.21%
Automotive	2.11%
Textiles & footwear	2.06%
Metal products & machinery	1.94%
Agriculture	1.54%
Mining	1.29%
Electrical & electronics	0.73%
Glass & non-metallic	0.63%
Petrochemicals & chemicals	0.62%
Pulp & paper	0.60%
Base metals	0.47%
Rubber & plastic	0.26%
Food & beverage	0.24%
Civil & construction	0.20%
Power generation	0.17%
Water	0.11%

Source: DACST 1998

High-technology exports, royalties and licences

The statistics regarding high-technology exports, royalties and licences for South Africa are presented in Table 2-3 together with data for various regions for comparison purposes. High-technology exports are products with high R&D intensity. They include high-technology products such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery. While South African high-technology exports account for nearly all such exports from sub-Saharan Africa, its performance, in terms of the proportion that such exports are of its total manufactured exports, puts South Africa in

Table 2-3. High-technology exports, royalties and licences (1999)

Region/country	High-technology exports		Royalties & licences	
	$ million	% of manufactured exports	Receipts $ million	Payments $ million
World	959 990	21	67 641	66 837
Low income	2 890	6	41	370
Middle income	180 967	21	1 400	8 682
High income	776 133	22	66 201	57 786
Sub-Saharan Africa	1 190	9	86	258
South Africa	**1 055**	**8**	**71**	**162**

Source: World Bank 2001

the league of low-income countries. The 'balance of payments' situation regarding royalties and licences is negative at $71 million received and $162 million paid in 1999. The situation is not much different from 1990 when receipts were $54 million and payments were $130 million (World Bank 1998).

S&T personnel

South Africa had 450 science R&D personnel per million of population in 2000 (Table 2-1). This is far less than developed countries which have between 2 000 and 9 800 R&D personnel per million of population. The World Bank (2001) reports similar statistics for 1997 with the emphasis on scientists, engineers and technicians (**Table 2-4**). Although the two studies are not directly comparable, the message is quite clear - by any measure South Africa is under-resourced in terms of S&T R&D personnel, and to achieve levels pertaining in developed countries, the number would have to be increased at least threefold. A further measure of R&D relating to personnel is the average amount spent per researcher. Here South Africa fares badly as may be seen from Table 2-5, and lies at a level

Table 2-4. S&T personnel in R&D 1997

Country/region	S&T personnel in R&D per million people	
	Scientists & engineers	Technicians
Japan	4 909	827
Sweden	3 826	3 166
USA	3 676	-
Europe EMU	2 127	1 510
South Africa	**1 031**	**315**
Egypt	459	341
Middle income	668	233
High income	3 166	-

Note. High income are countries with a per capita Gross National Income (GNI) of more than $9265. Middle income countries are those with a per capita GNI of between $756 and $9265.
Source: World Bank 2001

Table 2-5. R&D expenditure per researcher by regions/countries 1997

Region/country	**$ (PPP)**
United States	203 000
European Union	167 000
Japan	135 000
Developed countries	124 000
Newly industrialised economies	111 000
World average	**105 000**
Asia	85 000
Oceania	82 000
India	76 000
Developing countries	58 000
South Africa	**49 000**
Latin America and the Caribbean	48 000
China	38 000
Central and Eastern Europe	34 000
Africa	29 000
Arab States	24 000
Russian Federation	10 000

Source: UNESCO 2001

of half the world average, and is even below the average for developing countries.

R&D equipment

The ability to carry out R&D is to some extent affected by the equipment available. A survey of R&D equipment at non-private sector establishments (DACST 1998) found that there were 2 168 items of research and training equipment (with a value of at least R80 000 per item) of which:

- 966 items valued at R1.12 billion were at science councils
- 884 items valued at R376 million were at universities
- 202 items valued at R40 million were at technikons
- museums and government departments declared 118 items of equipment valued at R256 million

Table 2-6. Age profile of research and training equipment in the non-private sector in South Africa

Year of purchase	Number of items of equipment	Replacement value R (million)
before 1975	183	116
1976–1980	175	166
1981–1985	273	211
1986–1990	432	322
1991–1996	838	895
Total	1 901	1 710

Source: DACST 1998

The age profile of the equipment (Table 2-6) shows that in 1996, 33 percent of the equipment by replacement value was more than ten years old. Encouragingly, 44 percent of the items by value were added to the national stock between 1991 and 1996. Nevertheless it is concerning that the equipment base should display such an age spread.

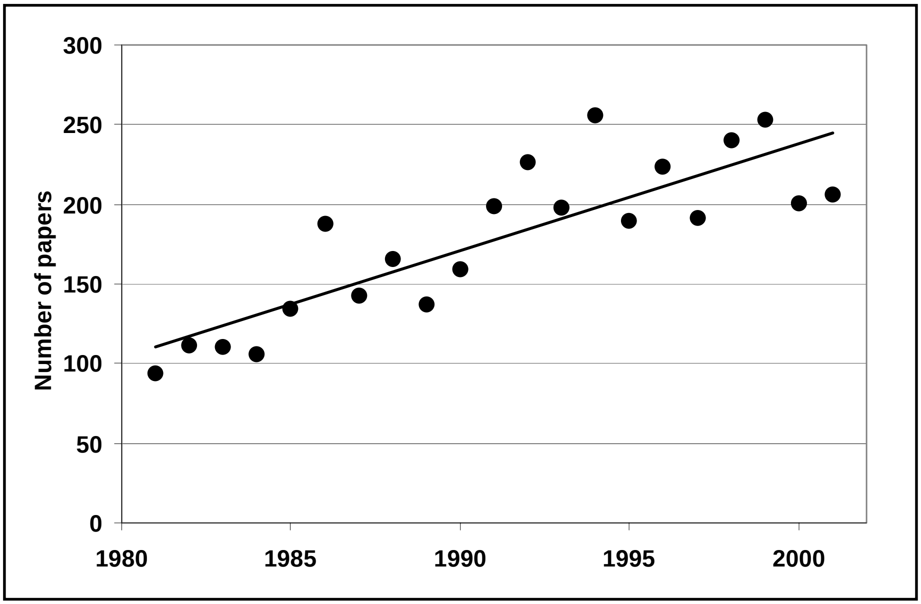
Education

In 1997 South Africa had only 19 percent of the relevant age group in tertiary education, compared to 62 percent for high-income countries. More disturbingly, only 3.4% of the relevant age group was enrolled for science and engineering tertiary studies, compared with 27.4 percent in Finland and 13.9 percent in the United States (Table 1-3). About 15 percent of students at tertiary education institutions in South Africa are enrolled for science and engineering studies. Of the total number of degrees awarded in South Africa in 1997, only 15 percent were awarded in science and engineering subjects. Secondary and tertiary science education statistics for South Africa are presented in more detail in Chapters 6 and 7 respectively.

Physics papers published

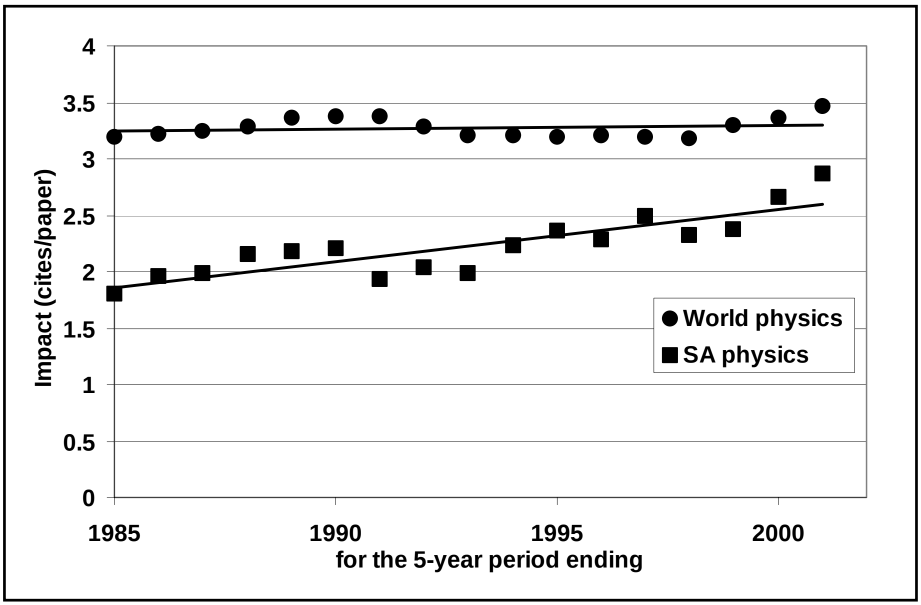
An indicator which gives a view on a component of the relative strength of R&D in a country is the quantity and quality of research papers published. Data for physics in South Africa in the twenty-year period 1981 to 2001 is available (Blankley 2002) and is presented in Figures 2-2 and 2-3. Figure 2-2 shows that the annual output of physics papers by South Africa has been steadily increasing and has doubled in the past twenty years. The data were compared with the total number of physics papers published world-wide in the same period (data not shown). The annual number of physics papers world-wide has increased at a rate similar to that for South Africa, from 45 000 in 1981 to 92 000 in 2001. South Africa's share of the total in this period has remained constant at an average of 0.26 percent, with annual values in the range 0.21 to 0.38 percent. The impact of both the South African and the world physics papers was also provided, and is shown in Figure 2-3. The impact is measured in terms of average citations per paper in five-year moving windows. For example, the total number of citations for the period 1981-1985 is divided by the total number of papers for that period to obtain the impact, and this is repeated for the period 1982-1986, and so on.

Figure 2-2. The number of physics papers published by South Africa annually



Source: Blankley 2002

Figure 2-3. The impact of South African and total world physics papers



Source: Blankley 2002

It may be concluded that South Africa has been holding its own in terms of the quantity of physics papers produced, and that the 'quality', as measured by impact defined above, has been improving throughout the past twenty years and is approaching the world average.

Summary

South Africa does not spend enough on R&D, and this omission is particularly acute when it comes to the business sector. A consequence of this low level of spending on R&D is the gap between the royalties paid to overseas companies for 'bought-in' technologies, and the royalties received by South Africa for exported innovation. This gap, which has slightly widened in the past decade, is arguably the result of two factors: the reluctance by industry to carry out applied research and development (R&D) and rather to purchase proven technology from overseas, and the lack of alignment between the R&D carried out in South Africa and the requirements of the market place.

The number and proportion of students in tertiary education studying science and engineering is well below the levels in developed countries, and contributes to the low numbers of R&D and related personnel in South Africa. A minimum threefold increase in proportionate numbers would be required to meet the minimum levels occurring in industrialised countries. It is quite clear that South Africa is not succeeding in increasing its technologically skilled manpower base to the levels existing in countries with which it needs to compete. R&D spend per researcher is low, even when compared to developing countries.

Research and training equipment shows a significant age spread, and further highlights South Africa's inability to invest in modern technology to facilitate R&D.

A brief examination of the output of physics papers by South Africa leads to the tentative conclusion, based on this indicator only, that South African physics is not in a state of decline.

A conclusion reached by The Task Force on Education and Society of the World Bank, (World Bank 2000) is that the problem of insufficient scientific capacity in developing countries is acute, but it is not insurmountable. Higher education has played a leading role in bringing about impressive scientific achievements under difficult circumstances in various parts of the developing world. Generally these achievements have arisen as a result of an early, deep and sustained commitment to particular areas of science and technology. The report cites the strong role played by India in software development as an example. It makes a number of suggestions for improving the general situation, but finds that developing countries are falling further behind industrialised countries in terms of their S&T capabilities and achievements. It appears that South Africa is no exception.

References

Blankley, W. 2002. A study of physics in South Africa, 1981-2001, as represented in the ISI database. National Research Foundation, Pretoria.

DACST. 1998. Technology and Knowledge: Synthesis Report of the National Research and Technology Audit. National Research and Technology Audit (1998*).* Pretoria: Department of Arts, Culture, Science and Technology.

Department of Education. 1993. SAPSE Reports 102, 122. Pretoria.

Garelli, S et al (Eds). 1996, 1998, 1999, 2000, 2001, 2002. World Competitiveness Yearbook 1996, 1998, 1999, 2000, 2001, 2002. Lausanne. IMD.

Roux, A (Ed). 2001. Business Futures 2001 Bellville: Institute for Futures Research, University of Stellenbosch.

UNESCO. 2001. The state of science and technology in the world 1996-1997. The UNESCO Institute for Statistics.

World Bank. 1998. World Development Indicators 1998. Washington DC: World Bank.

World Bank. 2001. World Development Indicators 2001. Washington DC: World Bank.

World Bank. 2000. Higher education in developing countries – Peril and promise. The Task Force on Education and Society. Washington DC. World Bank.

Future directions in physics

Introduction

At the beginning of the 21st century we are in the midst of the fifth industrial revolution or technological transformation (Ayres 1990) which started some twenty five years ago and will probably continue for fifteen to twenty-five years more. The key enabling technologies that are driving this revolution are:

- Information technologies: the convergence of computers and communications
- Materials technologies, including nanoscale technologies
- Energy technologies
- Biotechnologies: the new genetics and proteomics

An enabling (or dominant) technology is one which affects not only the area to which it is immediately directed, but one which also brings about basic changes in many other areas (Coates et al 1994). Significantly these technologies are synergistic and linked, in that developments in one area affect developments in another, and thereby enable progress to be made more rapidly than might have been the case if this were not so. Examples of such synergy abound, e.g. the use of synthetic materials to exploit the giantmagnetoresistivity (GMR) effect, enabling computer hard-drives to store large quantities of data, which data then can be used for advances in other areas; the developments of smaller and more powerful batteries which enable smaller portable communications and computing devices.

Some of the technologies are more mature and developed and others, but all are responsible for economic growth and improved quality of life and will continue to be so for at least the next two decades. Of particular relevance is that physics is at the heart of nearly all the above technologies, and is thus a key science for the future.

It is thus particularly appropriate to examine some of the developments and future directions of physics. This is done by summarising and presenting some material from recent reports published in the United States by the National Research Council of the National Academies and the United States National Nanotechnology Initiative, and also by briefly looking at a series of papers published by leading young physicists in the United Kingdom. In presenting the material below, the intention is not to be all-encompassing, but rather to convey that physics is alive and well and has many challenges to face in the future in examining some of the most profound questions that can be posed, and thereby continuing in its role as a key enabling science.

Physics in a new era

In a report entitled ‘Physics in a New Era: An Overview’ (PSOC 2001), the United States National Research Council’s Physics Survey Overview Committee concluded that physics has entered a new era of expanding opportunities and is having an increasing impact on science, technology, and the economy. It noted that the problems that physics can address are global problems, and that physics is becoming a more international enterprise. As a result, physics and physics education needed increasingly to address and reach an international society.

Finding that developments and accomplishments in physics, which include its expanding reach into the other sciences, have generated an unprecedented set of scientific opportunities, the committee identified six such opportunities across all of physics, extending from purely theoretical work and numerical simulation to research requiring large experimental facilities. These opportunities were chosen based on their intrinsic scientific importance, their potential for broad impact and application, and their promise for major progress during the next decade. They are as follows.

1. Developing Quantum Technologies

The ability to manipulate individual atoms and molecules will lead to new quantum technologies with applications ranging from the development of new materials to the analysis of the human genome. A new generation of technology to be developed will allow construction and operation entirely at the quantum level and could involve the direct engineering of quantum probabilities. Quantum computation, quantum cryptography, quantum-controlled chemistry and instruments of extraordinary sensitivity are some of the likely outcomes.

2. Understanding Complex Systems

The rapid advances of massively parallel computing, together with developments in theoretical analysis, have led to extraordinary growth in the ability to model and forecast complex and non-linear phenomena. Problems that may soon be rendered tractable include the strong nuclear force, turbulence and other non-linear phenomena in fluids and plasmas, the origin of large-scale structure in the universe, and a variety of quantum many-body challenges in condensed-matter, nuclear, atomic, and biological systems.

3. Applying Physics to Biology

Because all essential biological mechanisms ultimately depend on physical interactions between molecules, physics lies at the heart of the most profound insights into biology. Tools developed in physics, particularly for the understanding of highly complex systems, are vital for progress in a number of areas. These include an understanding of molecular chain folding to yield the specific biological properties of proteins; the biophysics of cellular electrical activity underlying the functioning of the nervous system, the circulatory system, and the respiratory system; and the mechanical and electrical properties of DNA and the enzymes essential for cell division and all cellular processes. Theoretical approaches developed in physics are being used to understand bio-informatics, biochemical and genetic networks, and computation by the brain.

4. Creating New Materials

The development of novel materials will continue to grow, and such materials will be widely employed in science and technology. Important areas include the synthesis, processing, and understanding of complex materials composed of many elements; the role of molecular geometry and motion in only one or two dimensions; the incorporation of new materials and structures in existing technologies; the development of new techniques for materials synthesis, in which biological processes such as self-assembly can be mimicked; and the control of a variety of poorly understood, non-equilibrium processes (e.g., turbulence, cracks, and adhesion) that affect material properties on scales ranging from the atomic to the macroscopic.

5. Exploring the Universe

The development of new instruments through which the universe and its origins can be studied in unprecedented detail will further extend the understanding of the universe, and will continue to contribute to a rich new interplay of physics and astronomy, with the universe now a laboratory for the exploration of fundamental and high-energy physics. In this regard the United States Committee on the physics of the universe, in a recent publication entitled ‘Connecting quarks with the cosmos: eleven science questions for the new century’ (CPU 2002) posed eleven questions which recognise that astronomical discoveries are driving advances in elementary particle physics, and that this knowledge in turn is driving an understanding of the universe and its contents. The questions are:

- What is dark matter?
- What is the nature of dark energy (which appears to be involved in the accelerating expansion on the universe?
- How did the universe begin - i.e. what was the cause of inflation?
- Did Einstein have the last word on gravity?, i.e. is it possible to incorporate quantum effects into a complete theory of gravity?
- What are the masses of neutrinos, and how have they shaped the evolution of the universe?
- How do cosmic accelerators work in producing beams of unexpectedly high energy and of unknown origin?
- Are protons unstable?
- Are there new states of matter at exceedingly high densities and temperatures, which conditions existed in the early universe?
- Are there additional space-time dimensions as postulated in string and related theories?
- How were elements from iron to uranium formed?
- Is a new theory of matter and light needed at the highest energies?

6. Unifying the Forces of Nature

The next decade will see much progress towards the goal of discovering a unified theory of the forces of nature. String theory is the most promising framework for developing a unified theoretical description of all the fundamental forces of nature, viz. the strong nuclear force, the electro-weak forces, and gravity. String theory has given rise to new and exciting interactions between physics and pure mathematics.

National Nanotechnology Initiative

The United States has recognised that with potential applications in virtually every existing industry and new applications yet to be discovered, nanoscale science and technology will no doubt emerge as one of the major drivers of economic growth in the first part of the new millennium. Since nanoscale technology spans a much broader range of scientific disciplines and potential applications than does solid state electronics, its ultimate societal impact may be many times greater than that of the microelectronics and computing revolution.

To support nanotechnology, the United States has established the National Nanotechnology Initiative (NNI 2002) which received funding of $1 billion in 2001. Some of the recommended actions which make up the NNI include:

- The formulation of a long-term plan with a 10-year timeframe which will specify ‘Grand Challenges’ and anticipated outcomes, together with timeframes and metrics for achieving these outcomes.
- Strong support for the development of an interdisciplinary culture for nanoscale science and technology, disciplines involved are biology, physics, chemistry materials science mechanical engineering and electrical engineering, particularly self-contained interdisciplinary groups.
- Increased investment at the intersection between nanoscale technology and biology.
- Industrial partnerships be stimulated and nurtured.
- The organisation regional competitive clusters.

Visions of the Future

‘Visions of the Future’ (Thompson 2001a 2001b) is the title of a series of papers written by leading young scientists in the United Kingdom and subsequently published as three books, with the subtitles ‘Physics and Electronics’, Astronomy and Earth Science’ and ‘Chemistry and Life Science’. The papers serve as definitive reviews and present a preview of future research directions. The physics related topics discussed include:

- Theoretical physics, in which it is argued that there is at present no generally accepted authority as all the most interesting theoretical ideas have run into serious difficulties, and a proposal is made that physicists should pay some attention to the nature of consciousness.
- The physics of exotic quantum fluids
- Quantum electronics
- Spin electronics
- Polymer electronics
- Quantum-enhanced information processing
- Magnets, microchips and memories
- Future high-capacity optical communications
- Big Bang riddles and their revelations
- The origin of structure in the universe
- The dark side of the universe, which deals with investigations into dark matter
- The hottest spots in space, which deals with astrophysical masers
- Our solar system and beyond, which emphasises the interaction of the interplanetary medium and the solar wind
- The geophysics of the Earth
- Geophysical and astrophysical vortices, and understanding of which requires further mathematical and numerical modelling
- Earth's future climate, which looks at global warming and climate change

Conclusion

Physics will continue to underpin advances in fundamental and applied research which will drive developments in particularly key technological areas such as materials science at the nano and quantum level, in the still emerging area of biotechnologies and in information technologies. At the same time, physics is the key science for furthering our understanding of the nature of the universe, present and past, through basic research.

References

Ayres, RU. 1990. Technological transformations and long waves, Part I & II. Technological Forecasting and Social Change, 37:1 and 37:111.

Coates, JF, Mahaffie, JB and Hines, A. 1994. Technological forecasting: 1970-1993. Technological Forecasting and Social Change, 47(1):23-33.

CPU. 2002. Connecting quarks with the cosmos: eleven science questions for the new century. Committee for the Physics of the Universe, NRC. National Academy Press.

NNI. 2002. Small Wonders, Endless Frontiers: A Review of the National Nanotechnology Initiative. National Academy Press.

PSOC. 2001. Physics in a New Era: An Overview. Physics Survey Overview Committee, NRC. National Academy Press.

Thompson JMT (Editor). 2001a. Visions of the Future: Physics and Electronics. Cambridge University Press.

Thompson JMT (Editor). 2001b. Visions of the Future: Astronomy and Earth Science. Cambridge University Press.

The state of physics in some other countries

Introduction

This chapter examines the state of physics in a few countries for which data could be obtained, particularly the United Kingdom, Australia and the United States. Where possible, data and information regarding physics directly are provided. Often publications only provide information at a more summarised level, such as physical science, the natural sciences or science and engineering. The intention in what follows is to provide a relevant overview.

Physics in the United Kingdom

The SET for Success review

A very recent review (Roberts 2002), commissioned by the UK government in the person of the Chancellor of the Exchequer, has identified a number of serious problems in the supply of people with the requisite high quality skills in science, technology, engineering and mathematics in the United Kingdom. While the aggregate numbers of students with broadly scientific and technical degrees has risen in the last decade, these numbers are not equally spread across science and engineering and there have been significant falls in the numbers taking physics, mathematics, chemistry and engineering qualifications. The review was concerned that these downward trends, combined with deficiencies in transferable skills among graduates, could undermine the UK's attempts to improve that country's productivity and competitiveness. The review noted that these downward trends and skill problems would have negative implications for research in key areas such as the biological and medical sciences, which are increasingly reliant on people who are highly numerate and who have a background in physical sciences.

The review provided a number of insights into the state of physics in the UK, and these are summarised in what follows.

In the five year period 1994/95 to 1999/2000, the total number of students graduating with first degrees increased by 12 percent, and the number graduating with first degrees in SET (Science, Engineering and Technology including mathematics) increased by 14 percent. However this overall increase in SET was primarily due to a 49 percent increase in biological sciences and a 35 percent increase in computer sciences, while mathematics and physical sciences showed a 2 percent decline and engineering and technology showed a 7 percent decline. The actual number of students graduating with first degrees in SET subjects in 2000 is shown in Table 4-1. It should be noted that only 3 percent of the total were degrees in physics.

Table 4-1. Students graduating with first degrees in SET subjects in the UK in 2000

Subject	Number	Percent
Engineering and technology	20470	30%
Biological sciences	18450	27%
Computer sciences	11220	17%
Earth and materials sciences	7460	11%
Mathematical sciences	4140	6%
Chemistry	3420	5%
Physics	2260	3%
Total	67420	100%

Source: Roberts 2002

Table 4-2 shows that at the stages when a positive decision to carry on studying mathematics or a physical science subject has to be made, such as from A-level (end of secondary education) to degree

Table 4-2.Percentage of 'year group' taking SET qualifications in the UK in 2000

	A-level	First Degree	PhD
Physics	4.1%	0.3%	0.07%
Chemistry	5.1%	0.5%	0.13%
Mathematics	7.8%	0.6%	0.05%
Biology	6.6%	2.5%	0.25%
Engineering & Technology	2.2%	2.8%	0.24%
Computer science	2.8%	1.5%	0.04%
Business studies	4.7%	4.4%	0.05%

Source: Roberts 2002

level, the number of individuals choosing SET subjects falls off significantly. This is in contrast to business studies, and the biological sciences to a lesser extent. In terms of the percentage change in proportion of cohort from 1994/95 to 1999/2000, A-level physics students fell by 16 percent, first degree physics students fell by 10 percent and physics doctorates remained constant. In SET subjects, at A-levels there were significant increases in engineering and technology and in computer science at the expense of mathematics and physics. At degree level there were increases in computer science and biology, with decreases in mathematics, physics, chemistry and engineering and technology. In all subjects except physics there were significant decreases in doctorates.

The review noted that a shortage of highly numerate graduates in mathematics, engineering and the physical sciences is starting to appear in the UK, with such graduates commanding higher, and faster increasing, salaries than most other graduates (including biological science graduates). Given the increasing importance of interdisciplinary and multidisciplinary research, these trends in engineering and the physical sciences could also affect research in other areas, for example, the biological sciences. Other sectors from which there is strong and growing demand for the skills and knowledge of science and engineering graduates, such as financial services, tend to offer salaries to science and engineering graduates 20 percent or more than those offered by many R&D businesses. As a result, they have taken increasing proportions of the best science and engineering students.

The factors that were found to act to reduce the attractiveness of a PhD included low stipends, when seen against the option of entering employment and reducing the substantial debt that many students will have built up during their first degree and concern from students that they are likely to take more than three years to complete their PhD, while generally, funding is only available for three years. It was found that the declining attractiveness of PhD study gave rise to concern about the quality of postgraduate students, partly because of inadequate training, particularly in the more transferable skills. Many employers do not initially pay those with PhDs any more than they would a new graduate, viewing the training (particularly in transferable skills) that PhD students receive as inadequate preparation for careers in business R&D.

The review made the following observations related to the physical sciences:

- The number of students studying A-level physics in England fell by 21 percent between 1991 and 2000.
- The demographic profile of academic staff in the mathematical and physical sciences, with over 25 per cent of academic staff in these disciplines over the age of 55, compared to an average across all subjects of 16 per cent, was a cause for concern.
- The number of doctorates awarded to UK domiciled students in the physical sciences fell by 9 percent between 1995/96 and 1999/2000
- There were also issues regarding the ability of students emerging from higher education to apply their scientific and technical knowledge in a practical and business environment, leading to an emerging 'disconnect' between the demands of businesses and other employers for high-level science and engineering skills, and the supply of suitably skilled scientists and engineers.

With regard to science teachers, the review found that between 30 and 40 percent of newly qualified science teachers left the profession within five years of joining, which is believed to be higher than for other subjects. Reasons given by teachers for leaving, and thus the main factors needing to be addressed, are:

- Heavy workloads
- Poor pupil behaviour
- Low salaries
- An excessive number of government initiatives

The review concluded that there were a number of deep-seated issues particular to SET subjects which were common to both school and further education that need to be addressed in order to improve the UK's future supply of high level science and engineering skills. These issues include:

- Shortages in the supply of physical science and mathematics teachers/lecturers, noting that the Institute of Physics estimates that over their working lives physics graduates choosing to teach would forego an average of £350 000 compared to their likely earnings in other jobs.
- Poor environments in which science, and design and technology practicals are taught.
- The ability of these subjects' courses to inspire and interest pupils, particularly girls.
- Careers advice which affect pupils' desire to study science, technology, engineering or mathematics at higher levels.

In broad summary the report recommend that the UK government should improve the remuneration of science teachers and of scientists and researchers, particularly those embarking on their careers. Better funding for students at all levels should be available, and the quality and duration of science should be improved. Universities and business should be able to ensure that they compete with their counterparts overseas to retain the best scientists and engineers in the UK by offering attractive and well-paid career structures and working environments.

The Institute of Physics Report of the Inquiry into Undergraduate Physics

The Institute of Physics (IoP 2001) report published in October 2001 and entitled 'Physics: building a flourishing future. Report of the inquiry into undergraduate physics' in essence makes similar points to those already presented above in the later review by Roberts (2002). The report pointed out that physics education develops strong intellectual and practical skills, well matched to the evolving needs of employers, and that physics provides the foundation for all of engineering and many scientific disciplines, including communications technologies, aerospace, the geosciences, biomedicine and the life sciences.

The IoP found that there was a crisis in the teaching of physics in UK schools and that the critical shortage of physics teachers in schools and colleges was the greatest threat to the future supply of skilled scientists and engineers. The economics and underfunding of university physics departments had led to the loss of more than ten university physics departments in the past ten years. Over the past 15 years, numbers taking physics degrees remained constant, but many 18-year olds with good school physics grades are not attracted by mathematically based physics courses but went on to study subjects such as IT, engineering and biomedical sciences. As a result employer demands for scientists and engineers in the UK were not being met.

The IoP found that physics in UK universities was well taught and well regarded by employers and students alike. A number of the recommendations of the report are similar to those proposed by Roberts (2002) above, and some of the others are noted below:

- The IoP must increase its efforts to interest young people in physics, and work with others to increase variety in university physics provision.
- The IoP should establish a programme actively to promote physics careers to women and to address the problems of enthusing girls to study physics.
- University physics departments must increase their linkages to schools and teachers, offering support, advice and access to equipment, and must receive due credit for doing so.

- University physics departments must consider re-balancing content, in order to strengthen skills in the use of mathematics for physics, to build transferable skills and to cater better for the changing knowledge base of new undergraduates, without losing the excitement of physics.
- The IoP should consider producing a series of mathematics modules to assist physics departments in addressing the mathematics needs of those studying degree programmes in physics.
- The IoP, with others, should establish a working group to explore the opportunity and practicalities of a 'New Degree', which would be interdisciplinary in focus, and would provide the intellectual education of physics with its analytical, modelling and practical aspects, and would be accessible by those with more modest mathematical experience.

Australia

In the period 1987 to 1997 the enrolments in science at the tertiary level grew 86 percent, above the overall of 67 percent and in fourth place behind law and legal studies (124 percent), business, administration and economics (110 percent) and health (101 percent) (Niland 1998). Nevertheless, this growth in science student numbers was largely in computer science and the life sciences, and data for the period 1992 to 1997 show that in terms of student load (a measure used to eliminate multiple counting of undergraduates) the physical/material sciences fell by 12 percent against an average science student load increase of 9 percent. Mathematics and statistics suffered a similar fate.

At the secondary level, over the period 1991 to 1997, there had been a shift away from advanced (higher level) science and mathematics courses to broader and more general courses. As an example, in New South Wales the number of candidates offering the highest level physics and mathematics courses declined in absolute number by 30 and 50 percent respectively. Of all the secondary science and mathematics courses in New South Wales, only Science for Life, Maths in Practice and Maths in Society showed gains in absolute numbers.

de Laeter et al (2000) found that enrolments in tertiary physics in Australia have all shown a significant decline between the mid and late 1990s. Averaging about 500 in the period 1968 to 1990, the number of third (final) year students from 1990 to 1993 increased steadily to just over 700 then dropped to 548 in 1999. In the first postgraduate (fourth) year the numbers showed a steadily increasing trend from 150 in 1968 to a high of 264 in 1996, and thereafter a dramatic fall to 163 in 1999.

MSc and PhD students showed a steady increase from about 430 in 1979 to about 600 in 1988. Thereafter the rate of change increased and peaked at just over 1 000 in 1993. They then decreased to 777 in 1999. This drop was to some extent ascribed to the introduction of fees for higher education, a restriction on postgraduate scholarships and funding difficulties for overseas students (especially from developing countries) wishing to study in Australia.

The female participation rates in physics in the period 1991 to 1999 all increased, at the final year stage increasing from 15 percent to 22 percent, in the first postgraduate (fourth) year from 16 percent to 25 percent, and for MSc and PhD studies from 12 percent in 1991 to 19 percent in 1999.

At the tertiary level, physics has undergone significant structural changes at Australian universities, with physics departments being merged with other departments, such as with electronic engineering, communications and information, and with engineering. Some physics courses have been reduced to a basic core, while astronomy has been introduced as an elective course in many universities. In general, universities have restructured their physics courses to make them 'more flexible and attractive to students' (de Laeter et al 2000).

Advertised job positions for physicists in Australia averaged around a steady 470 per annum in the period 1991 to 1999, down from the level of 700 per annum in the decade to 1990 (Prescott 2000). The single biggest contributor, at 25 percent of advertised jobs, was limited term research positions at universities. The demand for schools physics increased and physics employment opportunities in industry and commerce continued to be very low. In the period 1994 to 1997 the number of academic staff at Australian university physics departments declined by 17%, from 310 to 259, with a similar decline in general staff (Oitmaa & Weigold 1997).

Niland (1998) presented data which showed that the job categories of R&D manager, project manager/senior scientist, scientists/researcher and engineer/researcher in Australia were all paid less than their equivalents in France, Germany, Hong Kong, Japan, Singapore Taiwan, the United States and the United Kingdom. They were on a par with South Korea, and it was only in comparison with Malaysia that these job categories were significantly better paid in Australia.

Niland (1998) ascribed the situation regarding a decreasing interest in physical science at the secondary level in Australia as being due to a combination of factors including:

- A lower quality of science teaching and infrastructure at schools than in other subjects
- A shortage of teachers of mathematics and science at the secondary level, also leading to the reduced availability of advanced (higher) levels of courses in the final years of secondary education.
- A perception that tertiary science is insular and does not lead to a broad pathway of career options
- A need to include communications skills and industrial experience and communications skills, seen by students as important
- Lack of clarity about career prospects
- Lower salaries for scientists/researchers

The Australian Institute of Physics (AIP) has stated that physics is one of the enabling sciences and research in which eventually results in innovations in industry, technology, engineering and medicine in a long-term timeframe. Thus support for physics is therefore an investment in the technology of 5-20 years in the future. The AIP identified the following (still current) concerns ‘that need the most immediate attention for the scientific and economic well being of the Australian community’ (AIP 1999):

- Government support for physics is essential because of the long lead times between physics research and the innovations that eventually come about because of this research
- A lack of adequately trained secondary mathematics and science teachers, especially in physics
- The exodus of young Australian scientists, who are vital for the continuity of teaching of future generations and for developing research programs in new directions. This exodus has been prompted by declining budgets and student numbers.
- The increasing price of journal access is strangling effective research

The AIP has issued a press release (AIP 2001) together with the Royal Australian Chemical Institute, the Australian Mathematical Sciences Council and the Institution of Engineers Australia, to the effect that if the current rate of university staff losses continue, there will be no chemistry, physics, mathematics or engineering to support innovation after the year 2020, and similarly if the current rate of decline in secondary school participation in chemistry, physics and mathematics continues there will be no enabling science in secondary schools beyond 2020. The press release calls for a National Initiative in Science and Mathematics Education for the New Millennium which would encompass major new investment in:

- Public awareness of the importance of science, mathematics and technology
- Promotion of the opportunities provided by science, mathematics and technology
- A total review and rejuvenation of the school science and mathematics teaching program - more teachers with confidence in the enabling sciences, better conditions, more equipment, better recognition
- Better support for tertiary training in science and mathematics
- Greater support for research in science, mathematics and technology

New Zealand

de Laeter et al (2000) find that in the period 1991 to 1999 the number of third (final) year students showed a slightly increasing tendency and ranged between 100 and 138. The participation by females fluctuated around 16 percent. In the first postgraduate (fourth) year the numbers showed no clear trend, with a high low of 55 and a high of 73, indicating that about half of final year students continue with their studies. In contrast to the situation in Australia, this higher retention rate could be because of 'marginally' better employment prospects for Australian graduates. MSc and PhD students showed a steady increase from about 100 in 1991 to 175 in 1999. with females in postgraduate studies averaging 17 percent in the period 1997 to 1999.

Since 1997, two university physics departments have merged with other departments, and it was noted that there was a significant structural change in courses so as to make more accessible and alluring to more students ('with funding in the tertiary sector continuing to be dominated by quantity rather than by quality considerations') and by collaboration with B.Tech courses.

The paper noted that physics at the secondary level enjoyed increased participation and enrolment levels for physics had passed those of chemistry, which they had traditionally lagged. This was ascribed to changes in the secondary curriculum and in the examination style, which had softened the demands for relevance and context. While increasing numbers were now interested in physics, students were less prepared for tertiary physics than in the past, and at least two of the six universities had responded by offering introductory courses.

Canada and Germany

In Canada, the number of undergraduates enrolled in physics at Canadian universities fell steadily from 2 887 to 1 990 in the period 1986 to 1995 (a drop of 31 percent), and similar trends were in evidence in chemistry and mathematics. In the latter, enrolment dropped from 9 066 to 5 742 (by 37 percent) in this period (Ridd & Heron 1998). In Germany the number of new enrolments in first year physics dropped from 9 806 in 1990/1991 to 6 232 in 1994/1995, a drop of 36 percent.

The United States

When not otherwise acknowledged, most of the material in this section is taken from Science and Engineering Indicators 2002 (SEI 2002).

Federal funding of research as a percentage of GDP from 1985 to 1999 dropped 29 percent in the physical sciences, 15 percent in mathematics and 21 percent in engineering. (Good 2001). Federal funding in the period 1993 to 1999 for physical science and engineering dropped from 37 percent of the total budget to 31 percent, while funding for the life sciences rose from 40 to 46 percent of the total (NRC 2001). In particular, federal funding for physics (excluding astronomy) dropped by 20 percent in the period while research funding for astronomy in the tertiary sector increased by about 45 percent. It should be noted that the overall R&D expenditures of the US, at nearly $250 billion in 1999, exceed those of the rest of the G-7 nations combined (US Gov 2002). Most recently, nanotechnology received a 17 percent increase from 2002 to 2003 in federal research funding as the National Nanotechnology Initiative.

At primary and secondary level US learners generally perform comparatively better in science than in mathematics and learners in the primary grades demonstrate the strongest performance. Learners in grade 8 show weaker performance and that those in grade 12 show weaker performance still, relative to their counterparts in other countries. The US tends to have fewer young people taking advanced mathematics and science courses, and those that do take them score lower on assessments of advanced mathematics and physics than do learners who take advanced courses in other countries. In 1998, more graduating learners had taken advanced mathematics and science courses than their counterparts in the early 1980s. For example, almost all graduating seniors (93 percent) in the class of 1998 had taken biology, 60 percent had taken chemistry, and 29 percent had completed physics. Participation rates in advanced placement or honours science courses are considerably lower: 16 percent for biology, 5 percent for chemistry, and 4 percent for physics. Female and male learners have broadly similar coursetaking patterns, although there are some differences. In high school, girls are as likely as boys to take advanced mathematics classes and are more likely to take biology and chemistry. Girls are less likely to take physics.

A key challenge for undergraduate education in the US is to train teachers in science and mathematics. In the next decade 2.2 million new teachers, including 240 000 middle and high school mathematics and science teachers will be required. Of the total, 70 percent will be new to the profession because of older teachers retiring and the increase in student population.

The number of bachelor degrees awarded in the physical sciences since 1986 has declined by 13 percent. Corresponding figures for mathematics and engineering are declines of 19 and 21 percent respectively (Good 2001). The American Institute of Physics reported that the number of physics bachelor's degrees awarded annually has declined from a high of 6 000 in 1969 to about 3 800 in 1997, and that the trend has been constantly downward throughout the 1990s. This in contrast to the increase of 60 percent in total bachelor's degrees awarded in the same period (from 750 000 to 1 180 000). The US lacks behind most industrialised countries in the percentage of 24-year olds with natural science and engineering degrees.

Foreign students make up a significant proportion of those obtaining masters and doctorates in the US. For natural sciences in 1999 the figures were 42 and 47 percent respectively. Across all disciplines, the most graduate students were from China, India and Korea. In 1999 more than 72 percent of foreign students who earned science and engineering doctoral degrees reported that they planned to stay in the US after graduation, and 50 percent accepted firm offers to do so. These percentages represented significant increases over the past.

In 1999, Europe produced far more science and engineering doctoral degrees (54 000) than did the US (26 000) or Asia (21 000).

Long-term trends show that the proportion of women enrolled in all graduate science and engineering fields is increasing. By 1999, women constituted 59 percent of the graduate enrolment in social and behavioural sciences, 43 percent of the graduate enrolment in natural sciences, and 20 percent of the graduate enrolment in engineering. Women in underrepresented minority groups have a higher proportion of graduate enrolment than women in other groups; one-third of black graduate students in engineering and more than one-half of the black graduate students in natural sciences are women. At the doctoral level, the proportion of science and engineering degrees earned by women has risen considerably in the past three decades. However, dramatic differences by field exist. In 1999, women earned 42 percent of doctoral degrees in the social sciences; 41 percent of those in biological and agricultural sciences; 23 percent of those in physical sciences; 18 percent of those in computer sciences; and 15 percent of those in engineering.

One indicator of the quality of employment available to recent graduates is simply their answers to this question 'If you had the chance to do it over again, how likely is it that you would choose the same field of study for your highest degree?' When asked of those who received science and engineering degrees one to five years after their previous degrees, 16.6 percent of PhD recipients said they were 'not at all likely' compared with 20.2 percent of bachelor's recipients. This regret of field choice was lowest for recent PhD recipients in computer sciences (6.8 percent), electrical engineering (9.8 percent), and social sciences (12.5 percent). The regret was greatest in physics (24.4 percent), chemistry (23.9 percent), and mathematics (22.4 percent).

When postdocs in 1999 were asked to state their reasons for taking their current postdoctoral appointments for all science and engineering fields, 32.1 percent gave 'other employment not available' as their primary reason. 38.3 percent of physics postdocs gave this as a reason, the highest proportion of all.

A salary survey of PhDs, who were members of the American Institute of Physics (US AIP 2001), found that respondents continued to enjoy increasing salaries over the period 1996 to 2000, and that industry salaries were lower than those in national facilities. Most significantly, the highest salaries were reported by PhDs employed in hospitals or medical centres. In 1999, the reported unemployment rate for PhDs in physics and astronomy was zero (SEI 2002).

The following points of interest were noted from a survey of its members by the American Physical Society (APS) (Chu et al 1997). The data below refer to replies from employed physicists only. Non-physicists, students and retirees who were members of the APS also responded to the survey.

- 51 percent of physicists were employed in the tertiary sector.
- 94 percent were male.
- 96 percent of physicists held a PhD.
- 74 percent had attended at least one scientific or technological conference in a two year period, and 43 percent had attended 4 or more.
- The two main reasons given for not attending more meetings sponsored by the APS were work pressures including time conflicts, and limited travel budgets.
- The three main reasons for joining the APS were an obligation to join as a physicist, to keep in touch with the physics community and to keep in touch with developments in the field.
- The strongest point of agreement was that the APS should do more to help support science education at the school level.
- The most highly rated benefit or service from the APS was the publication ‘Physics Today’.
- 57 percent felt the APS should involve itself ‘somewhat or a great deal more’ in public affairs or outreach activities.
- A majority felt that the APS should be more involved with young physicists, student members and members working in industry.

Summary

It is recognised that sufficient numbers of graduates in physics, along with those in mathematics, chemistry and engineering are essential for a country to compete globally in high-technology areas, and that physics is an enabling science in a long-term framework, one which underpins future developments and innovations in other sciences and technologies. Nevertheless physics faces serious issues. The general trends are clear, and while they vary from country to country in detail, the main points are:

- Interest in physics at the secondary level is dropping, and learners prefer more broadly based and less challenging courses.
- There is a shortage of science and mathematics teachers, mainly due to poor pay.
- The quality of science and mathematics teaching at the secondary level is poor.
- Entrants to physics tertiary education are not as well prepared as they should be.
- The number of physics graduates is dropping as physics is not seen as an attractive career.
- Funding for physics research and for tertiary education in physics is under pressure.
- The situation is considered to have reached crisis proportions in certain sectors in the UK and Australia.

References

AIP. 1999. Issues of Concern to the AIP, 22nd November 1999 at http://www.aip.org.au/

AIP. 2001. National Initiatives in Education, a joint AIP, RACI, AMSC, IEAust Initiative, 20th September 2001 at http://www.aip.org.au/

Chu, RY, Curtin, JM & Czujko, R. 1997. The America Physical Society membership sample survey 1996. June 1997.

de Laeter, J, Jennings, P & Putt, G. 2000 Physics enrolments in Australian and New Zealand Universities 1994 - 1999. The Physicist, 37(1) pp 15-20. January/February 2000

Good, ML. 2001. New alliance targets funding shortfall. Research Technology Management 44(4) p9. July-August 2001.

IoP. 2001. Physics: building a flourishing future. Report of the inquiry into undergraduate physics. The Institute of Physics, October 2001. Available at http://physics.iop.org/Policy/UPI.html

Niland, J. 1998. The fate of university science - the future of Australian universities. Australian & New Zealand Physicist 35(4) pp 165 - 174. July/August 1998.

NRC. 2001. Trends in federal support of research and graduate education - executive summary. National Research Council. Washington DC. 2001.

Oitmaa, J & Weigold, E. 1997. AIP/National Committee for physics. Survey of Australian Physics Departments - July 1997. Australian & New Zealand Physicist 34(11/12) pp 205-208. November/December 1997

Ridd, JC & Heron, ML. 1998 Science in crisis? - participation in physics. Australian & New Zealand Physicist 35(6) pp 255 - 260. July/August 1998.

Roberts, G. 2002. SET for success: The supply of people with science, technology, engineering and mathematics skills. The report of Sir Gareth Roberts' Review April 2002

SEI. 2002. National Science Board, Science and Engineering Indicators – 2002. National Science Foundation, 2002.

US AIP. 2001. Physicists in industry continued to enjoy rising salaries. The American Institute of Physics Bulletin of Physics News, 541 May 30, 2001

US Gov. 2002. Analytical perspectives - Budget of the United States Government Fiscal Year 2003 (Chapter 8). Washington DC. 2002.

The structure of the science and technology system in South Africa as it relates to physics

Note regarding the formation of the Department of Science and Technology (DST)

As this review was being finalised, it was announced that from August 2002 the Department of Arts, Culture, Science and Technology (DACST), has been split into two separate departments, viz., the Department of Arts and Culture and the Department of Science and Technology (DST). The announcement at the new DST Website (www.dst.gov.za) summarises the situation as follows:

'The Department spans an increasingly active and diverse portfolio. And, as it happens, DACST has begun to evolve into two separate entities. Last week the President signed a presidential minute allowing for the separation of the Arts and Culture, and Science and Technology branches. It is tribute to the leadership of DACST that this diverse portfolio has grown to command massive budgets in eight short years. The Department was one of the newly created government departments and has seen some progressive, even cutting-edge, work done in both the sciences and the arts. The founding Minister, Dr Ben Ngubane, and his Deputy, Ms Brigitte Mabandla, will continue to lead the Department politically. But each department will have its own budget, two separate systems, key performance indicators and Directors-General. Since the official date of change over will be 1 August it is too soon to reflect on the past, but we can point out that DACST as it was known, transformed the sectors in which it operates.'

This is indeed a significant and encouraging development for the S&T community in South Africa, signalling the increased emphasis that Government is placing on S&T. As the above statement notes, DACST has begun to evolve into two separate entities. As this process has only just begun, the subsequent discussion in this chapter reflects the situation that pertained before August 2002, and while the reader is requested to bear the formation of DST in mind, all the information presented relating to DASCT is pertinent and unchanged by the announcement of the new DST.

Introduction

This chapter provides a brief overview of the structure that physics institutions in South Africa are embedded in and operate in . Developments in this structure have a significant affect on the physics community.

The national science and technology system in South Africa

South Africa began re-examining its S&T policy formulation early in the 1990s and this examination has resulted in a number of significant actions that are relevant to the physics community. The most notable include the following:

- The establishment of a government department that deals with S&T matters. This is the Department of Arts, Culture, Science and Technology (DACST).
- The formation of the National S&T Forum (NSTF) in 1995, an influential body composed of members from all sectors including business, which acts in an advisory capacity to the Minister of Arts, Culture, Science and Technology.
- The tabling of the 'White Paper on Science & Technology - Preparing for the 21st century' (DACST 1996).
- The establishment of the National Advisory Council on Innovation (NACI) in 1997, whose role is to support the Minister of Arts, Culture, Science and Technology.
- A special fund, the Innovation Fund, has been established to promote research and development in certain key areas.
- The carrying out of a National Research and Technology Audit, that is, a national stocktaking exercise of all science and technology skills and capabilities resident in South Africa, taking January 1996 as the base date. The audit has produced a number of reports (DACST 1998).

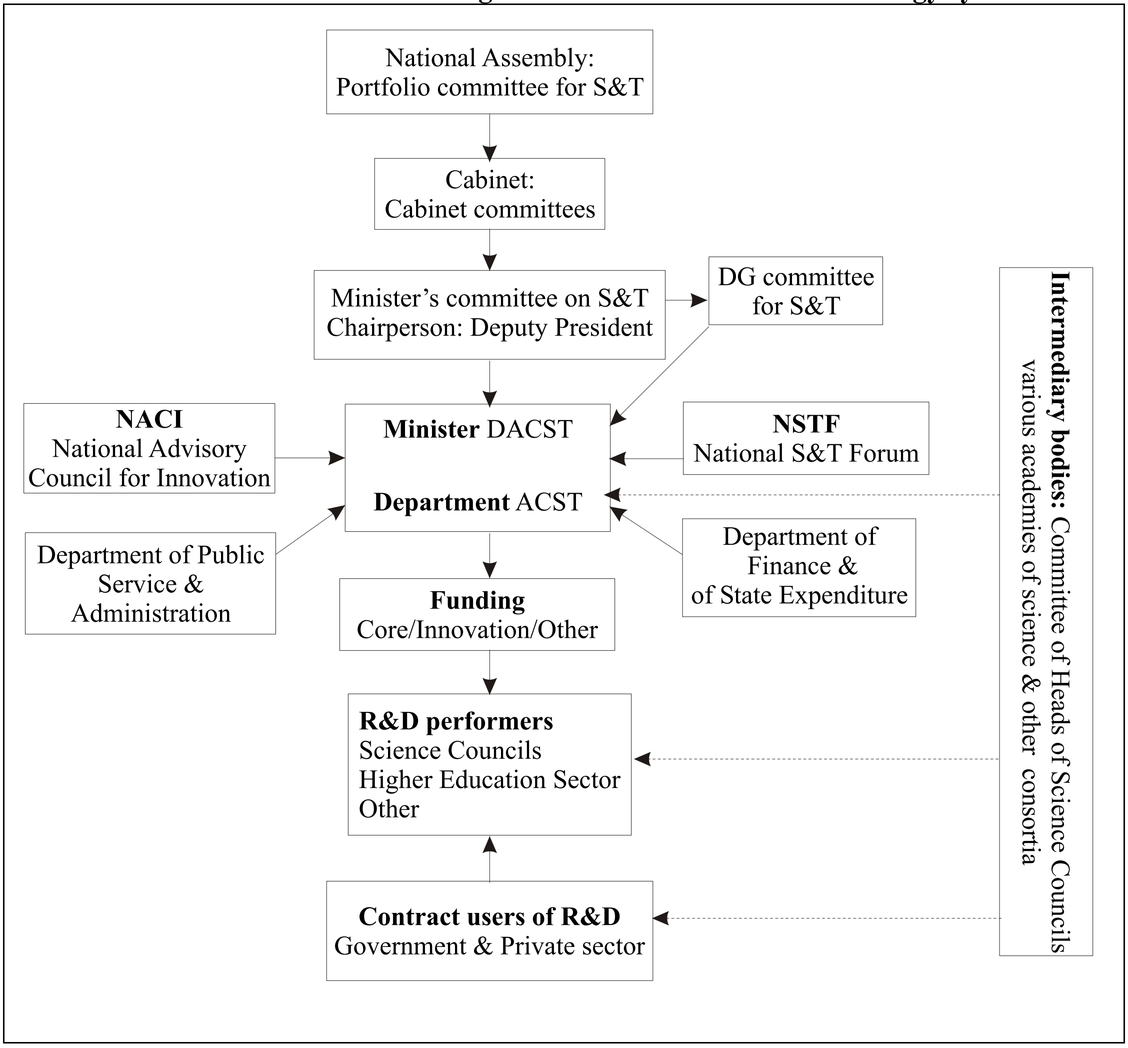
- It is intended that the activities of the country's science councils will be regularly reviewed by both scientists and end-users. To this end a review of the science councils (SCs) and related institutions in South Africa has been completed in 1998.
- South Africa became active in the Commonwealth Science Council (CSC) in 1995, was elected to its executive in 1997 and in 2000 Dr Ben Ngubane (SA Minister of ACST) was elected to serve as chairperson for a term of three years. The CSC provides many Commonwealth countries with an R&D funding framework to address their development needs and to enhance their capacity to utilise S&T for their social, economic, and environmental development.
- The establishment of the National Research Foundation (NRF) in 1999 which provides services and grants to support research and postgraduate research training.
- A National Research and Technology Foresight programme was completed in 2000.
- A ministerial committee on S&T has been set up by President Mbeki. It is presently chaired by the deputy-president.

The national science and technology system in South Africa is summarised diagrammatically in Exhibit 5-1. The organisations that are of particular interest to the physics community in South Africa are DACST, NSTF, NACI, and the R&D performers.

DACST

As can be seen from Exhibit 5-1, DACST, with its own Minister in Cabinet, is central to the national science and technology system in South Africa. DACST is divided in two sections, Arts and Culture, and Science and Technology. The S&T branch of DACST, under the Director-General of DACST, is

Exhibit 5-1. Overview of the national government's science and technology system



Source: Marais 2000 and DACST 2002

responsible for national policy regarding the functioning of the national S&T system. This mandate includes:

- Governance and structure of the S&T system
- S&T priorities
- S&T funding
- S&T promotion
- International S&T co-operation
- Regional S&T matters
- Overall co-ordination of the S&T system
- Monitoring and evaluation of the functioning of the S&T system

National Science and Technology Forum (NSTF)

The NSTF is an influential body composed of members from all sectors, including business, which acts in an advisory capacity to the Minister of ACST. The NSTF initiates and develops participation by science, engineering and technology (SET) stakeholders with the objective of performing a powerful consultative and lobbying role on general S&T policy matters. The NSTF contributes to policy formulation processes by other government departments that impact on S&T and acts as a constructive watchdog at the implementation stage of those policies (NSTF 2001). It does this by:

- Acting as a sounding board and a communication channel for the state president, parliament, government and any other legislative or administrative body or commission, on science and technology matters.
- Acting as a sounding board and a communication channel for the SET community.
- Seeking common understanding on short-term SET issues, transitional SET issues and issues involving the reconstruction of the SET system.
- Advancing, promoting and protecting the common interests of its members relating to science and technology.
- Supporting the development of an integrated science and technology system which reflects the principles inherent in a free and democratic South Africa.
- Liasing and co-operating with other organisations on matters of common interest.
- Organising workshops and conferences on national S&T matter.

The SET stakeholders are broadly seen to be any interested bodies, including NGOs. The executive committee of the NSTF has members from the following sectors:

- Business
- State utilities
- Government sector
- Professional bodies (the SAIP is a member of the professional bodies group)
- Education
- Science councils

National Advisory Council on Innovation (NACI)

The National Advisory Council on Innovation (NACI 2002) is a council appointed by the Minister of Arts, Culture, Science and Technology to advise him and through him, the Cabinet, on the role and contribution of science, mathematics, innovation and technology, including indigenous technologies, in promoting and achieving national objectives, namely to improve and sustain the quality of life of all South Africans, develop human resources for science and technology, build the economy, and strengthen the country's competitiveness in the international sphere.

Some specific issues that NACI is commissioned to advise on, and which could affect the physics community are:

- The development and maintenance of human resources for innovation through selective support for education, training and research and development in the higher education sector, at science councils and other science and technology institutions in the public and private institutions.
- Strategies for the promotion of technology innovation, development, acquisition, transfer and implementation in all sectors.
- International liaison and co-operation in the fields of science, technology and innovation.
- The structuring, governance and co-ordination of the science and technology system.
- The identification of research and development priorities in consultation with provincial departments and interested parties, and their incorporation in the process of government funding of research and development.
- The funding of the science and technology system in respect of its contribution to innovation.
- The promotion of mathematics, the natural sciences and technology in the education sector in consultation with the Minister of Education and the Minister of Labour
- Strategies for the promotion of dissemination and accessibility of scientific knowledge and technology.
- The promotion of the public understanding of science and technology and their supportive role in innovation for development and progress.
- The continuous revision of science and technology policy to address changing and new circumstances.
- Developments in the fields of science, technology and innovation which might require new legislation.

A national Innovation Fund has been established. This is intended to stimulate innovatory research, and to respond rapidly to changing research and technological priorities. The Innovation Fund is administered by the National Research Foundation (NRF) and provides funding for R&D over and above that provided by parliamentary grants.

The Science Councils (SC)

Theses institutions, whose sizes and recent annual budgets are shown in Table 5-1 for comparative purposes, are to be reviewed regularly to ensure that the science system is connected to SA’s new national goals. A number of the SCs provide employment and research opportunities for physicists.

Table 5-1. The Science Councils

Science Council	**Staff**	**Budget R million**
Agricultural Research Council	3 300	480
The Council for Scientific and Industrial Research (CSIR)	3 000	700
The SA Bureau of Standards (SABS)	1 400	241
Council for Minerals Technology (Mintek)	600	143
The National Research Foundation (NRF)	540	460
The Medical Research Council (MRC)	450	105
The Council for Geoscience	420	62
Human Sciences Research Council (HSRC)	350	120

Source: Marais 2000.

The first review was conducted in 1998 by both local and international experts from Germany, India and the US. The review also included the Atomic Energy Corporation (AEC) and the SA Weather Bureau. See for example Marais (2000) for further details. In future all these institutions are to be measured by a set of Key Performance Indicators (KPIs), a set of quantitative and qualitative indicators which will gauge the organisations' effectiveness, efficiency and sustainability.

National Research Foundation (NRF)

The National Research Foundation (NRF 2002) is the government's national agency responsible for promoting and supporting basic and applied research as well as innovation. It is the NRF's vision to be a key instrument in the creation of an innovative, knowledge-driven society where all citizens are empowered to contribute to a globally competitive and prosperous country. This is done through funding, human resource development and the provision of the necessary research facilities, in order to facilitate the creation of knowledge, innovation and development in all fields of the natural and social sciences, humanities and technology.

Funding from the NRF is largely directed towards academic research, developing high-level human resources, and supporting the nation's national research facilities. The NRF's task is to advance research in all fields of the humanities, social and natural sciences, engineering, and technology; including indigenous knowledge. By forging strategic partnerships locally and internationally, it extends the resources that researchers need to foster and expand South Africa's research capabilities.

The NRF is charged with overviewing **National Facilities**, of which the following are relevant to this review, and which are predominantly involved in research in various aspects of physics:

- iThemba Laboratory for Accelerator Based Sciences
- South African Institute for Aquatic Biodiversity
- Hartebeesthoek Radio Astronomy Observatory
- South African Astronomical Observatory which includes the SALT (Southern African Large Telescope) project, which is seen as a flagship science project on the African continent and signals that the South African government does not intend to eliminate basic research.
- Hermanus Magnetic Observatory

Although not classified as a National Facility, mention must also be made of the National Laser Centre (NLC), which was established in April 2000 with the mandate to grow laser expertise in South African industry and academia.

The NRF received 1 188 grant applications for 2001 totalling R308 million, of which 957 were in the natural sciences and engineering, and 231 in social sciences and humanities. The total amount requested exceeded available funding, and South African researchers received research grants to the value of more than R162 million for 2001.

The NRF administers the **Innovation Fund** which provides grants to fund the end-stage research process of novel research ideas with vast potential for commercial success, and seeks technological solutions in the identified focus areas that will yield significant national benefits. The fund assists in the conversion of the research idea into a commercially useful end- product by funding items such as equipment, research and development expertise, managerial skills, securing of Intellectual Property Rights and construction of prototypes, so that research knowledge can be translated into new and improved products, processes or services. The driving force of the initiative is to meet national objectives such as the sustained improvement of the quality of life of all South Africans, the development of human resources for science and technology, the strengthening of the country's competitiveness in the international sphere and economic growth.

The **National Research and Technology Foresight** (DACST 1999), one of whose objectives was to identify those technologies and latent market opportunities that are the most likely to generate benefits for South Africa, was completed in 2000. One of its outcomes was that three areas have been identified as being key future research and technology priority areas for South Africa. The Innovation Fund is supporting these areas in 2002 by calling for research proposals. They are listed in some detail below as they include a number of areas relevant to physics.

- **Molecular-based Biotechnologies**, such as molecular biology, bioinformatics, genomics, proteomics, immunology, genetics, molecular modelling and structural biology

- **Information and Communication Technology** in the following areas: Systems design and implementation including human-computer interfaces, distance learning support, extension of e-commerce and the development of networks which transcend language and cultural barriers; information management including content/data analysis informatics, data storage, data integration and information access; applications in science and engineering including simulations, modelling, forecasting and advanced computation; and enhanced communications technology including applications in mobile and distributed work environments e.g. telecommuting, collaboration techniques and communication in virtual environments

- **New Materials and Advanced Manufacturing** in areas such as systems integration (design and engineering), net shape and rapid solidification processing, integrated sensor technologies (sensor technologies with embedded electronics and software), materials handling (e.g. automatic storage and retrieval), materials beneficiation, advanced materials (e.g. the move towards new and improved alloys and other materials based on South Africa's natural resource advantage).

Tertiary Institutions

In terms of their importance to physics and related fields, the tertiary institutions comprise universities, technikons and to a lesser extent technical colleges. At the time that this report was being finalised (August 2002), the structure and number of universities and technikons was under review.

Universities

21 universities with physics departments are listed in 'A catalogue on research activities in physics and related fields in South Africa' (Gertenbach et al 1999) and are shown in Exhibit 5-2. The catalogue provides full details of staff, research activities, equipment available, papers published etc, up to 1998. More up-to-date details are available on the Web sites of most university physics departments, the Internet addresses of some of which may conveniently be obtained from 'the list of Physics Institutions in Africa' at http://physnet.uni-oldenburg.de/PhysNet/africa.html

Exhibit 5-2. Universities in South Africa with Physics departments

Medical University of South Africa
Potchefstroom University
Rand Afrikaans University
Rhodes University
University of Cape Town
University of Durban-Westville
University of Fort Hare
University of Natal (Durban)
University of Natal (Pietermaritzburg)
University of Port Elizabeth
University of Pretoria
University of South Africa
University of Stellenbosch
University of the North
University of the Orange Free State
University of the Western Cape
University of the Witwatersrand
University of Transkei
University of Venda
University of Zululand

Vista University

Technikons

Technikons provide experiential and vocational education, with study programmes designed to prepare students for a specific role in the economy. The technikons listed (Exhibit 5-3) would provide some physics education at the undergraduate level, and could be involved in applied research involving physics from time to time.

Exhibit 5-3. Technikons in South Africa

Border Technikon
Cape Technikon
Eastern Cape Technikon
Technikon Free State
Mangosuthu Technikon
ML Sultan Technikon
Technikon Natal
Technikon North West
Technikon Northern Gauteng
Peninsula Technikon
Port Elizabeth Technikon
Technikon Pretoria
Technikon South Africa
Technikon Witwatersrand

Comments

Since the White paper on S&T was published in 1996, it is encouraging that South Africa has clarified and rationalised its national S&T structure, and has put in place clear objectives for the future (DACST 2002a). While the restructuring and rationalisation process is ongoing, especially as regards the tertiary institutions, the focus is now shifting to truly new initiatives, and integrating policy with that of other government departments to achieve overarching and urgent national objectives. Within this S&T structure physics has a key role to play in supporting the ongoing initiatives.

References

DACST. 1996. White Paper on Science & Technology: Preparing for the 21st Century. Pretoria: Government Printer 1996 (also available at http://www.polity.org.za/ govdocs/ white_papers/scitech.html.

DACST. 1998. Technology and Knowledge: Synthesis Report of the National Research and Technology Audit. . Department of Arts, Culture, Science and Technology. Pretoria

DACST. 1999. Dawn of the African Century. National Foresight and Technology Foresight Project. Department of Arts, Culture, Science and Technology. Pretoria.

DACST. 2002. http://www.dacst.gov.za/science_technology/st_profile/overview.htm

DACST. 2002a. Department of Arts, Culture, Science and Technology - Strategic Plan 1 April 2002 - 31 March 2005. Available at http://www.dacst.gov.za/default_strategic_plan.htm

Gertenbach, I, Chetty N & Hasselgren, L. 1999. A catalogue on research activities in physics and related fields in South Africa. International Program in the Physical Sciences. Uppsala University.

Marais, HC. 2000. Perspectives on science policy in South Africa. Network Publishers, Pretoria.

NSTF. 2001. National Science and Technology Forum. http://www.nstf.org.za

NACI. 2001. National Advisory Council for Innovation. http://www.naci.org.za

NRF. 2001. National Research Foundation. http://www.nrf.ac.za

Physical science and mathematics education at the secondary level in South Africa

Chapter 1 made the point that education in science and technology is of key importance for national competitive advantage and prosperity. It is also important that the public at large have some degree of scientific literacy or ‘public understanding of science’ so that they can participate meaningfully in democratic policy formulation, particularly in policy matters relating to science and technology. Given the debates around such matters as HIV/AIDS, nuclear power and genetically modified organisms for example, it can be seen that a sufficient level of the understanding by the majority the public is essential for meaningful policy formulation. This chapter deals with the situation regarding physical science and mathematics education at the secondary level in South Africa.

Background

In 2000 there were 11.913 million learners enrolled at schools in South Africa (Roux, 2001). Of these, 4.751 million (35 percent) were enrolled in secondary schools and of these, 3.871 million were estimated to be Black/African learners (this statistic is relevant in the later discussion). Females were in the majority. 94.9 percent of the 7 to 19 year old population was enrolled in education in 1997, a number on a par with first world countries, and well above the average of 41.4 percent for sub-Saharan Africa. However the figure for South Africa is somewhat skewed by the high over-enrolment per age group as a result of high failure rates.

The number of school teachers (primary and secondary) was 348 000 in 2000, and of these 85 501 or 24.6 percent were under-qualified or unqualified (Shindler & Beard, 2001:12). The situation pertaining to mathematics and science teachers is far worse. This is discussed later in this chapter.

The average number of learners per classroom decreased from 43 in 1996 to 35 in 2000, and despite 50 000 new classrooms having been built since 1994, the backlog of classrooms in November 2000 stood at 67 199. The number of schools in excellent condition decreased from 9 000 in 1996 to 4 000 in 2000 (Department of Education 2001d).

The World Competitiveness Yearbook (Garelli 2002) ranked South Africa’s educational system 45th out of 49 in terms of its ability to meet the needs of a competitive economy. On the other hand South Africa’s university education was ranked 24th out 49. South Africa was placed at 46th out of 49 countries for its secondary education pupil-teacher ratio. South Africa had a ratio of 32 in 1999, behind India at 31 and Chile at 29.1. The first 43 countries in the ranking all had ratios of less than 23, with a minimum of 7.9 (Israel) and a maximum of 22.7 (Thailand).

489 299 candidates wrote the matriculation (also known as senior certificate) examination in 2000, and 58 percent passed. Only 14 percent obtained matriculation exemption, which allows entrance into tertiary education.

In the past decade (to the financial year 2001/2002) the total government expenditure on education in South Africa has been an average of 21.4% of the total budget, being the largest single allocation, and in the most recent fiscal year amounted to R58.5 billion, or 5.9 percent of GDP (Roux 2001). Of the total amount, primary and secondary schools received R42.0 billion of which by far the major component was for teachers salaries, leaving very little for infrastructure, development and improvement. The World Competitiveness Yearbook (Garelli 2002) ranked South Africa sixth out of 49 countries in terms of total public expenditure on education measured as a proportion of gross domestic product (GDP). Only Denmark, Canada, Israel, Sweden and the USA were ranked ahead of South Africa. This implies that education in South Africa is not under-funded by world standards when measured by the proportion of public money spent. To investigate the comparative situation further, the amount spent per student at all educational levels a was calculated from the data presented in World Bank (2001). The amount spent per student at the individual levels (primary to tertiary) was not available in most cases. As the country data refer to the latest available in a 4-year period, the numerical values must be regarded rather as estimates, but nevertheless useful for purposes of comparison. They are shown in Table 6-1 together with the satisfaction rating of the adequacy of science teaching in schools (Garelli 2002). South Africa was ranked second last out of 49 countries in this latter indicator. As regards the spend per student, the amount spent by South Africa is far less than

Table 6-1. Estimated public funding spend per student (all levels, primary to tertiary), and satisfaction with science teaching in schools, for selected countries

Country	Estimated* education spend per student (all levels) US $ 1997	Satisfaction with the adequacy of science teaching in schools (0 to 10 scale) 2002
Denmark	13749	5.31
Norway	12919	3.74
Switzerland	12474	6.76
Sweden	11075	5.05
Finland	8754	7.16
Austria	7883	6.62
USA	7626	5.87
Germany	7046	4.53
France	6985	6.94
Netherlands	6411	6.10
Japan	6374	4.62
Canada	6082	6.85
Italy	6051	3.15
United Kingdom	5379	4.54
Iceland	5217	5.58
Ireland	5217	5.09
Israel	4436	6.30
Australia	4148	6.09
New Zealand	4043	5.57
Belgium	3574	6.23
Spain	3493	4.58
Portugal	2658	3.25
Greece	2119	5.50
Czech Republic	1466	6.39
Slovenia	1370	4.20
Poland	1327	3.79
Estonia	1248	6.27
Hungary	1197	7.00
Argentina	1140	3.37
Brazil	1074	3.59
Mexico	830	3.23
South Africa	**729**	**3.10**
Malaysia	702	6.17
Chile	676	4.08
Thailand	509	4.05
Turkey	476	4.59
Colombia	399	3.50
Philippines	120	4.48
China	108	4.88
India	72	6.55
Indonesia	36	4.00

* For illustrative purposes only. See text for explanation of 'estimated'.

Sources: Garreli 2002 and calculated from data presented in World Bank 2001.

that spent by first world countries. To increase the spend to first world levels is clearly not feasible in the foreseeable future, as it would entail spending the entire South African budget on education only, or increasing the size of the economy by 3 to 5 times, or finding an additional source of funding of some R120 to R250 billion per annum.

Learner performance in final secondary level physical science and mathematics examinations.

Of particular relevance is the performance of learners in physical science and mathematics examinations at the end of their secondary education as those successful constitute the pool from which potential tertiary physics students can be drawn. This also applies to the pool available for training as mathematics teachers. Tables 6-2 and 6-3 show the number of candidates and pass rates, at both the higher and standard grades in both subjects. A pass is an achievement of 40 percent or more.

Table 6-2. Senior certificate performance in physical science in South Africa 1997-2000

	Total candidates[1]	Physical Science Higher grade			Physical Science Standard grade		
	Total	Wrote	Passed[2]	Percent	Wrote	Passed[2]	Percent
1997	559 000	76 100	27 000	35.5%	65 200	35 200	54.0%
1998	552 000	73 300	26 700	36.4%	83 000	43 200	52.0%
1999	511 000	66 500	24 200	36.4%	93 500	44 000	47.1%
2000	489 900	55 700	23 300	41.8%	125 100	55 000	44.0%

Note 1: Total candidates is the number of full time candidates with six or more subjects
Note 2: Passed means obtained a pass on the grade that they wrote the examination.
Source: Complied from Department of Education 2001a

Table 6-3. Senior certificate performance in mathematics in South Africa 1997-2000

	Total candidates[1]	Mathematics Higher grade			Mathematics Standard grade		
	Total	Wrote	Passed[2]	Percent	Wrote	Passed[2]	Percent
1997	559 000	68 500	22 800	33.3%	184 200	66 900	36.3%
1998	552 000	60 300	20 300	33.7%	219 400	68 600	31.3%
1999	511 000	50 100	19 900	39.7%	231 200	72 200	31.2%
2000	489 900	38 500	19 300	50.1%	254 500	79 600	31.3%

Note 1: Total candidates is the number of full time candidates with six or more subjects
Note 2: Passed means obtained a pass on the grade that they wrote the examination.
Source: Complied from Department of Education 2001a

It can be seen from these tables that the number of candidates successfully passing physical science or mathematics in either grade is low (15.9 percent of the total learner population for physical science and 20.2 percent for mathematics in 2000). Success at the higher grade is far lower at 4.7 percent of the total learner population for physical science and 3.9 percent for mathematics in 2000. The data do not indicate the number of learners who passed both subjects on the higher grade, it is however apparent that it must be less than 19 300, the number who passed mathematics on the higher grade. It is this (smaller) group who would most likely be drawn to a career in physics.

Pass rates in both subjects are unsatisfactory, and while there is an apparent pass rate improvement over time at the higher grade, to some extent this is because the less able students are encouraged to sit the examination at the standard grade (Business Day 2002), presumably so as to increase pass rates. In this context it is also disturbing that in absolute terms, both the enrolments and number of passes in the higher grade in both subjects is dropping over time, particularly so in mathematics where the number writing at the higher grade has almost halved in a 4 year period (Table 6-3).

Of particular concern is the situation and performance regarding African learners in these two subjects. As already mentioned, such learners constitute the vast majority of secondary level learners, and yet very few of the more than 400 000 African candidates (more than 80 percent of the total) in the senior certificate examinations in 2000 wrote physical science or mathematics at the higher grade, and those that did, had low pass rates as shown in Table 6-4.

Table 6-4. African candidates' performance in senior certificate physical science and mathematics in South Africa in 2000

Candidates	Physical science Higher grade			Mathematics Higher grade		
	Wrote	Passed	Percent	Wrote	Passed	Percent
African	33 657	5 136	15%	20 243	3 128	15%
Total	55 700	23 300	42%	38 500	19 300	50%
percent African	60%	22%		53%	16%	

Source: Complied from Department of Education 2001a

The situation did not improve in 2001. According Business Day (2002), only 4 898 African learners passed physical science on the higher grade and 2 751 passed mathematics on the higher grade in 2001, a drop on the 2000 numbers. Education deputy director-general Khetsi Lehoko was quoted as saying that the disparity was due to the apartheid policy of actively discouraging Africans from studying mathematics and science. It resulted in a lack of skilled teachers, perpetuating the shortage of pupils studying and passing the subjects, he said.

The situation regarding the lack of trained teachers was also compounded in the middle 1990s when many qualified teachers were, in effect, encouraged to take early retirement. Government has recognised this, and part of the Tirisano strategy (see later in this chapter) is to attract those with experience back into the teaching profession.

Effectiveness of secondary level science education.

In a study of 4 332 newly admitted first-year students at the five tertiary educational institutions in the Western Cape, Laugksch and Spargo (1999) found that the scientific literacy among the students, as measured by the 110 test-item Test of Basic Scientific Literacy questionnaire, to be significantly higher among those students who had included physical science as a matriculation subject at school. The study also found that African students had consistently the lowest levels of scientific literacy of all population groups in every science subject combination, and displayed scientific literacy levels one third to one fifth that displayed by the population group with the highest scientific literacy. The authors ascribed this result to the previous apartheid policies.

Science and mathematics teachers and their training

The low level of output of successful learners, particularly in mathematics at the higher grade, severely constrains the education system from producing adequately qualified teachers in mathematics and science. Those that have obtained a good pass find it unattractive to choose teaching as a career and therefore opt to study in the science-related fields (Department of Education 2001b). As a result, few learners enter teacher training programmes in mathematics and science. The Department of Education (2001b) notes that a 1997 report found that that most mathematics and science teachers were not qualified to teach these subjects. While 85 percent of mathematics teachers had a suitable teaching qualification, only 50 percent had specialised in mathematics in their training. Similarly, 84 percent of science teachers had teaching qualifications, but only 42 percent were qualified in science.

An estimated 8 000 mathematics and 8 200 science teachers need to be targeted for in-service training to address their lack of subject knowledge. In addition, teachers in these subjects generally had a low level of teaching experience. More than a third of mathematics teachers, over 45 percent of general science teachers and almost 40 percent of physical science teachers had less than two years' experience teaching their subjects (SAIRR, 1998).

Annual graduate teacher production at universities (excluding UNISA) through the HDE is currently about 100 for secondary mathematics and 60 for physical science (Department of Education 2000). The output from colleges of education of three-year diploma teachers suggest annual ‘production’ of about 1 100 teachers with secondary mathematics and 850 with science. The overwhelming majority (greater than 90 percent) of college diplomates are African.

Chuene, Lubben and Newson (1999), in a detailed study into the attitudes and expectations of 17 trainee (pre-service) and 17 newly trained (novice) black mathematics teachers in the Northern (now Limpopo) Province, found few of the novice teachers (those with less than four years teaching experience) and trainee teachers to be committed to teaching. Many had come to colleges of teacher education because their admission criteria were ‘relatively relaxed’ compared to other tertiary institutions. More than half said they planned to leave teaching and hoped that their training and teaching experience would enable them to obtain higher qualifications, leading to better employment opportunities.

Some of the findings of the study were:

- A quarter of the trainee teachers saw attendance at colleges of teacher education as a way to avoid unemployment.
- Only a minority of trainee teachers expected college to educate them to be better managers of classes.
- The trainee teachers were enthusiastic about using student-centred approaches to encourage creativity, whereas the novice teachers (who had some practical experience) preferred traditional ‘chalk and talk’ methods. Novice teachers reported difficulties in introducing student-centred approaches when standards of discipline were low, when learners could not follow explanations in English or when teachers and students spoke different first languages.
- Novice teachers complained at the inconsistency in guidance provided by lecturers and supervisory teachers.
- The main expectation of the novice teachers was that of gaining a teaching qualification, which led the study to conclude that teacher education was seen as a preparation for a job, possibly outside of teaching, rather than a preparation for the teaching profession.

In terms of senior certificate statistics for 2000, the North West province is fairly typical, having had 8.2 percent of senior certificate candidates, 58 percent of whom passed (the same as the national average). It is thus worthwhile considering a detailed survey carried out among 1 221 secondary physical science and general science teachers at the 497 secondary schools in the North West province (Smit et al 1997). The survey found that**:**

- 54 percent of the teachers had no post-matriculation training in physics or chemistry.
- Less than 100 of the teachers had a third year university or higher qualification in physics or chemistry.
- The highest qualification of 82 percent of the teachers was a teacher’s diploma or certificate.
- The science teachers spent 41 percent of their time teaching subjects other than science.
- The average experience of the physical science teachers was 2.1 years.

The survey found that the teachers tended to use out-of-date teaching methods, with little or no practical or group work. Little was being done to re-train or upgrade the qualifications of the teachers on an on-going basis, and indeed, the seven colleges of education in the North West province had no programmes for the in-service development of teachers.

Concern was expressed that there was a large gap between the quality of training available at the two local universities on one hand, and the colleges of education on the other. The survey found that the colleges of education had low entrance requirements, unprepared first year students, diploma courses that were too short, and the colleges were lacking in infrastructure.

Public understanding of science

The low level of the public understanding of science has been revealed in a study of 2 207 randomly selected South African adults (Blankley and Arnold 2001). The survey found that 30 percent of adults

had never studied mathematics at school, 50 percent had never studied biological science and 55 percent had never studied physical science. Indeed, according to the 1996 population census, 19 percent of adults had received no education at all (Roux 2001). The study concluded that most South Africans thus lack the background to take an informed interest in science matters and to assimilate available information, and that science and technology are low-salience i.e. non-significant issues for most South African adults.

Summary of the situation

The situation regarding education in South Africa is extremely unsatisfactory and especially so when it comes to science and mathematics secondary level education and teacher training. The vast majority of learners leave school without significant education in these two key subjects. This then compounds the lack of competent teachers, which in turn leads to lower educational standards. The qualitative lack of and shortage of skills in the sciences erodes the competitive position of South Africa in the global market-place. The World Competitiveness Yearbook (Garelli 2002) finds that improving education and skills development is the second-most important of five challenges presently facing South Africa.

State spending on education is already at a high level and it cannot be expected to increase significantly in relative terms. This leads to the conclusion that the only significant way to improve the quality of education at primary and especially at secondary levels, is by focusing on efficient, effective and innovative ways of utilising the available funds. That education in South Africa is in crises is hardly a new observation, and the situation has been recognised by government. In 2000, President Mbeki stated that, ‘Special attention will need to be given to the compelling evidence that the country has a critical shortage of mathematics, science and language teachers, and to the demands of the new information and communications technologies.’ (Department of Education 2001a). To solve the crises a national mobilisation plan for education and training has been announced, and is called Tirisano: working together to build a South African Education and Training System for the 21st Century

Tirisano - a way forward

Tirisano, literally ‘working together’, is, in the words of Education Minister Kader Asmal, now focused on creating greater equity and quality of learning conditions, and improving standards and learner outcomes. A key feature of this phase is ‘the deepening reform of institutional processes in all sectors and focusing, with other Government departments, our efforts on building the capacity of our education managers and educational institutions in the eighteen urban and rural development nodes to provide an education and training service fit the 21st century.’ (Department of Education 2001b).

The National Strategy for Mathematics, Science and Technology Education (Department of Education 2001a) includes the following actions relating to Tirisano:

- The establishment of 100 special focus schools. The objective is to double the number of African learners that pass these mathematics and science on the higher grade. To this end 102 dedicated high schools for mathematics and science have been selected (Table 6-5), as a short term cost-effective way of deploying scarce resources in the teaching of these subjects. The schools offer mathematics and science in the higher grade and have competent teachers in both mathematics and science. The policy intends to incorporate more schools into the programme in the future.

- A set of actions to ensure an adequate supply of qualified and competent mathematics and science teachers. These include the upgrading of under-qualified and unqualified teachers; attracting learners to train as mathematics, science and technology teachers by providing them with bursaries to enter higher education; and making a ‘concerted effort’ to attract back into teaching those mathematics, science and technology teachers who retired or took voluntary separation packages.

In addition, consideration is being given to the recruitment of mathematics, science and technology teachers from other countries.

Table 6-5. Distribution by province of the 102 dedicated schools for mathematics and science

Province	Number of schools
Free State	6
North West	7
Eastern Cape	15
Mpumalanga	7
Northern Cape	4
Gauteng	11
Kwazulu-Natal	23
Limpopo	23
Western Cape	6

Source: Complied from Department of Education 2001b

- A 'language in education' implementation programme which will provide more effective home language learning and teaching, as well as the learning and teaching of English as a second language. Mathematics and science are usually taught in English, which for the majority of learners is not their or home language. The Department recognises that it is therefore important to strengthen the teaching of English second language.

Further Education and Training (FET)

The reader should be aware that there is a process underway at present that could result in significant changes to the senior (grades 10 to 12) secondary curriculum, and which thus could affect the discussion in this chapter. This is the National Strategy for Further Education and Training (Department of Education 2001c), which provides the basis for developing a nationally co-ordinated further education and training system, comprising the senior secondary component of schooling and technical colleges. It will result in the FETC or Further Education and Training Certificate. Although the great majority of grade 10 to 12 learners are in schools, many study in colleges and through private providers. Schools have traditionally been oriented to academic approaches and higher education, while colleges emphasise vocational programmes and the workplace.

The curriculum for FET is being developed as a single national framework for schools, colleges and private providers. Consideration is being given introducing vocational education into the school curriculum. FET is outcomes-based and learner-centred, with unit standards and registered programmes drawn from twelve fields of learning. FET will lead to a single certificate, the FETC, with programmes of two types; general/academic/vocational (offered in schools) and vocationally specific (offered in technical colleges). Instead of learners choosing from the present fixed portfolio of subjects, they will in future choose within subjects. The curriculum is to have a fundamental component (communication and mathematical literacy), a core (in the area of specialisation) and electives. A consequence will be that the number of subjects available in the general/academic certificate will be greatly reduced, especially those in subjects in which enrolments have been low. An objective is to make the delivery of secondary education more manageable, more equitable and more effective.

Conclusion

It is indeed commendable that the Department of Education has embarked on the strategy as described above to address the crisis in secondary science and mathematical education that exists for the vast majority of learners. Nevertheless it has to be asked, is it a case of too little, too late? South Africa urgently needs to significantly increase its output of school leavers competently qualified in science and mathematics. Assuming that that each of the 102 schools is able in the next two to three years to annually produce 30 learners with a pass in physical science or mathematics on the higher grade per annum, the strategy will of itself at best double the number of successful African senior certificate candidates at this level. Of course, as the strategy is widened to encompass more schools, and more teachers are produced, standards of science and mathematics education will improve, albeit slowly. It is thus clear, given the numbers described in this chapter, that the Department of Education strategy needs to be supported and complemented by other means, so as to more rapidly achieve its aims. It is in providing such support that, amongst others, the SAIP and the broader physics community, whether in industry or in academia, could significantly contribute to making the strategy more effective.

References

Blankley, W and Arnold, R., 2001. Public understanding of science in South Africa - aiming at better intervention strategies. South African Journal of Science 97:65-69. March/April 2001.

Business Day 2002. ‘Maths and science plan not working’. 1 February 2002.

Garelli, S et al (Eds). 2002. World Competitiveness Yearbook 2002. IMD.

Chuene, K, Lubben, F and Newson G. 1999. The views of pre-service and novice teachers on mathematics teaching in South Africa related to their educational experience. Educational Research, 41/1, p23-34, Spring 1999

Department of Education 2000. Draft intervention strategy for science, mathematics and technology education. 11 September 2000

Department of Education. 2001a. National strategy for mathematics, science and technology education in general and further education and training. June 2001.

Department of Education 2001b. Implementation Plan For Tirisano 2001-2002 at http://education.pwv.gov.za/Tirisano_Folder/Tirisano%202001_2/Tirisano%202001_2.htm

Department of Education 2001c. Education in South Africa - Achievements since 1994. May 2001

Department of Education 2001d. Education in South Africa at http://education.pwv.gov.za/Policies-Reports/Reports-2001/education-in-South-Africa….2001/08/08.htm

Laugksch, RC and Spargo, PE. 1999. Scientific literacy of selected South African matriculants entering tertiary education: a baseline survey. South African Journal of Science 95:427-432. October 1999

Roux, A (Ed). 2001. Business Futures 2001. Chapter 2 - Education and training. Institute for Futures Research, University of Stellenbosch.

SAIRR. 1998. South Africa Survey 1997/1998. SAIRR.

Shindler, J. and Beard, S. 2001. An analysis of the 2000 senior certificate examination. EduSource Data News, No 32.

Smit, JJ et al. 1997. The Training of Physical Science Teachers in the North West Province. University of Potchefstroom for CHE and the University of the North. September 1997.

World Bank. 2001. World Development Indicators 2001. Washington DC: World Bank.

Physics graduates 1987-1997 and students 1998-1999

This chapter deals with trends in the number of physics graduates, i.e. students completing the degree in that particular year, from universities in South Africa for the period 1987-1997, and presents some available statistics regarding physics student numbers at some South African universities in the period 1998 to 1999.

Comparative trends in the numbers of physics graduates 1987-1997

The number of graduates from South African universities in physical sciences was obtained from the National Research Foundation as an extract from SAPSE (Department of Education 1997). (SAPSE is an acronym for 'South African post-secondary education'). The data contained in the extract are examined in this chapter so as to gain an impression of the trends in the number of physics graduates at various degree levels in the period 1987 to 1997. A number of introductory remarks are in order.

- The available data break down the natural sciences into the following categories: mathematical sciences, physical sciences, chemical sciences, earth sciences and biological sciences. The assumption for the following analysis is that the numbers of 'physical sciences' graduates equate to physics graduates. The available data for 1987-1995 excludes universities in the so-called 'TVBC states'. For 1996 and 1997 this data is included.
- For each degree level, the data presented below is for the physical, chemical and mathematical sciences for comparison purposes, as well as the total for the natural sciences (as defined above), the natural sciences and engineering (which comprise the natural sciences, the agricultural sciences, engineering and technology, and architecture), and the total degrees (which comprise the natural sciences and engineering, the health sciences, and the social sciences and humanities).
- From 1998 onwards, data regarding graduates in the physical sciences has been aggregated with that of graduates in the life sciences (Department of Education, 2001). This makes it impossible to extract any information about numbers of physics graduates in the period from 1998 to the present.
- The HSRC publication giving profiles and recent trends for South African graduates in the period 1991-1997 (Shapiro and Jacobs, 1999) was prepared with the aim of providing employers information on potential employees. It was unfortunately not an appropriate source of data for two reasons. First, data for graduates in the physical and chemical sciences were grouped together, thus giving no information about the physical sciences alone, and secondly, those with multiple qualifications were repeated in various categories, thus giving results which were not suitable for the purposes of this chapter.

The data

Tables 7-1 to 7-4 present a summary of degrees awarded in the 11 year period 1987 to 1997. The data are also presented graphically by category in Figures 7-1 to 7-5, with the exception of the mathematical sciences, which are presented in the tables for the interested reader, but are not discussed any further.

Table 7-1. Bachelor degrees awarded in South Africa 1987-1997 by selected category

Year	Physical sciences	Chemical sciences	Mathematical sciences	Natural sciences	Natural sciences & Engineering	Total for all categories
1987	106	180	847	1 948	3 984	20 800
1988	113	189	821	2 053	4 041	22 089
1989	112	173	909	2 038	4 328	22 019
1990	117	182	869	2 175	4 452	24 230
1991	107	179	888	2 196	4 484	27 230
1992	121	216	972	2 376	4 677	28 274
1993	150	240	1 011	2 469	4 885	29 480
1994	141	262	1 066	2 469	5 048	30 012
1995	171	267	1 062	2 687	5 089	32 013
1996	164	340	1 190	2 931	5 136	35 678
1997	197	351	1 241	3 100	5 249	35 896

Table 7-2. Honours degrees awarded in South Africa 1987-1997 by selected category

Year	Physical sciences	Chemical sciences	Mathematical sciences	Natural sciences	Natural sciences & Engineering	Total for all categories
1987	61	83	227	760	1 054	7 139
1988	54	92	297	895	1 202	7 929
1989	63	71	326	981	1 285	8 241
1990	65	94	318	969	1 307	8 462
1991	71	96	423	1 177	1 514	9 069
1992	66	108	369	1 072	1 399	9 577
1993	64	111	380	1 088	1 420	10 409
1994	75	91	402	1 097	1 465	10 481
1995	74	91	378	1 049	1 452	11 786
1996	76	122	380	1 131	1 502	11 837
1997	71	96	395	1 110	1 560	11 378

Table 7-3. Masters degrees awarded in South Africa 1987-1997 by selected category

Year	Physical sciences	Chemical sciences	Mathematical sciences	Natural sciences	Natural sciences & Engineering	Total for all categories
1987	39	40	47	294	670	2 547
1988	41	33	65	295	671	2 885
1989	44	43	47	328	739	2 770
1990	31	39	55	321	776	2 942
1991	37	44	64	370	824	3 266
1992	43	49	83	385	881	3 478
1993	41	42	85	427	847	3 666
1994	47	50	78	413	869	3 460
1995	49	43	73	400	876	3 815
1996	45	52	88	489	915	3 980
1997	54	60	75	505	965	4 233

Table 7-4. Doctorates awarded in South Africa 1987-1997 by selected category

Year	Physical sciences	Chemical sciences	Mathematical sciences	Natural sciences	Natural sciences & Engineering	Total for all categories
1987	12	14	12	116	188	536
1988	25	25	11	149	223	619
1989	18	16	17	157	227	663
1990	22	23	8	147	214	604
1991	22	14	26	172	255	652
1992	20	16	12	154	230	658
1993	19	26	22	167	257	637
1994	22	27	22	177	283	733
1995	20	30	22	173	266	712
1996	15	30	22	160	240	699
1997	26	32	26	176	281	697

Figure 7-1. Physical sciences degrees awarded in South Africa 1987-1997

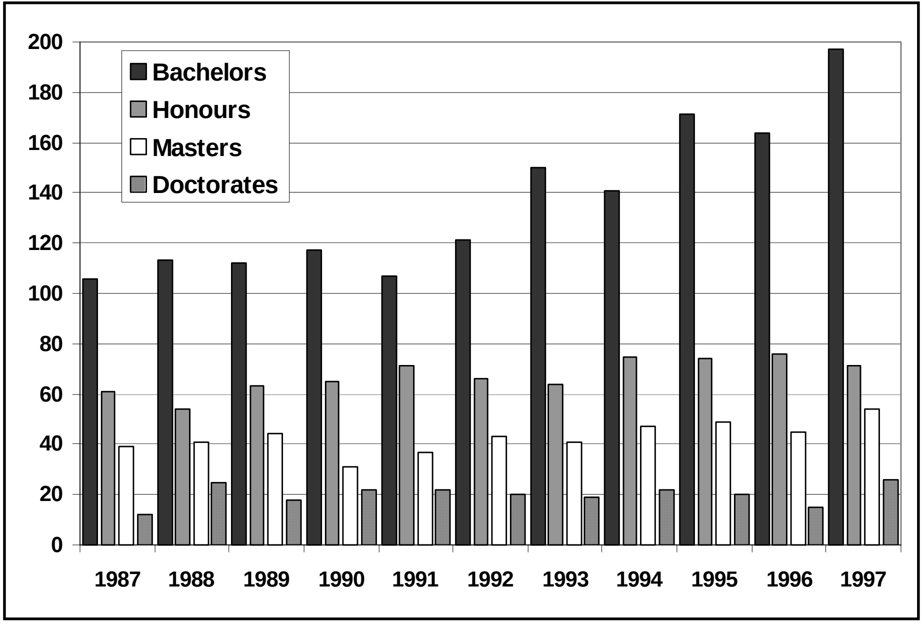


Figure 7-2. Chemical sciences degrees awarded in South Africa 1987-1997

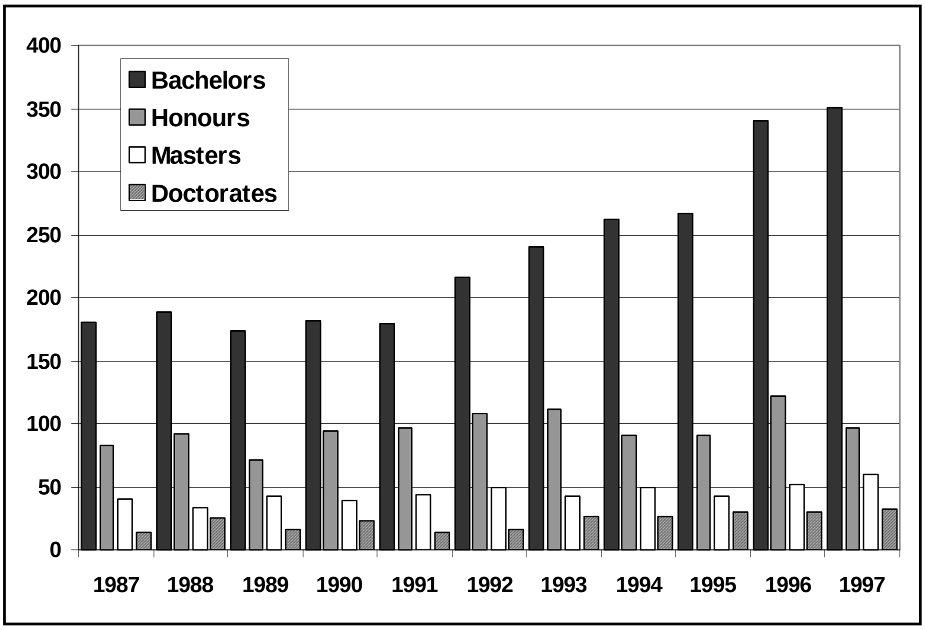


Figure 7-3. Natural science degrees awarded in South Africa 1987-1997

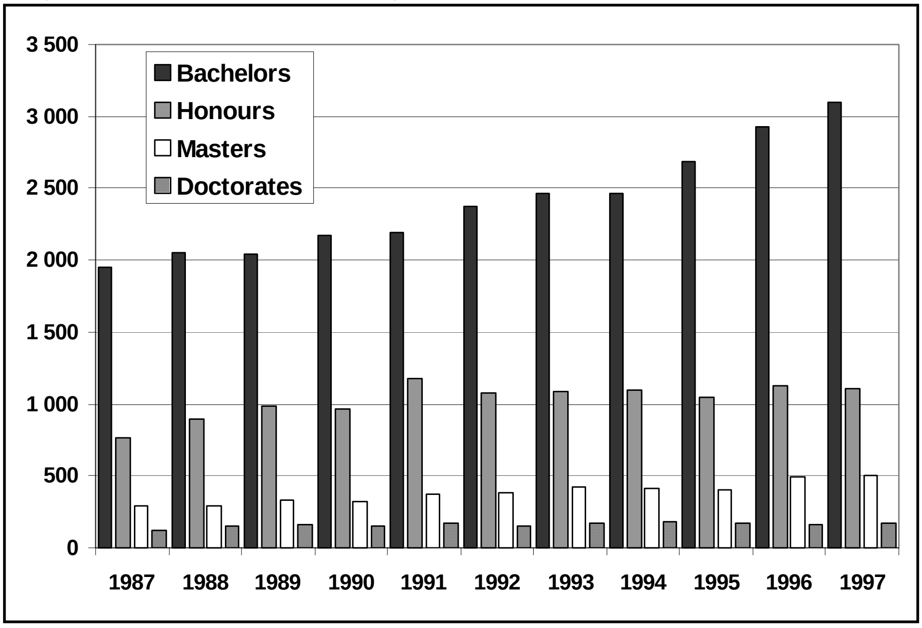


Figure 7-4. Natural sciences and engineering degrees awarded in South Africa 1987-1997

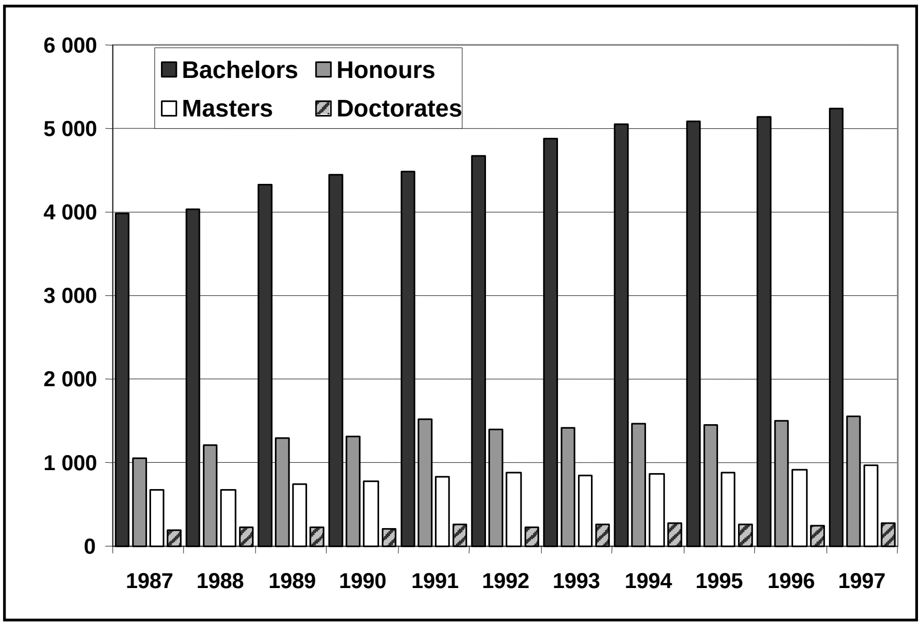
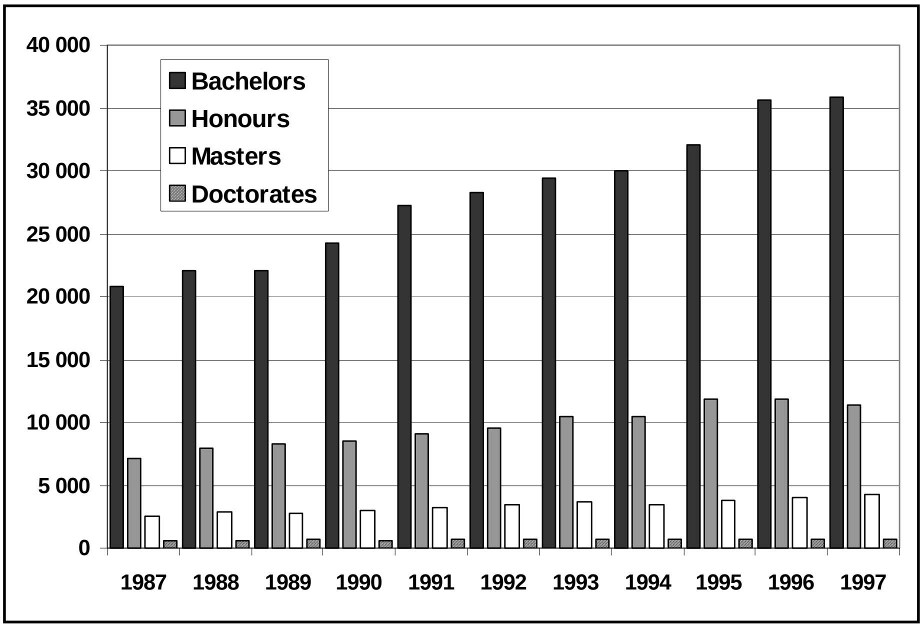


Figure 7-5. All degrees awarded in South Africa 1987-1997



Discussion

On investigation, it appears that all the trends in all the data series can be simply approximated by linear or straight-line trends. This process of simple linear regression was carried out for all the data series, and the results were then used to calculate the total percentage growth in the number of degrees in the eleven year period under consideration. The results are presented in Table 7-5.

Table 7-5. Growth in the number of degrees in the period 1987-1997

Degree type	Physical sciences	Chemical sciences	Natural sciences	Natural sciences & Engineering	Total for all categories
Bachelors	98%	140%	63%	34%	85%
Honours	29%	28%	32%	36%	71%
Masters	37%	52%	80%	43%	65%
Doctorates	16%	115%	30%	36%	24%

At the bachelors level, the number of graduates in physical sciences doubled in the eleven year period. In all the disciplines included in the natural sciences and engineering this was the second highest growth rate (data not shown), and was only exceeded by the growth in number of graduates in the chemical sciences. Other categories where graduate numbers at the bachelor level more than doubled were nursing, education, law, libraries/museums and the humanities.

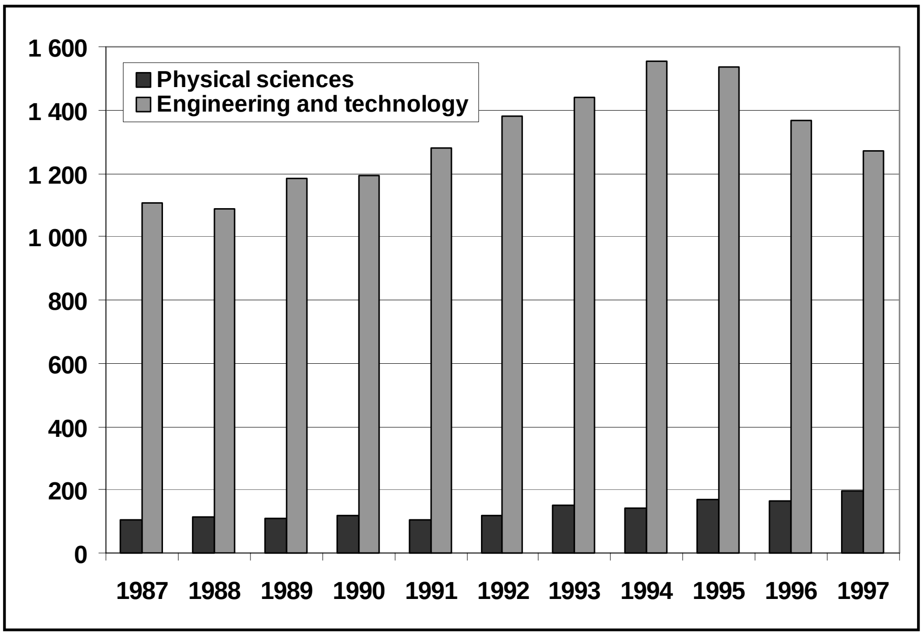
At the postgraduate-level, the growth rates numbers in the physical sciences tended be about the same as that for all natural sciences at the honours level, and for higher degrees the growth rates were low compared to other categories in table 7-5.

It can seen that in the period 1987 to 1997 there was an increase in the proportion of bachelor degrees when compared to post-graduate degrees. This means that bachelor graduates increasingly tended not to undertake further studies. The possible reasons for this could be that the job market became more attractive than further studies for bachelor graduates, i.e. there was a perception that further degrees would not significantly enhance career prospects, or that bachelor graduates increasingly could not afford to study further, or more of them did not qualify to study further. It could also be speculated that students chose to study further overseas. These observations apply generally to all the data presented above.

Looking at the proportion of post-graduate degrees to first degrees, this can be seen to be significantly higher in the physical sciences than in the chemical or mathematical sciences, i.e. the tendency for physical science graduates to continue their studies is higher than in the other categories. Not only can this be seen in the figures above, but by comparing Table 7-1 and Table 7-4, it is clear that while the absolute numbers of bachelor graduates in the chemical and mathematical sciences are higher, the number of doctorates is approximately the same in each discipline, once again showing that proportionately more physical science students tend to obtain advanced degrees.

As some physicists who are employed in industry have a perception that they compete with engineers (chapters 8 and 9), the number of bachelor degree graduates in engineering and technology, and in the physical sciences are compared shown in Figure 7-6. While bachelor degrees in the physical sciences doubled in the eleven year period, the number of bachelor engineering and technology graduates experienced a peak in 1994 and a significant fall from the peak after that. Any conclusion drawn from this observation is tenuous, but because of the different type of trends one could speculate that the factors leading students to study engineering and technology are different to those for engineering and technology students.

Figure 7-6. Bachelor degrees in engineering & technology, and in the physical sciences. 1987-1997



Conclusions regarding graduates

In the period 1987 to 1997, the number of bachelor degree physical sciences graduates nearly doubled (a 98 percent increase), a growth rate higher than that for any other disciplines in the natural sciences and engineering category, with the exception of the chemical sciences.

The growth rate in the number of bachelor degree physical sciences graduates was on a par with increases in other high growth categories such as nursing, education, law, libraries and the humanities.

In the period 1987 to 1997, first degree graduates increasingly tended not to continue their studies. The physical sciences were no exception.

Although absolute numbers of bachelor physical science graduates are small by comparison with most other scientific and engineering disciplines, physical sciences graduates tended to continue their studies proportionately to a greater extent than did graduates in other disciplines. This resulted in the absolute number of doctorates in the physical sciences being about the same or more than in most other scientific and engineering disciplines, with the exception of the biological sciences and engineering and technology.

It can thus be concluded that physical science as a course of study has not experienced any decline in the period 1987 to 1997, and that it compares well in relative terms with most other disciplines.

It is recommended that the matter of recording the number of physics graduates in South Africa annually be taken up with the relevant authority. As things stand at present, this data is not available from 1998 onwards as it is recorded under code 1500, being physical and life sciences combined.

Physics student numbers 1998-1999

As data regarding physics graduates are longer available from the Department of Education, it was felt that data regarding some physics student enrolments at a number of South African universities which have been collected by Malherbe (2002) should be presented. The data deal with 3rd year level and post-graduate student numbers. According to Malherbe, 'The original questionnaire sent to Heads of Departments requested only that the number of graduates be supplied. However the responses were not consistent, especially with regard to the postgraduate student numbers. Clearly the postgraduate data of some universities (probably those with the large numbers) reflect their total enrolment for that particular year, while for others it was only the number of graduates. This inconsistency of the data makes the comparison between universities impossible. However, the breakdown in terms of gender and race does provide interesting comparisons'. Data were not obtained from the following universities: Cape Town (physics department), Durban-Westville, Fort Hare, Medunsa, North West, The North, Unisa (physics department), Venda, Western Cape and Zululand. Of the universities that did submit data, one provided data for as far back as 1961, while some of the others provided data for only one or two recent years. Although the data are incomplete in a number of ways and possibly inconsistent, it is felt that it would be useful to present some of them here.

The data for 1998 and 1999 are presented in Tables 7-6 to 7-9 below, for 3rd year, Honours, Masters and PhD level, respectively. The numbers are also broken down into gender and race category (black and white). Blanks indicate that no data was provided. Each table is sorted by total number of student in 1999.

Table 7-6. Final (3rd) year physics student numbers 1998-1999

University	1999				1998			
	Total	White	Black	Female	Total	White	Black	Female
Unin	63	0	63	10	67	0	67	8
Vista	25	0	25	0	14	0	14	0
Natal	23	5	18	5				
Orange Free State	21	10	11	2	21	14	7	7
Port Elizabeth	14	9	5	2	10	7	3	0
Rhodes	9	7	2	2	10	9	1	2
Venda	8	0	8	1	11	0	11	3
Rand Afrikaans	7	3	2	3	4	2	1	2
Witwatersrand	7	3	4	0	6	3	3	0
Potchefstroom	4	3	1	0	5	5	0	0
Pretoria	4	3	1	3	3	3	0	0
Cape Town (astrophysics)	3	3	0	1	7	4	3	4
Transkei	3	0	3	1	0	0	0	0
Unisa (astronomy)	3			1	3			0
Stellenbosch					10	10	0	2
Total	194	46	143	31	171	57	110	28
Percent	100%	24%	74%	16%	100%	33%	64%	16%

In the absence of data from Natal for 1998 and from Stellenbosch for 1998, no comparison between 1998 and 1999 is possible. Nevertheless, it can be seen that at the 3rd year level, black students are in a significant majority. The proportion of female students is very low at 16 percent for both years.

At the Honours level (Table 7-7), the numbers were about 20 percent that of the 3rd years. This is not in line with the data presented for physical sciences graduates in tables 7-1 and 7-2 above, where proportions ranging between 36 and 66 percent can be seen. Unfortunately, the incompleteness of the data in tables 7-6 and 7-7 does not allow any conclusion in this regard to be reached. Numbers are equally spread between black and white students, while females are a minority.

Table 7-7. Honours physics student numbers 1998-1999

University	1999				1998			
	Total	White	Black	Female	Total	White	Black	Female
Unin	9	0	9	2	2	0	2	1
Port Elizabeth	5	4	1	2	3	1	2	
Pretoria	4	2	2	1	4	3	1	1
Witwatersrand	4	3	1	0	5	4	1	1
Orange Free State	3	1	2	1	8	3	5	4
Potchefstroom	3	3	0	0	1	0	1	0
Unisa (astronomy)	3	3	0	1	3	2	1	1
Venda	3	0	3	1	1	0	1	1
Rand Afrikaans	2	0	2	0	1	1	0	0
Rhodes	2	2	0	0	2	2	0	1
Vista	2	0	2	0				
Cape Town (astrophysics)	1	1	0	1	1	1	0	1
Natal	1	1	0	0				
Transkei	1	0	1	0	0	0	0	0
Stellenbosch					2	1	1	2
Total	43	20	23	9	33	18	15	13
Percent	100%	47%	53%	21%	100%	55%	45%	39%

At the Masters level (Table 7-8), it is becomes noticeable that the universities with the most students are not the same ones that have the most students at the 3rd year and Honours level. Witwatersrand and Pretoria are cases which illustrate this observation, in both relative and absolute terms.

Table 7-8. Masters physics student numbers 1998-1999

University	1999				1998			
	Total	White	Black	Female	Total	White	Black	Female
Natal	12	7	5	1				
Pretoria	10	3	7	2	8	4	4	2
Witwatersrand	10	6	4	3	13	5	8	3
Rand Afrikaans	8	5	3	2	7	4	3	2
Unin	7	0	7	1	7	0	7	0
Orange Free State	6	4	2	1	8	7	1	3
Rhodes	5	4	1	1	3	2	1	0
Port Elizabeth	4	3	1	1	6	4	2	
Cape Town (astrophysics)	2	2	0	0	3	1	2	0
Potchefstroom	1	0	1	0	4	3	1	2
Transkei	0	0	0	0	1	0	1	0
Unisa (astronomy)	0	0	0	0	0	0	0	0
Stellenbosch					4	3	1	0
Total	65	34	31	12	64	33	31	12
Percent	100%	52%	48%	18%	100%	52%	48%	19%

The most striking observation that can be made about numbers at the PhD level (Table 7-9), is the very high number of PhD numbers reported by Witwatersrand. Also notable is that in both 1998 and 1999 there were more PhD than Masters and Honours students. At the PhD level, the ratio of white to black students is 2 to 1 on average. Females are very much in the minority.

Table 7-9. PhD student numbers 1998-1999

University	1999				1998			
	Total	White	Black	Female	Total	White	Black	Female
Witwatersrand	33	19	14	0	40	24	16	1
Pretoria	11	6	5	2	10	6	4	1
Port Elizabeth	8	8	0	4	8	8	0	
Natal	6	4	2	1				
Orange Free State	4	3	1	0	4	3	1	1
Rand Afrikaans	4	3	1	1	5	4	1	1
Cape Town (astrophysics)	3	2	1	1	3	2	1	1
Rhodes	2	1	1	1	2	1	1	0
Unin	2	0	2	0	0	0	0	0
Potchefstroom	1	1	0	0	1	1	0	1
Transkei	0	0	0	0	1	0	1	0
Unisa (astronomy)	0	0	0	0	0	0	0	0
Venda	0	0	0	0	0	0	0	0
Stellenbosch					1	1	0	0
Total	74	47	27	10	75	50	25	6
Percent	100%	64%	36%	14%	100%	67%	33%	8%

References

Department of Education 1997. SAPSE statistics with regard to students and personpower, 1987-1997. Appendix 2-15. pp 2-3.

Department of Education, 2001. Personal communication with Mr H. de Beer, and data provided by him.

Malherbe, J. 2002. Personal communication.

Shapiro, Y and Jacobs, J. 1999. South African Graduate Statistics 1999. Profiles and recent trends. HSRC. 1999

The Electronic 1999 Survey

In the first quarter of 1999 the SAIP sent out by e-mail a survey questionnaire to investigate the state of physics in South Africa. The survey went to about 120 SAIP members, all physics departments at universities and technikons, the major national facilities that employ physicists, and a selection of large South African companies such as de Beers, CSIR, MINTEK, etc. A request was made to recipients to forward the questionnaire to all other physics graduates. This survey is referred to as the Electronic 1999 survey.

There were 122 responses to the Electronic 1999 survey, of which 68 percent were from members of the SAIP, 30 percent were from non-members and 2 percent were unspecified. Of the 122 respondents, 23 also responded to the later HSRC 2000 survey (discussed in Chapter 9). Because of the way in which the survey was distributed (only by e-mail, and to a selected group) the responses are not necessarily representative of physics graduates in South Africa as a whole. Nevertheless the survey is analysed in detail below.

The format and content of the questionnaire was very similar to the later HSRC 2000 survey questionnaire, with some questions that appeared in the latter omitted, and two questions added. These were:

Questions in the HSRC 2000 survey **not asked** in the Electronic 1999 survey

- Source and phase of financial support if received during studies
- Details of persons reporting, budget, publications, and patents
- Does the SAIP embrace equity?

Questions in the Electronic 1999 survey **not asked** in the HSRC 2000 survey

- Additional comments were solicited regarding physics in South Africa and to the SAIP in particular
- Additional comments relating to this particular survey and how it could be improved for the future

The complete Electronic 1999 survey questionnaire is presented in Appendix 1.

The survey results will be presented under the following headings:

- **Demographic information**
- **Physics background**, including questions relating to teaching and the undergraduate physics curriculum
- **Career**, including skills utilised and membership of professional societies
- **Perceptions regarding the SAIP**

It should be noted that not all respondents answered all questions, so that responses do not, in many cases, add up to 122. Data entry and some basic analysis of the responses had earlier been carried out by Dr N Chetty and co-workers at the SAIP, and this chapter acknowledges that work and builds upon it.

Demographics

- **Age and Gender**

Table 8-1. Gender

Gender	Count	Percent
Female	19	16%
Male	109	84%
Respondents	120	

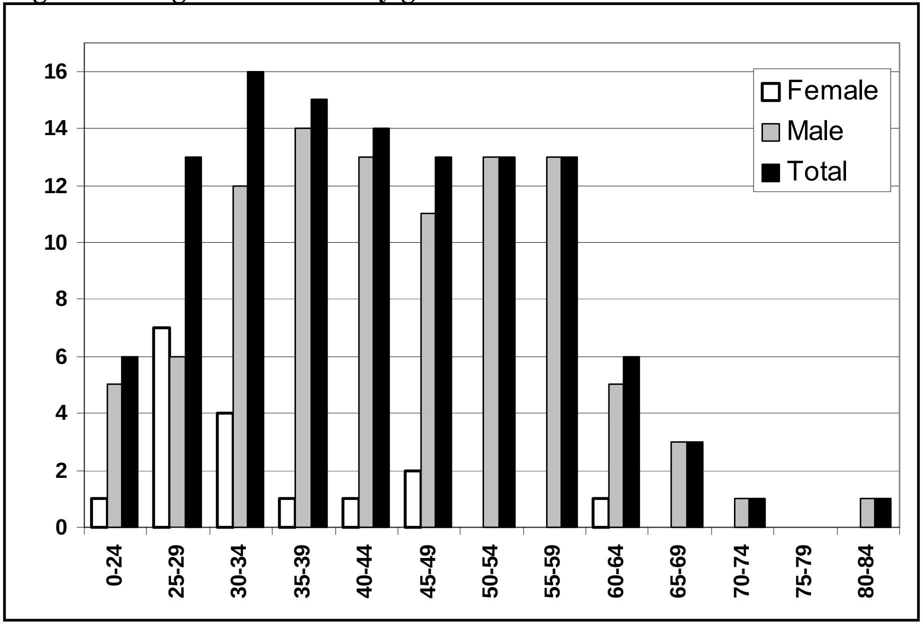
Table 8-2. Age statistics

	Median	Average
Overall	41	42.7
Respondents	114	

Table 8-3. Age distribution by gender

Age	Male	Female	Total	% Female
0-24	5	1	6	17%
25-29	6	7	13	54%
30-34	12	4	16	25%
35-39	14	1	15	7%
40-44	13	1	14	7%
45-49	11	2	13	15%
50-54	13	0	13	0%
55-59	13	0	13	0%
60-64	5	1	6	17%
65-69	3	0	3	0%
70-74	1	0	1	0%
75-79	0	0	0	0%
80-84	1	0	1	0%
Respondents	97	17	114	15%

Figure 8-1. Age distribution by gender



In terms of age, the lowest age was 21 years and the highest age was 83 years. Five out of the 114 respondents (4%) were of retirement age (>64) and actually indicated that they considered themselves retired (Table 8-19 below).

While the sample is male dominated, in Figure 8-1 the age distribution of the two genders can be seen to be significantly different, with young females being predominant. Owing to the small number and percentage of females (15 percent) in the sample, it was felt that **it would not be meaningful to**

further analyse any of the responses (with the exception of remuneration) **in terms of gender breakdown**.

- **Race**

Table 8-4 shows that whites are in the overwhelming majority in this sample of physicists in South Africa. Given the age distribution of the respondents, this is obviously due to educational and career disparities in the previous dispensation, but to what extent is not clear.

Table 8-4. Distribution by race

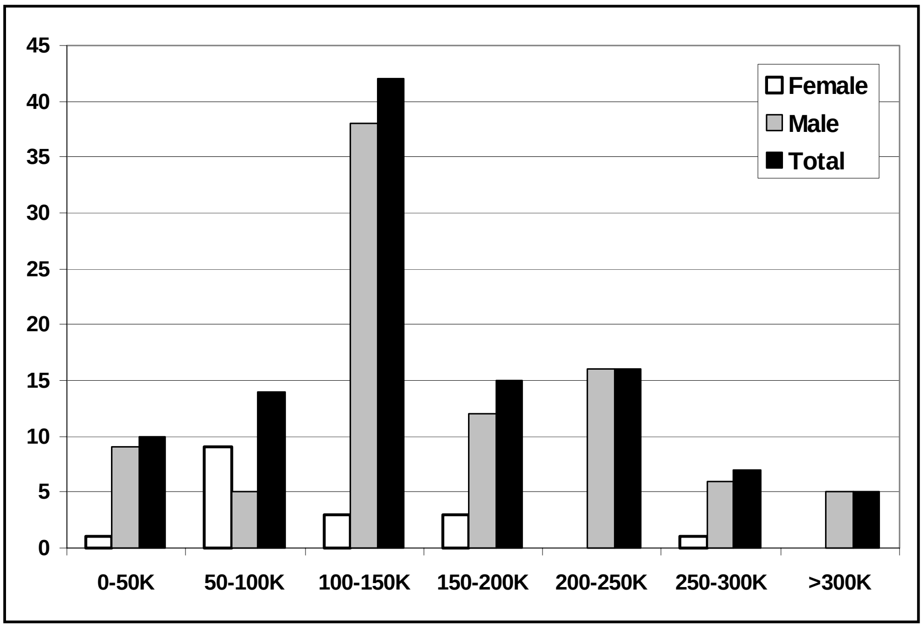
Race	Count	Percent
African	8	7%
Coloured	1	1%
Indian	7	6%
White	93	85%
Total	109	100%
Unknown	13	

Of all the respondents, a significant number (9 percent) indicated in one way or another that they were dissatisfied with being asked which race they belonged to.

- **Remuneration**

Figure 8-2 shows quite clearly an apparent disparity in income distribution between the genders. Nevertheless, this is, to quite an extent, related to the different age distributions between the genders in the respondents (Figure 8-1). Assuming that maximum earning potential is reached sometime after the age of 40, there is not enough data available come to any conclusion as to whether there is a difference in remuneration between the genders in this sample.

Figure 8-2. Remuneration distribution by gender (Rand)



- **Membership of professional societies**

101 (83 percent) of respondents indicated whether they belonged to professional societies or bodies. Apart from the SAIP, the only other societies that appeared frequently to any extent were the SA Council for Natural Scientific Professions (16 occurrences) and the Royal Society of South Africa (12

occurrences). Table 8-5 below shows the number of professional societies or bodies that respondents reported membership of, with the majority belonging to 4 or fewer professional societies. Table 8-6 shows the number of societies that respondents who were members of the SAIP belonged to.

Table 8-5. Membership of professional societies

Number of professional societies by respondent	Count
0	6
1	35
2	31
3	12
4	10
5	2
6	2
7	2
8	1
Total	101

Table 8-6. Membership of SAIP and other professional societies

Membership of SAIP +	Count
0	22
1	21
2	11
3	7
4	2
5	2
6	2
7	1
Total	68

Physics background

- **Level of education (B1)**

Table 8-7 shows the highest level of education attained by the sample. There is a marked difference in the distribution between the genders, with females being equally represented at all degree levels, while males dominate at the MSc and PhD level.

Table 8-7. Highest level of education

	Count	Percent
PhD	83	68%
MSc	25	20%
Hons	12	10%
BSc	2	2%
Respondents	122	

The survey also asked respondents to indicate other degrees, and these responses are summarised in Table 8-8 below.

Table 8-8. Other degrees held

D.Sc	2
M.Sc (Engineering)	1
MS	1
B.Sc (Electrical Eng.)	1
Diploma	2
Total	7

Major subjects offered for the BSc degree are presented Table 8-9. It should be noted that 39 percent of the sample did not provide this information. The majority of respondents offered physics with another major subject (86 percent), and in 51 percent of the cases this other subject was mathematics. Interestingly, the majority of respondents (63 percent) indicated that they had majored in three subjects.

Table 8-9. Major subjects for BSc

Subjects	Count	Percent
Physics	10	14%
Physics, mathematics and applied mathematics	4	5%
Physics and maths (and other)	34	46%
Physics and applied maths (and other)	9	12%
Physics and chemistry	9	12%
Physics and other	8	11%
Respondents	74	100%

- **University attended (B2)**

This information is presented in Table 8-10. 71 percent of Bachelor's degrees were obtained at the first nine universities. Notably Unisa and foreign universities had significantly more higher degrees than Bachelor degrees.

Table 8-10. University attended

University	Bachelor's degree	Highest degree
Natal	13	7
Cape Town	12	11
Port Elizabeth	11	9
Pretoria	9	10
Rhodes	9	7
Stellenbosch	9	7
Orange Free State	8	4
Potchefstroom	7	5
Witwatersrand	7	8
Unisa	3	6
Rand Afrikaans	4	3
Durban-Westville	3	3
Fort Hare	1	1
Medunsa	2	
North West	1	
The North		
Venda		
Zululand		
Western Cape		
Transkei		
Vista		
Foreign (see Table 8-9)	20	37
Respondents	119	118

The breakdown of foreign degrees by country is shown in Table 8-11, with the UK by far the most 'popular' country, followed by the USA and Germany.

Table 8-11. Breakdown of foreign degree by country

Country	Bachelor's degree	Highest degree
UK	5	13
USA		10
Germany	4	4
India	2	2
Belgium	1	2
Canada		2
Bulgaria	1	1
Czechoslovakia	1	1
Kenya	1	1
Russia	1	1
Australia		1
DR Congo	1	
Italy	1	
Romania	1	
Swaziland	1	
Zimbabwe	1	
Total	20	38

Distribution of degrees with respect to time

The detailed distribution of bachelor degrees by university and time interval is presented in Table 8-12 (see next page). Table 8-13 presents the same information for the PhD degree only.

Table 8-13. Distribution of PhD degree by year obtained and university (respondents = 82)

	1945-49	1950-54	1955-59	1960-64	1965-69	1970-74	1975-79	1980-84	1985-89	1990-94	1995-99
Cape Town					1	2			2	1	2
Natal							1			1	1
OFS										2	2
Port Elizabeth						1	1	1		2	1
Potchefstroom					1	1		1			
Pretoria						1			2	1	
RAU					1			1			
Rhodes								1		1	1
Stellenbosch						1		3		2	
Unisa					1	1			1	1	2
Witwatersrand										1	4
Foreign	1	0	3	2	4	5	6	0	1	7	2

No PhDs were reported from the following universities: Durban-Westville, Fort Hare, Medunsa, The North, North West, Transkei, Venda, Vista, Western Cape and Zululand.

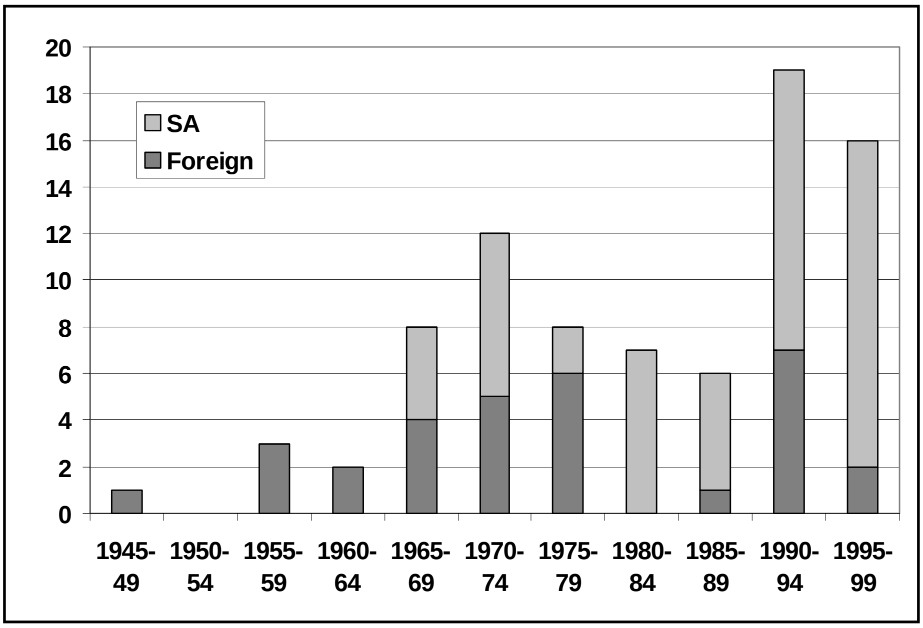
A summary of PhD degrees by period is presented graphically in Figure 8-3 below, and shows that the number of PhD degrees awarded by foreign universities to respondents does not follow a specific trend.

Table 8-12. Distribution of bachelor degree by year obtained and university (respondents =116)

University	1935-44	1945-49	1950-54	1955-59	1960-64	1965-69	1970-74	1975-79	1980-84	1985-89	1990-94	1995-99
Stellenbosch					2	2		3	1			
Pretoria		1		2	2	1			2	1		
Cape Town				1	3	3	1	2	1	2		
Natal			1	1		1	2	1	1		5	1
Potchefstroom				1	1		3	1				1
Witwatersrand	1				2				1	1	2	
OFS			1		2			2	3			
Rhodes				1	2	1	1	1		1		1
Port Elizabeth						1	1	3	1	2	2	1
RAU										3		1
Durban-Westville										1	2	1
Unisa								1			1	
North West												1
Medunsa												1
The North												
Venda												
Fort Hare											1	
Zululand												
Foreign		1			3	3	3	1		2	3	1

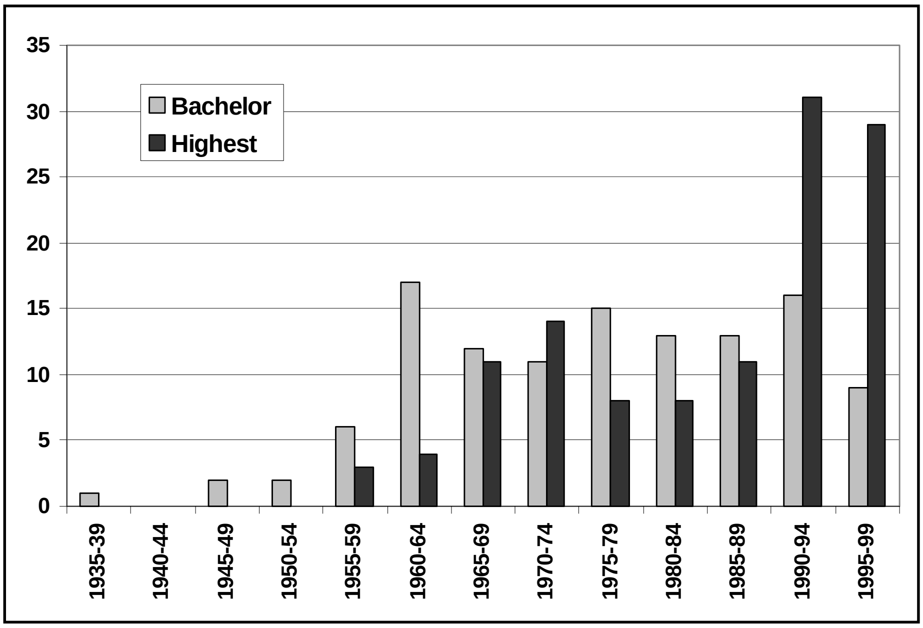
No Bachelor degrees were reported from the following universities:, Transkei, Vista and Western Cape.

Figure 8-3. Distribution of PhD degrees over time (respondents = 82)



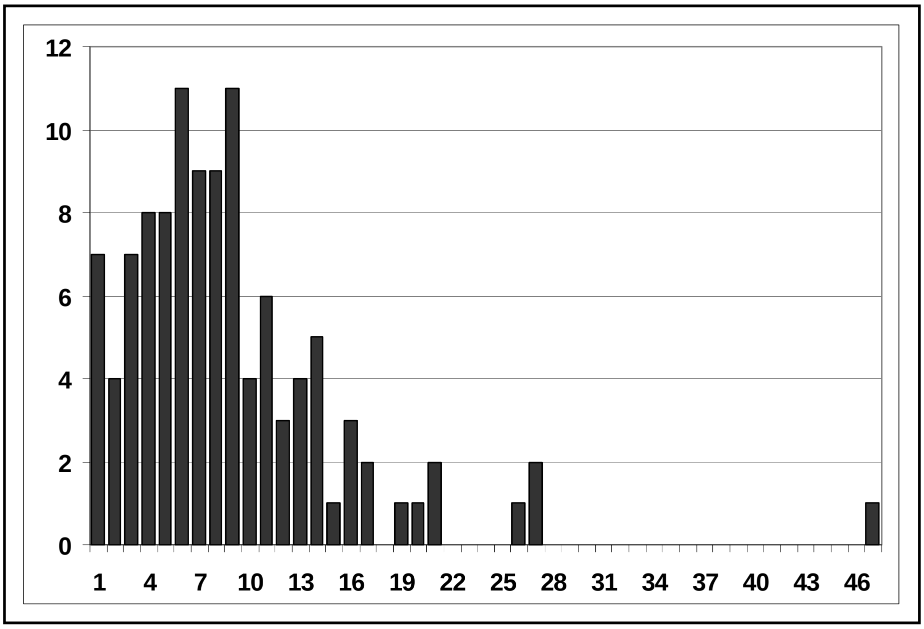
The distribution of the Bachelor and highest degree with respect to time is presented in Figure 8-4. The reason for the relatively small number of bachelor degrees reported in the period 1995-1999 is not known. A possible explanation, that there is a delay in registering graduates with the HSRC after their graduation, was ruled out in a discussion with the HSRC, who stated that universities usually send lists of graduates to the HSRC within weeks, or at worst, a few months, after graduation has taken place.

Figure 8-4. Time distribution of Bachelor and highest degree obtained



The time difference in years between obtaining the bachelor's degree and the highest degree obtained was analysed. There were 110 respondents, and the average interval was calculated to be 8,9 years. The distribution is presented in Figure 8-5. Respondents did include honorary degrees as their highest degree, thus partially accounting for the long 'tail' in the histogram.

Figure 8-5. Time interval between bachelors degree and highest degree



- **Professional self-identification (Question B3)**

There were 15 cases where multiple responses were received. These were adjusted to 'scientific or technical manager' if this was an included response, and otherwise to the first response encountered. The results are presented in Table 8-14. It is interesting to see that while 53 percent of the respondents have job titles relating to the tertiary education sector (Table 8-20) and 51 percent are employed by universities (Table 8-23), only 5 respondents gave their professional self-identification as lecturer or educator. This could be simply because there was no category in question B3 for lecturer or educator (only 'other'), or it could mean that physicists see their physics activities as taking priority over their lecturing activities.

Table 8-14. Occupation (professional self-identification)

Broad category	Percent of total	Detailed category	Number	Percent of total
Physics	85%	Experimental	41	36%
		Applied/Industrial	24	21%
		Computational	13	11%
		Other physicist	10	9%
		Theoretical	9	8%
Management	9%	Scientific or technology manager	10	9%
Education	4%	Lecturer/Educator	5	4%
Other	2%	Information Technology	1	1%
		Business	1	1%
Total	100%		114	100%

- **Physics specialisation (B4)**

Physics specialisation, ranked by primary field of specialisation is presented in Table 8-15. The reader should bear in mind that the question is phrased in such a way that this is not necessarily the present field of specialisation, but only the last one specialised in, which could have been some time in the past. So Table 8-13 unfortunately does not necessarily reflect the current distribution of active workers in the different fields.

Table 8-15. Last physics specialisation (ranked by primary field)

Specialisation	Primary field		Secondary field	
	Number	Percent	Number	Percent
Condensed matter/solid state physics	28	24%	8	7%
Other	19	16%	5	4%
Nuclear physics	13	11%	7	6%
Material science and engineering, metallurgy	11	9%	18	15%
Astronomy, astrophysics, cosmology	9	8%	5	4%
Space physics	6	5%	1	1%
Physics education, tertiary	5	4%	8	7%
Electronics, electrical engineering	5	4%	4	3%
Atomic and molecular physics	4	3%	3	3%
Crystallography	2	2%	2	2%
Optics	3	3%	9	8%
Medical physics	2	2%	1	1%
Atmospheric sciences	2	2%		
Chemical physics	2	2%	1	1%
Physics education, school	1	1%	1	1%
Mathematical physics	1	1%	2	2%
Biophysics	1	1%		
Acoustics	1	1%		
Plasma physics	1	1%	2	2%
Radiological physics			3	3%
Elementary particles & fields, high energy physics			2	2%
Fluid dynamics			2	2%
Low temperature physics			4	3%
None	2	2%	30	25%
Total respondents	118	100%	118	100%

The occurrence of combinations of primary and secondary fields of specialisation was examined. The following combinations occurred with frequency greater than two (Table 8-16).

Table 8-16. Fields of specialisation occurring in combination

Primary field	Secondary field	Frequency of occurrence
Condensed matter	Material science and engineering, metallurgy	11
Condensed matter	Low temperature physics	4

- **Co-supervision of Masters (B5)**

Out of the total of 122 respondents, 39 indicated that they would be prepared to co-supervise a Masters student. When these replies were cross-checked with the respondent's employing body, it was found that of the 39 respondents who had responded positively, 10 were employed in tertiary education and thus only 28 had indicated a 'correct' positive response. 16 indicated that they were not prepared to supervise . Of these one was employed at a tertiary institution.

Nevertheless a number of 28 who were prepared to co-supervise a Masters student is a positive and encouraging response and indicates a commitment to post-graduate physics education by those at the time of the survey not in tertiary education.

- **The undergraduate physics curriculum in South Africa (B6) - preparation for the outside**

In the questionnaire it was stated that 'it had been suggested that South African tertiary institutions do not adequately prepare students for employment outside academia'. In this context, respondents were asked to comment on gaps in the undergraduate curriculum that needed to be filled, as well as curricular material that was perceived to be redundant.

Redundancies in the curriculum

40 respondents gave useable responses to the question, 'what material in the undergraduate curriculum do you perceive to be redundant?'. Some gave multiple responses, but interestingly, more than half of the response i.e. (58 percent) stated that there were no redundancies in the undergraduate physics curriculum. A further 13 percent of the responses felt that the curriculum could be structured better in one way or another so as to eliminate repetition or to fall in line with relevant material being covered in other undergraduate courses. The responses are summarised in Table 8-17.

Table 8-17. Perceived redundancies in the undergraduate physics curriculum

Redundant material	Count	Percentage
None	28	58%
Avoid repetition (among years) (with maths courses), have better correlation, more interesting	6	13%
Learn less but better	2	4%
(Advanced) nuclear/atomic physics	2	4%
Quantum mechanics	2	4%
Thermodynamics	2	4%
Advanced statistical mechanics	1	2%
Some optics	1	2%
Eliminate specialised topics	1	2%
Less emphasis on problem solving	1	2%
Electromagnetism	1	2%
Relativity	1	2%
Total	48	100%

Gaps in the curriculum

74 respondents offered areas where there were perceived gaps in the undergraduate curriculum. Many respondents offered more than one area of deficiency for a total of 126 responses, i.e. an average of 1.7 responses per respondent. These responses are grouped by category in Table 8-18. While gaps relating to physics subjects drew the most responses in a single category (23 percent), 56 percent of the responses indicated that gaps existed related to non-core curriculum education and training. These were industry related skills and exposure, business skills, (written) communications skills, thinking skills and techniques, and project skills. The main gaps in the physics content itself were computational/numerical/modelling techniques, modern physics and applied physics. Related to this was the perception by 8 percent of the respondents that a gap existed with regard to (advanced) computer literacy.

Eight percent of the respondents felt that there were no gaps in the undergraduate physics curriculum, or that it was too full.

Table 8-18. Perceived gap areas in the undergraduate physics curriculum

Category	Percent	Count	Specific gap
Total	100%	126	
Physics	23%	7	Computational physics & numerical modelling
		4	Modern physics
		3	Applied physics
		3	Broader base
		2	Experimental physics
		2	Mathematical physics
		2	Optics/light/lasers
		2	Statistical physics and thermodynamics
		1	Analytical instruments
		1	Classical mechanics
		1	Materials science
		1	Statistics, data analysis
Industry	17%	5	Practical skills in co-operation with industry
		4	Industrial applications
		4	Industry experience
		3	Industry related
		3	Practical work in industry
		1	Industry skills
		1	Visits to industry
Business skills	16%	9	Business
		9	Business management
		2	HR management
Communication	12%	9	Communications skills
		6	Writing & presentation
Computer literacy	8%	10	Computer literacy/ computing skills/computer science
Thinking skills and techniques	7%	3	Problem solving
		2	Critical thinking
		2	Thinking skills
		2	Creativity
Electronics	4%	5	Electronics
Project control	4%	5	Project control/management
Practical	2%	1	Practical skills
		1	Job-related skills
None	2%	3	Specifically stated that there were no gaps
Too full	2%	3	Undergraduate curriculum is too full
General	2%	2	Have science/maths/technology options
Career info	1%	1	Career information
Other	1%	1	Review curriculum constantly

Career

- **Present type of employment (C1.a)**

The employment mode of the respondents is shown in Table 8-19. All answered and none were unemployed. The majority (72 percent) were in full-time employment, 13 percent were students, about half of whom had employment as well, 11 percent were on contract for one year or more and 4 percent were retired.

Table 8-19. Employment mode

Occupation	Count	Percent
Full-time	88	72%
Contract for 1 or more year	13	11%
Student with employment	8	7%
Student	7	6%
Retired	5	4%
Temporary employment less than 1 year	1	1%
Unemployed	0	0%
No response	0	0%
Total	122	100%

- **Job title (C1.b)**

The most frequently occurring job titles were those of professor (all levels, from associate to honorary and emeritus), and lecturer (all levels). Business and the information technology sector were poorly represented, and there were no teachers at all in the survey. The full results are presented in Table 8-20.

Table 8-20. Job Title

Broad area	Job Title	Count
No response (11%)		13
Responses (89%)		109
Tertiary education responses (53%)	Professor (all levels)	30
	Lecturer (all levels)	24
	Dean	2
	Education officer	1
	Rector, vice rector	1
Science and technology responses (43%)	Division/group head	6
	Research officer	6
	Researcher	4
	Technical manager	4
	Director, deputy-director	3
	Geophysicist	3
	Meteorologist	3
	Postdoctoral research fellow	3
	Research assistant	3
	Research scientist	2
	Engineer	1
	Medical physicist	1
	Physicist	1
	Principal research officer	1
	Programme leader	1
	Radiation physicist	1
	Research fellow	1
	Scientist	1
	Systems engineer	1
	Technical consultant	1
Business responses (2%)	Bond analyst	1
	Company director inc. CEO & MD	1
Information technology responses (2%)	Project manager	1
	Regional manager	1

• Unemployment (C2)

According to the data presented in Table 8-21, 10 percent of respondents had experienced unemployment in the five year period from 1995 to 2000. However only 4 respondents specified the period for which they had been unemployed, and the survey did not ask when in the five year period they had been unemployed. The respondents had earlier indicated that none of them were unemployed at the time of the survey (Table 8-19). All this makes it impossible to make any meaningful observation on whether the problem of unemployment for physics graduates is a serious one or not. (By comparison, the overall official unemployment rate in South Africa in 1999 was 23.3 percent, ranging from a low of 4.4 percent for White males, 5.1 percent for White females, about 14 percent for male Indians and Coloureds, 17 percent for female Indians and Coloureds, 24.5 percent for Black/African males, to a high of 35 percent for Black/African females (StatsSA 2001))

Table 8-21. Respondents experiencing unemployment in the past 5 years (1995 -2000)

Category	Count
Not unemployed in past 5 years	101
No response	9
Total unemployed in past 5 years	12
For a period of:	
• Unspecified	8
• 0 to 6 months	0
• 6 months to 1 year	0
• 1 to 2 years	2
• More than two years	2

.

• Length of employment (C3)

The respondents are an experienced group with 41 percent having been in employment more than 20 years, while the rest are more or less equally divided between 0 to 10 years, and 10 to 20 years. The results are very much in line with the age distribution of respondents (see Table 8-3 and Figure 8-1). An obvious conclusion from these data is that those engaged in physics in South Africa are in general on the older side, and that there has been a decrease in the number of graduates entering the field in recent years. Whether this is due to a decline in the number of physics graduates in recent times, or because physics graduates are finding employment outside of physics is not clear from the data available in this survey.

Table 8-22. Total length of employment

Total employment period	Percent	Count
• 0 to 10 years	23%	28
• 10 to 20 years	27%	33
• More than 20 years	41%	50
No response	9%	11
Total	100%	122

• Employing body (C4)

By far the majority of respondents were employed by a university (51 percent), followed by national research facilities (14 percent) and industrial research facilities (10 percent). The results are in line with the sample that was sent the survey (see page 9-1). Some respondents provided multiple responses, hence the total of 135. Details are shown in Table 8-23.

Table 8-23. Employing body

Employing body	Percent	Count
Education - broken down into:		
- University	51%	69
- Technikon	1%	2
- Other tertiary	1%	2
- Secondary	1%	1
Research	1%	1
- Industrial	10%	14
- National facility	14%	19
- Other statutory research organisation	4%	5
No response	5%	7
Mining/ extraction	4%	5
Other	2%	3
Computer Software/ Hardware	1%	2
Financial/ insurance	1%	1
Manufacturing	1%	1
General business	1%	1
Hospital or medical services	1%	1
Utilities	1%	1
Legal services/ consulting		0
Publishing		0
Communications		0
Construction		0
Services, repair or maintenance		0
Total	100%	135

- **Aspects of work (C5)**

Table 8-24. Extent of involvement in various aspects (skill categories) in present work*

Skill Category	Total	no answer or not at all	→	some	→	→	exten-sively
Physics content knowledge overall	122	15	3	64	7	5	28
Physics 1st year level	122	48	9	5	17	14	29
Physics 2nd year level	122	59	15	4	18	7	19
Physics 3rd year level	122	62	17	2	13	9	19
Physics Hons level	122	56	9	5	12	14	26
Physics MSc level	122	65	4	4	14	8	27
Physics PhD level	122	62	1	12	8	7	32
Computer	122	22	7	3	26	31	33
Lab/instrumentation	122	37	10	3	17	26	29
Mathematical	122	34	10	3	16	28	31
Modelling	122	48	6	3	19	19	27
Problem solving	122	32	16	3	30	23	18
Written communication	122	42	22	4	18	18	18
Interpersonal	122	28	4	4	16	28	42
Management	122	27	6	4	12	33	40
Verbal communication	122	21	6	5	19	23	48

*It was assumed that if a response was left blank, that this meant 'not used at all'

Respondents were asked to indicate the extent to which they were engaged in each of the following aspects of work in their present position, using a 5 point scale from ‘not at all’ to ‘extensively’. Those respondents who indicated that they used an aspect, without indicating to what extent, were assumed to use the aspect to ‘some’ degree. The detailed results are presented in Table 8-24.

So as to extract some useful information from Table 8-24, the responses were ranked in two tables. Table 8-25a ranks the aspects of work from ‘most used’ to ‘least used’, while Table 8-25b ranks the aspects of work that are used extensively and quite extensively viz. the rightmost two columns of Table 8-24 (scale values 1 and 2 in the questionnaire), under the heading ‘used a lot’.

Table 8-25a. Skill category ranked by usage

Skill category	Used	Not used
Physics content knowledge overall	88%	12%
Verbal communication	83%	17%
Computer	82%	18%
Management	78%	22%
Interpersonal	77%	23%
Problem solving	74%	26%
Mathematical	72%	28%
Lab/instrumentation	70%	30%
Written communication	66%	34%
Physics 1st year level	61%	39%
Modelling	61%	39%
Physics Hons level	54%	46%
Physics 2nd year level	52%	48%
Physics 3rd year level	49%	51%
Physics PhD level	49%	51%
Physics MSc level	47%	53%

Table 8-25b. Skill category ranked by frequency of usage

Skill category	Used a lot
Management	60%
Verbal communication	58%
Interpersonal	57%
Computer	52%
Mathematical	48%
Lab/instrumentation	45%
Modelling	38%
Physics 1st year level	35%
Problem solving	34%
Physics Hons level	33%
Physics PhD level	32%
Written communication	30%
Physics MSc level	29%
Physics content knowledge overall	27%
Physics 3rd year level	23%
Physics 2nd year level	21%

The skills with the highest usage (greater than 70 percent), irrespective of the extent of usage, are:

- Physics content knowledge overall
- Verbal communication
- Computer
- Management

- Interpersonal
- Problem solving
- Mathematical

The skills that are ranked (greater than 50 percent) at the top of those used a lot i.e. extensively and quite extensively, are:

- Management
- Verbal communication
- Interpersonal
- Computer

From the above it could be concluded that the skills most ‘heavily’ used are not those of the physics curriculum, whether under- or post-graduate, despite many of the respondents being involved in lecturing. A slightly surprising result is that the use of written communication skills does not rate highly in either of the rankings.

- **Evolution of career (C6)**

A total of 110 (90 percent response rate) unstructured responses were received in reply to the request to ‘summarise your employment history briefly’. So as to make the information provided useful without overwhelming the reader with too much detail, each response was placed into a maximum of four career phases. Thereafter all duplicates (i.e. similar career paths) were deleted, giving a broad picture of different careers that respondents have followed. By far the most frequent entries were ‘lecturer’ and ‘lecturer to professor’. The responses are presented in alphabetical order within career phase in Table 8-26.

Table 8-26. Evolution of career

Phase 1 →	Phase 2 →	Phase 3 →	Phase 4
CSIR	Marketing	Product manager	Researcher
Engineer	Professional officer		
Geomagnetist	Student	Research officer	Professor
Geophysicist			
Geophysicist	Head data processing	Manager	
Learner technician	Scientist	Technical manager	
Lecturer			
Lecturer	Engineer	Financial analyst	
Lecturer	Geophysicist		
Lecturer	Medical physicist		
Lecturer	Post-doctoral		
Lecturer	Professor		
Lecturer	Professor	Dean	
Lecturer	Professor	Dean	Vice-principal
Lecturer	Professor	Centre director	
Lecturer	Professor	Vice-rector	
Lecturer	Research officer		
Lecturer	Researcher		
Lecturer	Researcher CSIR	Professor	
Lecturer	Scientist		
Medical physicist			
Medical physicist	Scientist	Director	Programme manager
Meteorologist			
Nuclear reactor physicist	Research officer industry		

… continued

… continued

Table 8-26. Evolution of career

Phase 1 →	Phase 2 →	Phase 3 →	Phase 4
Plant supervisor	Researcher NAC		
Postdoctoral			
Professor			
Professor	Deputy vice-chancellor	Research fellow	
Project leader			
Research			
Research assistant			
Research assistant	Engineer	Physicist	
Research assistant	Lecturer	Professor	Dean
Research assistant	Programmer	Researcher	Head/computer group
Research assistant	Scientist	Deputy director	
Research associate	Lecturer	Professor	
Research fellow	Reader	Professor	
Research fellow	Research scientist		
Research officer			
Research officer	Lecturer		
Research officer	Project leader	Project consultant	
Research officer industry			
Research scientist			
Research scientist	Division/group head		
Research scientist	Lecturer	Professor	
Research scientist CSIR	Research scientist	Research scientist	
Research scientist industry			
Research scientist industry	Facilities manager	Software special	Regional manger software company
Research scientist industry	Lecturer		
Researcher			
Researcher	Deputy head/ group		
Researcher	Lecturer	Professor	
Researcher	Programmer	Software manager	
Researcher	Researcher CSIR	Reservoir engineer	
Researcher CSIR			
Researcher CSIR	Lecturer		
Scientist			
Scientist	Director	Professor	
Scientist	Project manager	Information systems	Company owner
Scientist	Researcher		
Scientist	Technical manager		
Scientist - industry			
Secondary teacher	Lecturer		
Student			
Teacher	Lecturer		
Teacher	Science pro		
Technician	Lab assistant	Researcher	
Technician	Research officer		
Tyre engineer	Lecturer		

Perceptions regarding the South African Institute of Physics (SAIP)

- **Membership of the SAIP**

Table 8-27. Membership status of respondents

Status	Percent	Count
Member of the SAIP	68%	83
Non-members who wish to join	15%	18
Non-members who do not wish to join	12%	15
No response	5%	6
Total	100%	122

Of the 254 respondents, 69 (27 percent) indicated they were members of the SAIP and 178 (70 percent) stated they were not members of the SAIP. Seven (3 percent) choose not to answer.

- **Joining the SAIP - yes or no?**

Although fifteen non-member respondents had indicated they would not like to join the SAIP, 17 respondents gave 18 responses why they would not join. The overwhelming reasons are that there are no perceived benefits in joining the SAIP, and that the respondents lacked information about the SAIP. Both these arguments could be addressed by the SAIP by providing information about the SAIP and its benefits to the physics community regularly. The situation is summarised in Table 8-28.

Table 8-28. Reasons for not joining SAIP

Percent	Count	Reason
100%	18	Total
39%	7	No benefits to me
28%	5	Lack of information about SAIP
6%	1	Not relevant or not of interest
6%	1	No time for membership
6%	1	Scope of the SAIP is too broad
6%	1	Unsure of SAIP executive motives
6%	1	No meaningful support to basic science in SA
6%	1	Conference date clash

- **Perceived benefits of the SAIP (D3)**

Table 8-29. Benefits of SAIP membership

Category	Percent	Count	Specific reason
Total	100%	114	
Contact	37%	40	Contact/interaction/communication
		1	Access to industry
		1	Contact for job opportunities
Events	25%	27	Conference
		1	HOD meeting
Information	20%	11	Informed, information
		10	Newsletter (electronic)
		1	Kept up to date
		1	Surveys
Negative perceptions	10%	6	No benefits
		5	Not aware of benefits
Other	9%	8	Represents physicists
		1	Professional status
		1	Discounts

More than 61 percent of the respondents (75 in total) provided 114 responses to the question, 'what benefits of SAIP membership do you regard as important?' The benefits regarded as important have been binned and grouped by five categories and are shown in Table 8-29. The most significant benefit is perceived to be contact (with other physicists) (37 percent), followed by events held by the SAIP (25 percent), and various aspects of information provided (20 percent) and. Ten percent of responses were negative in that respondents perceived there to be no benefits to SAIP membership, or were not aware of them.

- **Additional features/activities SAIP could provide to members (D4)**

53 respondents (43 percent of the total) provided a total of 70 responses to the question, 'what additional features / activities SAIP could provide to members?', thereby demonstrating that there was a high degree of interest in the topic. Most frequent were suggestions relating to the promotion of physics by the SAIP. This was followed by requests to provide information on employment opportunities. Suggestions related to the dissemination of information followed. The full range of categories and summarised responses is presented in Table 8-30. Only one respondent felt that the SAIP should be involved at schools, but this could be because the question was not about what the role of the SAIP was in general terms, but rather, what it could provide for its members.

Table 8-30. Additional benefits and features the SAIP could provide

Category	Percent	Count	Specific reason
Total	100%	70	
Promote and represent physics	30%	4	Co-operation with other physics and scientific bodies and with industry / government. Lead in S&T and policy
		4	Promote status of physics as a career - get more final years
		3	Promote more physics more widely
		3	Links to international physics community (including for funding)
		2	Market physics, do market research
		2	High profile competitions for students /young researchers. Prize is to work with experts
		1	Publicise successes - successful careers
		1	Promote skills of physicists to industry
		1	Support for research in teaching physics
Employment	16%	10	Info about career / job opportunities on database or via newsletter
		1	List of employers of physics graduates
Information dissemination	14%	5	More or regular info on physics (including e-mail, newsletters, or the Internet)
		2	Contacts between members or a member database (with available resources, industrial contacts)
		1	Journal still important
		1	Publicise website - keep it up to date
		1	Publish a Year Book, with a summary of members' activities
Conferences/ workshops	11%	3	More and specialised working groups / colloquia
		2	Workshops on applied aspects of physics
		1	Student participation at conferences
		1	Talks at local centres, lab/plant visits
		1	Wine tasting expeditions

… continued

… continued

Table 8-30. Additional benefits and features the SAIP could provide

Category	Percent	Count	Specific reason
Widen approach	10%	5	Promote greater involvement of physics in industry. Have contact with industry problems and challenges
		1	Stimulation of career development accessed through a physics education outside the traditional academic / research focus
		1	Promote industry interest in physics (sponsorships)
Financial	10%	3	Discounts on academic books/journal
		2	Discounts on attendance at local & international conferences
		1	Free workshops or provide financial assistance
		1	Have a paid Secretary/Treasurer
Nothing	7%	5	Unknown/nothing/fine…
Schools	1%	1	Involvement at high schools

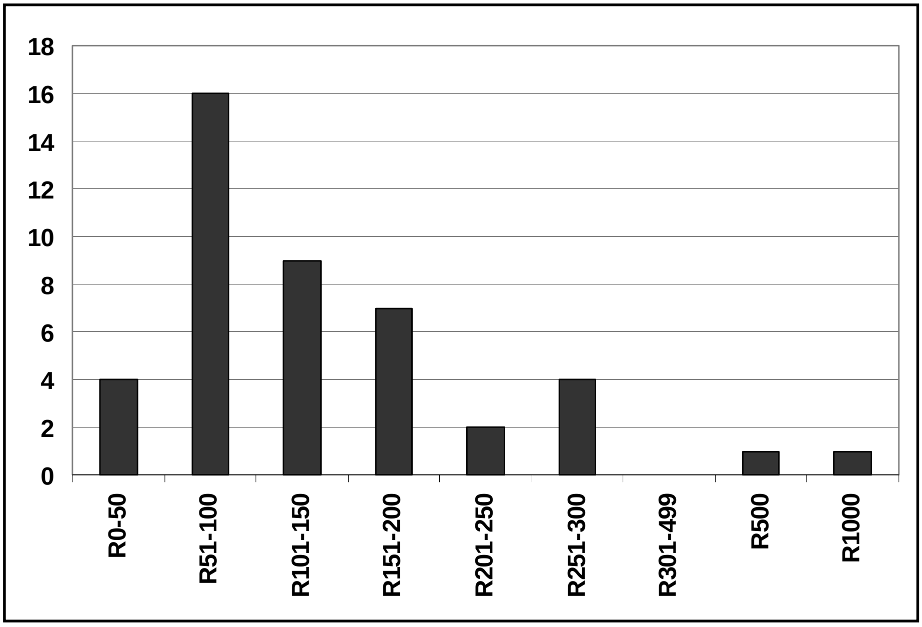
- **Should additional activities be available at an extra cost? (D5.a)**

There were 34 responses (28 percent of respondents) to this question. 24 of these responses indicated that they would like to have additional activities, at an extra cost, there were 7 that did not want additional activities at a cost, and 3 were uncertain, but positively so. It appears that the SAIP could consider this action as it was acceptable to the majority of those responding.

- **What is the acceptable level of SAIP membership dues? (D5.b)**

There were 54 responses. Bearing in mind that the level of membership dues was R85 (per annum) at the time of the survey, a histogram of responses is shown in Figure 8-6. 13 were satisfied with the (then) present level and 2 wanted the dues kept as low as possible. These 15 responses are included in the histogram, taking ‘low’ to mean R0 to R50. 10 respondents indicated that they didn’t know what level would of dues would be acceptable. The results indicate that the SAIP could consider increasing its annual dues into the R100 to R150 bracket (in 1999 rands, of course) should this be necessary.

Figure 8-6. Acceptable SAIP membership dues



- **Suggestions for making the SAIP more relevant to the wider physics community. (D6)**

It was stated that the SAIP has a relatively small fraction of members employed outside of academia, and the question then went on to ask: 'Do you have any suggestions as to how the SAIP can become more relevant to the wider group of physics graduates?' 56 respondents replied to this question, a few providing multiple suggestions. The suggestion of making SAIP conferences or seminars of wider appeal by having more general or industry related topics, and by inviting speakers from industry was the most frequent (11 percent of all the responses). Advertising to employers was the second most frequent (9 percent of all the responses). The responses are summarised and categorised in Table 8-31.

Table 8-31. Suggestions for making the SAIP more relevant to the wider physics community

Category	Percent	Count	Specific reason
Total	100%	64	
Suggested actions	38%	4	Use/expand applied physics interest group
		3	Show where physics can add value in new SA/ make physics more relevant/popularise physics
		3	Provide a (value for money) service to non-academics
		2	Train students for (the possibility of) an industrial career
		2	Learn from the American Physical Society, which has more than half its members outside academia
		2	Encourage non-academics to join
		1	Communicate/collaborate/closer ties/liaison with industry
		1	Stronger emphasis on industrial and environmental physics
		1	Provide mechanisms for inter-institutional collaboration and cross-feeding
		1	Use students to solve industrial problems/internships
		1	Facilitate joint supervision of masters and PhD theses
		1	Joint projects between academics and industry
		1	Convince employers as to the importance of SAIP membership for their physicists
		1	Help scientists outside academia to publish
Other	19%	4	No suggestions
		3	Yes (have suggestions), but not provided
		2	Do not know
		1	Be a leader, be pro-active
		1	Physics graduates don't work in physics therefore SAIP not relevant to them
		1	Why does the SAIP want to become more relevant?
Publicity	16%	6	Advertise/send prospectus to major employers
		2	Promote SAIP to students (from 1st year)
		1	Publicise SAIP outside academia and to new graduates
		1	SAIP should be visible at gatherings such as Scifest etc.
Conferences/work-shops/seminars	16%	7	Conferences/Seminars of more general, applied and industry interest/relevant topics. Have industry speakers/representatives (on Organising Committee)
		2	Layman level specialist presentations
		1	Provide continuing education
Communication	9%	1	Use Newsletter
		1	Provide relevant information (including. international)
		1	E-mail newsletter to industry/everyone whether or not members
		1	Maintain contact with previous higher degree students
		1	Reach more non-academic research institutions
		1	Free quarterly journal with list of abstracts in member's field of interest
Secondary education	3%	2	Involve physical science teachers/schools in SAIP

• Additional comments

Additional comments relating to physics in South Africa and to the SAIP in particular (E1)

45 percent of the respondents (55 in all) provided responses to the above request, indicating that there was significant interest in further contributing information to the purpose of the survey, viz. 'to investigate the present status of physics in South Africa with a view to assessing future directions in our discipline and its applications'. The responses have been summarised and a presented by broad category in Table 8-32. To a large extent the points raised have been raised in previous sections of this questionnaire. The main point made is that physics should make itself more relevant to industry and to South African society at large and that universities should review their curricula with a view to supporting this change. Respondents felt that the SAIP should take a greater role in promoting physics in a number of ways. Funding for research, improving the quality of science teaching at schools and the greater involvement of physicists and the SAIP with secondary school level activities were also raised.

Table 8-32. Additional comments regarding physics in SA and the SAIP

Category	Count	Count	Response
General	16	6	None or no comment
		2	Adapt to the needs of SA, look for innovation in solutions of the needs of our environment
		2	Find out how physicists are doing in other countries (where the public purse is being tightened)
		1	Need to engage ourselves on all spheres that involve physics, meaning government, industry and academia
		1	Need to improve the standing of our scientists in the eyes of those outside the sciences
		1	Use the opportunity of SALT to market and expand physics (awareness)
		1	Need bigger budgets to be internationally competitive in research.
		1	Nuclear Science, excluding the AEC, is hopelessly underfunded
		1	The strong affirmative action drive of the NRF will have a detrimental affect on physics in SA
SAIP	16	3	SAIP not industry orientated - remedy this. Physicists are as good as engineers
		3	Market physics and the SAIP. Be at exhibitions. Use Web pages as does the IOP
		1	SAIP should get involved in public issues - press releases
		1	SAIP should seek more sponsorship aggressively and more industrial partnerships
		1	SAIP should consider a campaign similar to APS in US Congress (for funding)
		1	Strengthen the SAIP for survival in 21st century
		1	SAIP is not actively recruiting
		1	Don't know much about SAIP
		1	Have more workshops, meetings, where the application of physics in industry is addressed
		1	There should be greater opportunities for attending talks outside of one's own speciality at the SAIP conference
		1	Need the SAIP for mutual progress and encouragement
		1	Make English the language medium for the SAIP (visitors don't understand other SA languages)

… continued

… continued

Table 8-32. Additional comments regarding physics in SA and the SAIP

Category	Count	Count	Response
University	16	6	Address declining numbers of physics students
		2	Physicists should be trained and be involved in pursuits that society considers more useful
		2	Train students for industry
		1	The role of the university is not to train students for the workplace
		1	Much needs to be done to revive physics as a career
		1	Fundamental change is needed, get students involved in defining this
		1	Need better MSc and PhD courses with Graduate school lecture component approach
		1	Info exchange between different physics departments
		1	Invite students to national facilities to see real applications
Industry	7	3	Make employers/industry aware of what physics graduates have to offer.
		1	Share knowledge and research facilities with industry
		1	More applied physics required
		1	Need to press for industrial science research funding
		1	Industry is too raw material focused to employ physicists as industrial physicists. Our physicists are not pro-active enough to move into industrial physics.
School	6	2	Improve the quality of physics teachers and science teaching standards
		1	SAIP should get involved in schools, raise money for sending candidates to the IphO (Olympiad)
		1	Get involved in curriculum 2005 (i.e. advise on school curricula)
		1	Physicists need to be much more involved with schools and school teachers
		1	SAIP and NRF should creating an awareness of science and technology at school level
Career	4	2	Provide much more info re job opportunities to students
		1	Students perceive few physics job opportunities - SAIP could publish job/career info for physicists
		1	Lack of physics job opportunities in SA

Additional comments relating to this particular survey and how it could be improved for the future. (E2)

33 respondents (27 percent of the total) answered this question, with some respondents providing multiple responses. The responses have been summarised and grouped by broad category and are presented in Table 8-33. There were no significant negative comments and respondents generally felt that a survey should be conducted regularly, and should be used to advance the interests of physics in South Africa. In general, there was a feeling that more, rather than less, information could be obtained, and from a broader base of respondents. Quite a few respondents suggested making the survey available on the Web, and also that the information should be maintained in a database.

Table 8-33. Comments relating to the survey itself

Category	Count	Count	Response
General	17	7	Generally positive comments
		5	None, no comment
		3	Circulate results broadly, use them (to encourage students to go into physics and to convince them that there are broad career options)
		1	Run a workshop on how to make physics relevant again
		1	Not clear on the purpose of the survey
Specific improvements	14	5	Put it on the Web (have a database)
		3	Update it and/or run it periodically
		1	Shorten it
		1	Ask a little less personal information
		1	The 1 to 5 scale where 1 is highest could confuse respondents.
		1	Need full names, not just name and surname for a database
		1	Be clearer about degrees obtained overseas
		1	Section D question 5 was unclear
Suggested questions	6	2	Ask for future needs, requirements, wish lists
		1	Involve more students and more physicists to get a better view
		1	Have a survey that is specifically for physics students. Future career plans, vacation jobs, research presentations etc would be more relevant to students
		1	Ask those with degrees in physics where they are now, what use their physics has been or is to them, what training they would have liked to have had at university, and whether they would do it again
		1	The issue of employment within SA, within Africa and overseas should be addressed
Physics Departments	3	2	Get information on the new programme structure for higher education from physics departments.
		1	Ask a lot of detailed questions on the status of individual university physics programmes such as: • Numbers of students by level • Have courses changed significantly over the last three years • What new programmes are being instituted • Which undergraduate degrees besides the usual BSc is physics involved in • What is the current status of research in your department • How is credit given to research in your department • Is salary coupled to performance in any way?

Reference

StatsSA. 2001. South Africa in transition. StatsSA.

The HSRC 2000 Survey

In the second half of 2000 the SAIP commissioned the Human Sciences Research Council (HSRC) to execute a targeted mail-out of a survey questionnaire to a sample of South African physics graduates on the HSRC 'Register of Graduates'. The sample consisted of all those who had a BSc(Hons) degree in physics and a randomly chosen sample of about half of those who had completed the 3rd year in undergraduate physics. The questionnaire itself had been drawn up by the SAIP and was based on the Electronic 1999 survey questionnaire (see Chapter 8) with some additional questions. The HSRC 2000 survey questionnaire (appendix 2) consisted of 40 questions in four subject areas:

- **Demographic information**
- **Physics background**, including questions relating to teaching and the undergraduate physics curriculum
- **Career**, including skills utilised, responsibilities, papers published, patents and membership of professional societies
- **Perceptions regarding the SAIP**

A total of 1614 questionnaires were mailed out, and 258 responses were received. Of these, four were returned blank for the following reasons: 1 deceased, 1 too old and 2 because the questionnaire was not provided in Afrikaans. Thus **the sample size is 254**, a response rate of 15,7%. It should be noted that not all respondents answered all questions, so that responses do not, in many cases, add up to 254.

This chapter will analyse the responses received in some detail.

Demographics

- **Age and Gender**

Table 9-1. Gender

Gender	Count	Percent
Female	48	20%
Male	197	80%
Respondents	245	

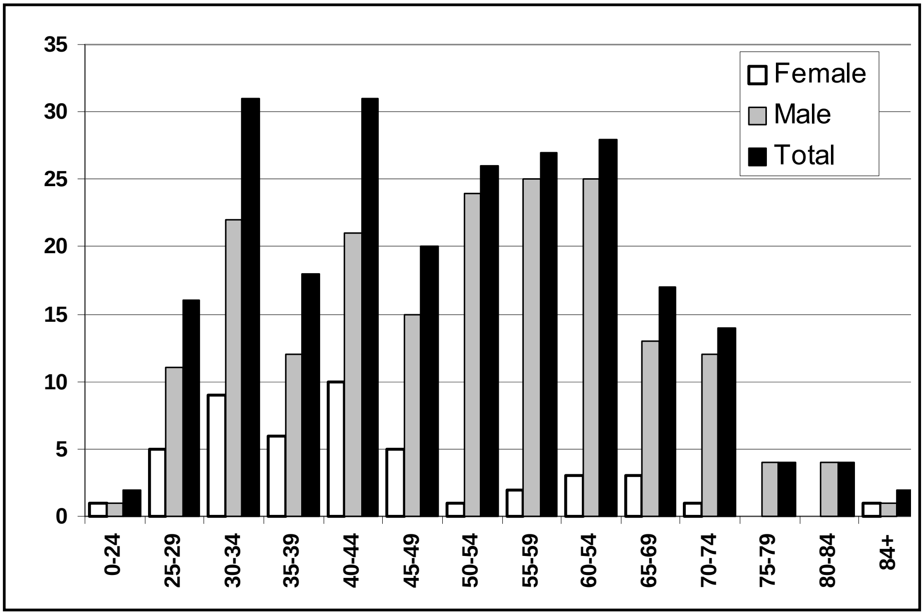
Table 9-2. Age statistics

Gender	Median	Average
Female	40	42.6
Male	53	51.4
Overall	49	49.2

Table 9-3. Age distribution by gender

Age	Female	Male	Total	% Female
0-24	1	1	2	50
25-29	5	11	16	31
30-34	9	22	31	29
35-39	6	12	18	33
40-44	10	21	31	32
45-49	5	15	20	25
50-54	1	24	26	4
55-59	2	25	27	7
60-64	3	25	28	11
65-69	3	13	17	18
70-74	1	12	14	7
75-79	0	4	4	0
80-84	0	4	4	0
84+	1	1	2	50
Respondents	47	190	240	0.25

Figure 9-1. Age distribution by gender



In terms of age, the lowest age was 23 years and the highest age was 98 years. 41 out of the 240 respondents (17%) were of retirement age (>64).

Very noteworthy is the trend break at age 50 and above, where the percentage of females changes abruptly from less than 10% above age 50, to about 30% or more below age 50. The explanation for this is to be found in the change of social attitudes after the Second World War, from the 1950s on (the baby-boomers) and in the post-Woodstock (1969 - the high point of youth counterculture) generation of female liberation attitudes. Graduates born after 1950 or entering tertiary education from 1969 onwards would have certainly had a different attitude to a career than did their predecessors. This is borne out by the data in Table 9-3 and Figure 9-1.

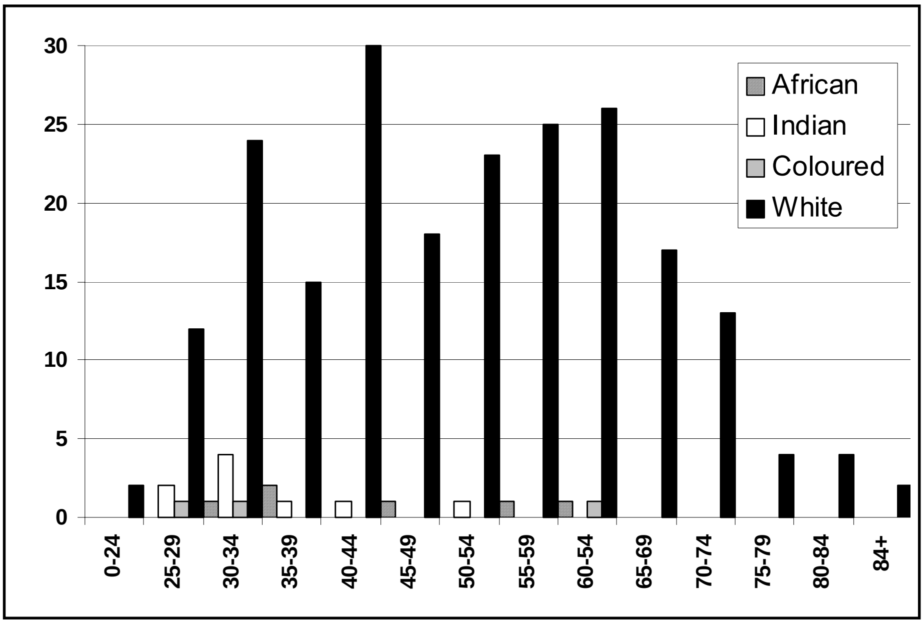
- **Age and Race**

Table 9-4. Distribution by race, age and gender

Age	African	percent female	Indian	percent female	Coloured	percent female	White	percent female
0-24	0		0		0		2	50
25-29	0		2	100	1	0	12	25
30-34	1	0	4	25	1	0	24	33
35-39	2	0	1	0	0		15	40
40-44	0		1	0	0		30	33
45-49	1	0	0		0		18	28
50-54	0		1	n/a	0		23	4
55-59	1	0	0		0		25	8
60-64	1	0	0		1	0	26	12
65-69	0		0		0		17	18
70-74	0		0		0		13	8
75-79	0		0		0		4	0
80-84	0		0		0		4	0
84+	0		0		0		2	50
No age	2		0		0		6	17
Responses	8		9		3		221	45

Of the 241 respondents who specified which racial group they belonged to, 3.3 percent were African, 3.7 percent were Indian, 1.2 percent were Coloured and 91.7 percent were White.

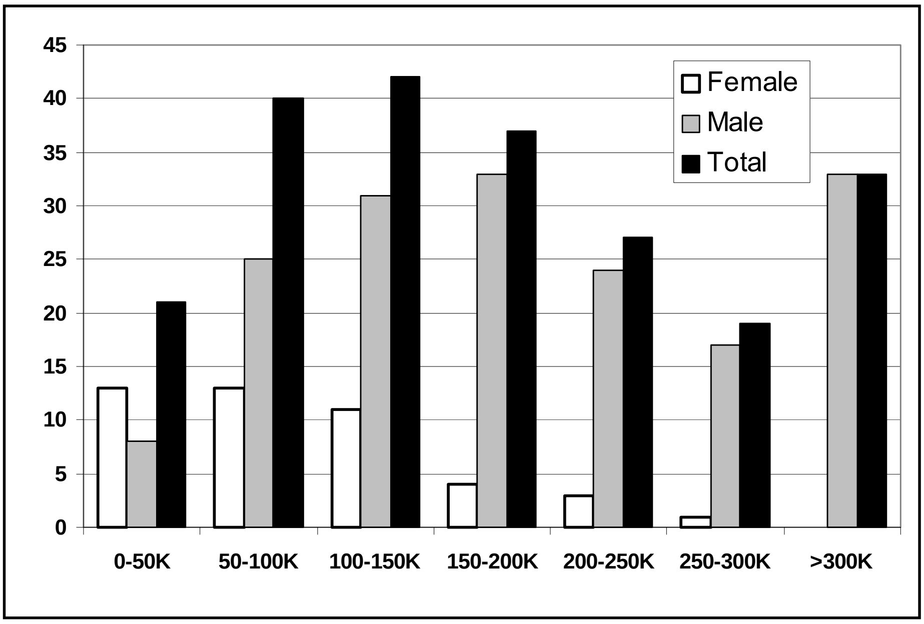
Figure 9-2. Age distribution by race



- **Remuneration**

Figure 9-3a shows quite clearly the disparity in income distribution between the genders. Please refer to Figure 9-3b for disaggregation of remuneration into retired persons and others.

Figure 9-3a. Remuneration distribution by gender (Rand)



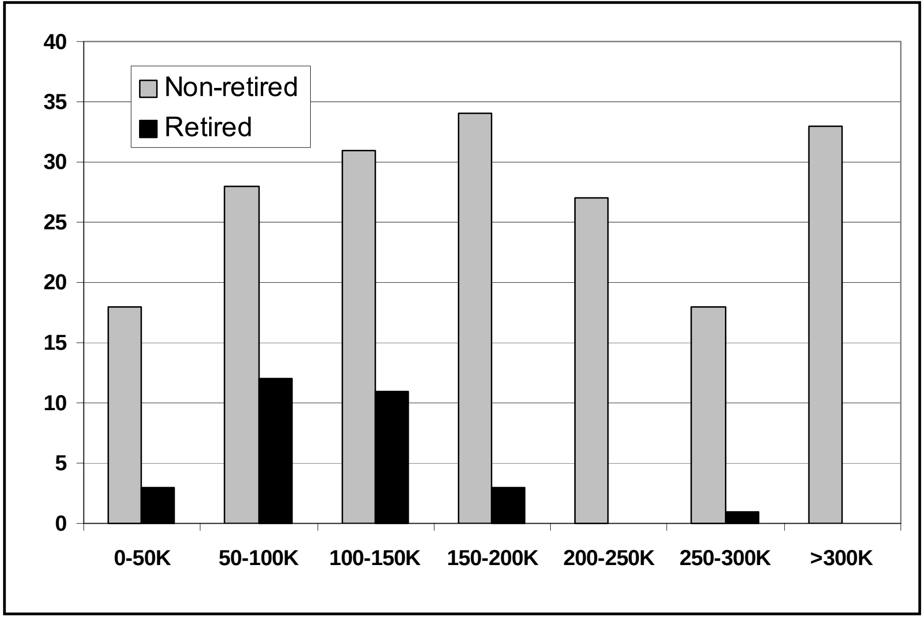
- **Retired physics graduates**

As the proportion of those indicating that they are retired is large, these statistics are presented here so that they may be borne in mind when reviewing the results presented in this Chapter. Fifty-one out of 252 respondents indicated that they were retired i.e. **20 percent are retired persons.** The age distribution is shown in Table 9-4, together with the overall number in the age group for comparison.

Table 9-4. Age distribution of retirees

Age	Total retired	Total in age group
50-54	1	26
55-59	2	27
60-64	12	28
65-69	13	17
70-74	10	14
75-79	4	4
80-84	2	4
84+	1	2
No age	6	n/a
Respondents	51	n/a

Figure 9-3b. Remuneration distribution by non-retired and retired (Rand)
Respondents = 219



Physics background

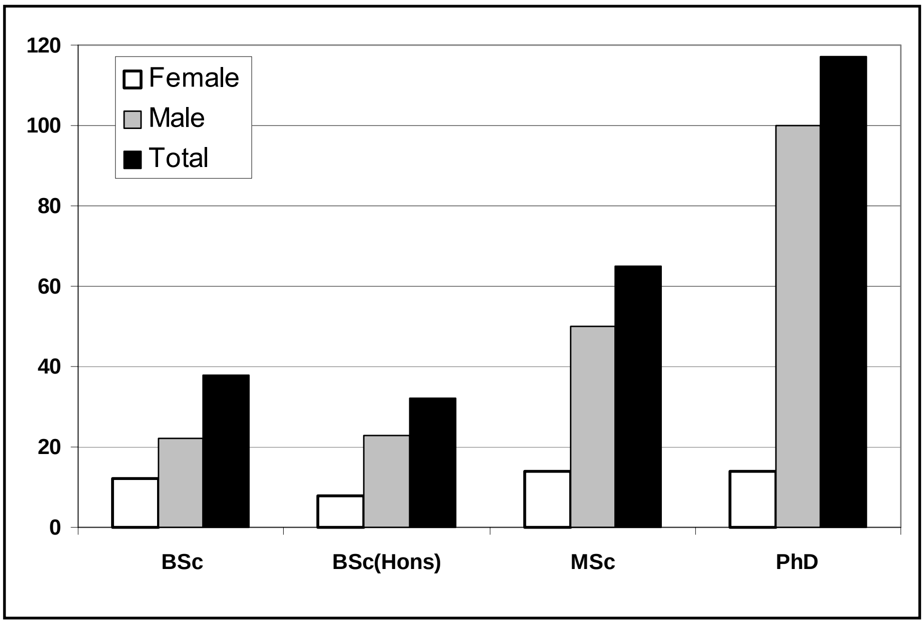
- **Level of education (B1)**

Table 9-5 and Figure 9-4 show the highest level of education attained by the sample. There is a marked difference in the distribution between the genders, with females being equally represented at all degree levels, while males dominate at the MSc and PhD level.

Table 9-5. Highest level of education

	Female	Male	Total
PhD	14	100	117
MSc	14	50	65
Hons	8	23	32
BSc	12	22	38
Other	0	1	1
Respondents	48	196	253

Figure 9-4. Highest level of education by degree



The survey also asked respondents to indicate other degrees, and these responses are summarised in Table 9-6 below.

Table 9-6. Other degrees held

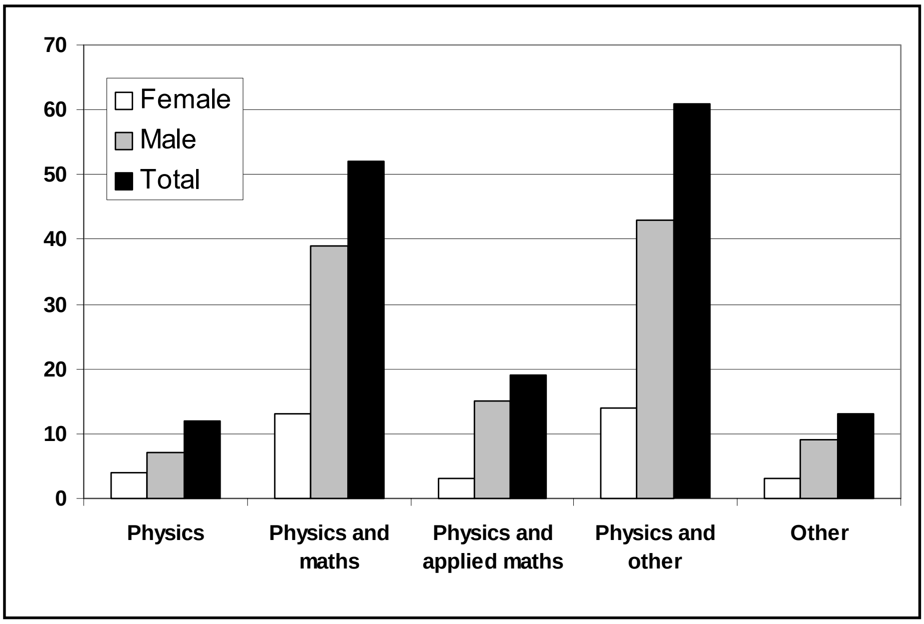
D.Sc	4
D.Ed	1
Dr-Ing	1
Masters	6
MBChB	2
Honours	1
Bachelor	1
Diploma	5
other	9
Total	30

Major subjects offered for the BSc degree are presented Table 9-7 and Figure 9-5. It should be noted that 37 percent of the sample did not provide this information. The majority of respondents offered physics with another major subject (84 percent), and in 33 percent of the cases this other subject was mathematics. There is no gender difference in the distribution of subjects offered.

Table 9-7. Major subjects for BSc

Subjects	Female	Male	Total	Percent of total
Physics	4	7	12	7.6%
Physics and maths	13	39	52	33.1%
Physics and applied maths	3	15	19	12.1%
Physics and other	14	43	61	38.9%
Other	3	9	13	8.3%
Respondents	37	113	157	

Figure 9-5. Major subjects for BSc



- **University attended (B2)**

This information is presented in Table 9-8. 80 percent of Bachelor's degrees were obtained at the first eight universities. Notably Unisa and foreign universities had significantly more higher degrees than Bachelor degrees.

Table 9-8. University attended

University	Bachelor's degree	Highest degree
Stellenbosch	54	40
Pretoria	28	24
Cape Town	27	23
Natal	21	18
Potchefstroom	19	18
Witwatersrand	18	20
Orange Free State	18	15
Rhodes	16	6
Port Elizabeth	11	7
Rand Afrikaans	8	7
Durban-Westville	6	3
Unisa	4	11
The North	3	0
Fort Hare	1	1
Venda	1	0
Zululand	1	0
Western Cape	0	2
Medunsa	0	1
North West	0	1
Transkei	0	0
Vista	0	0
Foreign (see Table 9-9)	14	38
Respondents	250	235

The breakdown of foreign degrees by country is shown in Table 9-9, with the UK by far the most ‘popular’ country.

Table 9-9. Breakdown of foreign degree by country

Country	Bachelor’s degree	Highest degree
UK	8	24
USA	2	8
Germany		3
Denmark	1	1
India	1	1
Australia	1	
Belgium		1
Zimbabwe	1	
Total	14	38

Distribution of degrees with respect to time

The detailed distribution of bachelor degrees by university and time interval is presented in Table 9-10 (see next page). Table 9-11 presents the same information for the PhD degree only.

Table 9-11. Distribution of PhD degree by year obtained and university (respondents = 112)

	1945-49	1950-54	1955-59	1960-64	1965-69	1970-74	1975-79	1980-84	1985-89	1990-94	1995-99
Cape Town			1			2		2	1	4	1
Durban-Westville											1
OFS					1		1		1	1	1
Natal					1		2		2		2
Port Elizabeth							2	1			2
Potchefstroom					1		1	4	1		2
Pretoria	1	1	1	1	1				3		
RAU								1			
Rhodes								1			1
Stellenbosch		1			1	3	1	3	1	4	3
Unisa						2			1		3
Witwatersrand				1				2	1	1	3
Foreign	1	2	7	6	3	2	2	2	1	3	3

No PhDs were reported from the following universities: Fort Hare, Medunsa, The North, North West, Transkei, Venda, Vista, Western Cape and Zululand.

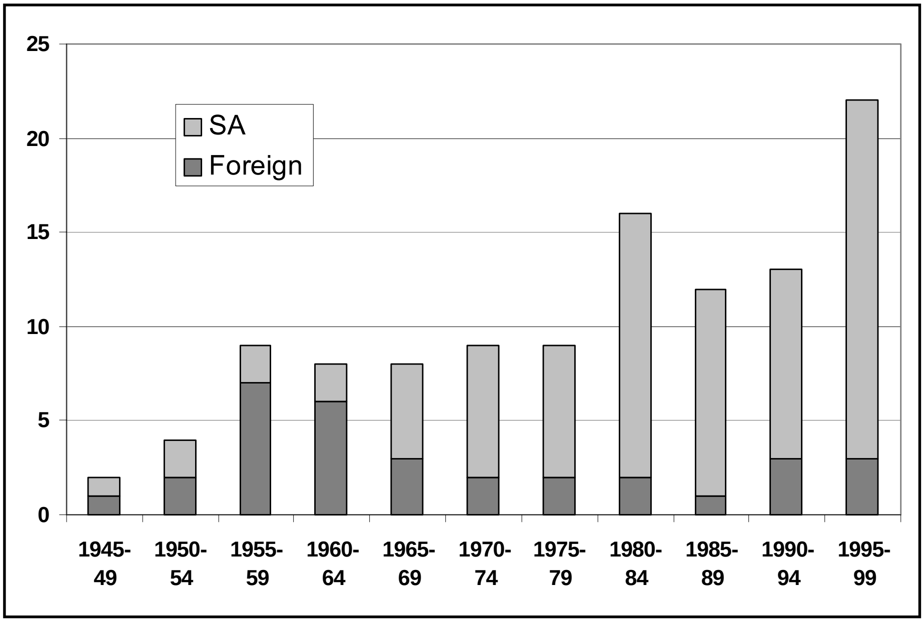
A summary of PhD degrees by period is presented graphically in Figure 9-6 below, and shows that the number of PhD degrees awarded by foreign universities has dropped after reaching a peak in the period 1955-1965

Table 9-10. Distribution of bachelor degree by year obtained and university (respondents = 246)

	1920-24	1925-29	1930-34	1935-39	1940-44	1945-49	1950-54	1955-59	1960-64	1965-69	1970-74	1975-79	1980-84	1985-89	1990-94	1995-99
Stellenbosch		1		1	3	2	3	6	6	5	3	7	6	3	6	2
Pretoria					1	4	2	3	2	2	4	3	3	1	2	
Cape Town	1				1	1	1	2	8	3	1	2	2	1	1	2
Natal					2			4	3	4	1	3	3	1		
Potchefstroom						2		2	1	4	3	3		2	2	
Witwatersrand						1	2		1	1	1	3	3	2	4	
OFS						1		2	2	1	1	5	2	2	1	1
Rhodes							2	6	2		3		1	1	1	
Port Elizabeth										1	2	1	3	2	2	
RAU												3	1	1	1	2
Durban-Westville														3	3	
Unisa													1		1	
The North											1			1	1	
Venda																1
Fort Hare															1	
Zululand												1				
Foreign				1		2	3		2	2	1		1		1	1

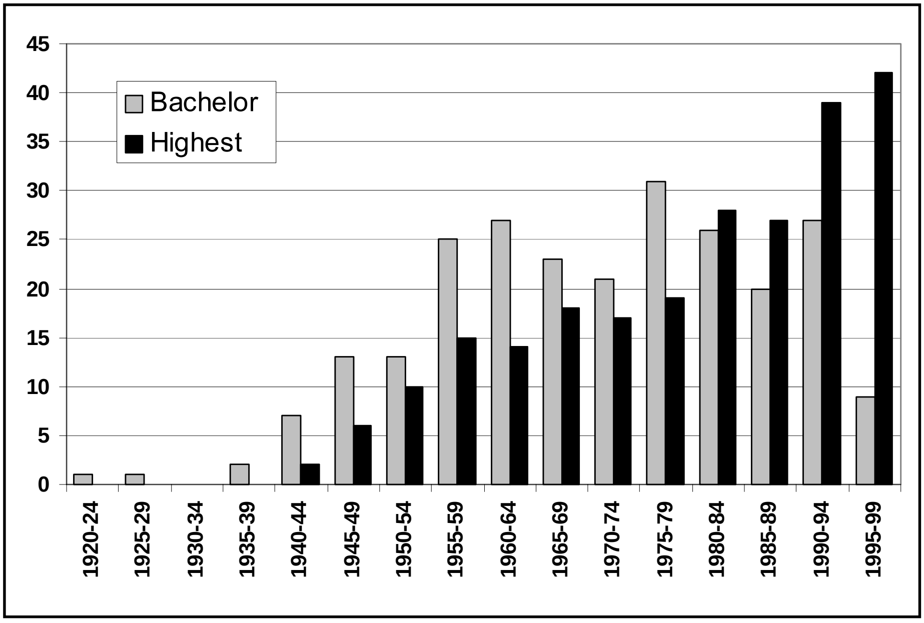
No Bachelor degrees were reported from the following universities: Western Cape, Medunsa, North West, Transkei and Vista.

Figure 9-6. Distribution of PhD degrees over time (respondents = 80)



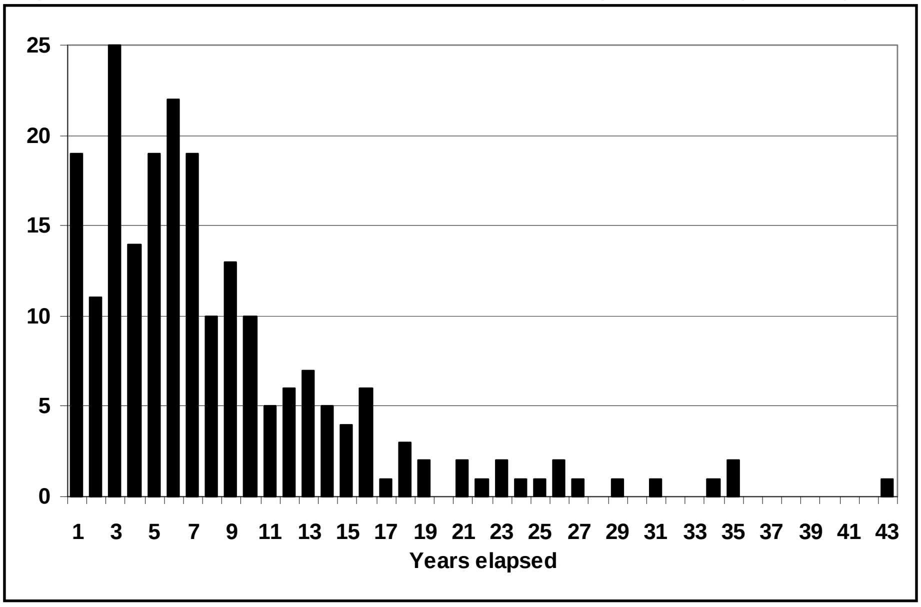
The distribution of the Bachelor and highest degree with respect to time is presented in Figure 9-7. The reason for the relatively small number of bachelor degrees reported in the period 1995-1999 is not known. In a discussion with the HSRC, delays in registering graduates with the HSRC after their graduation was ruled out as a cause, as graduates are registered within weeks or at the latest, months, after graduating. The reason for this small number may bear further investigation, as it could possibly be that the apparently 'missing' physics graduates are pursuing careers outside of physics, and did not feel that the survey applied to them.

Figure 9-6. Time distribution of Bachelor and highest degree obtained



The time difference in years between obtaining the bachelor's degree and the highest degree obtained was analysed. There were 217 respondents, and the average interval was calculated to be 8,4 years. The distribution is presented in Figure 9-8. Respondents did include honorary degrees as their highest degree, thus partially accounting for the long 'tail' in the histogram.

Figure 9-8. Time interval between bachelors degree and highest degree



- **Professional self-identification (Question B3)**

There were 15 cases where multiple responses were received. These were adjusted to 'scientific or technical manager' if this was an included response, and otherwise to the first response encountered. The results are presented in Table 9-12.

Table 9-12. Occupation (professional self-identification)

Broad category	Percent of total	Detailed category	Number	Percent of total
Physics	46	Applied/Industrial	25	11
		Experimental	41	17
		Theoretical	18	8
		Other physicist	18	8
		Computational	7	3
Education	19	Lecturer/Teacher/Educator	45	19
Management	13	Scientific or technology manager	30	13
		Other manager	2	1
Other	22	Professional	23	10
		Other	16	7
		Information Technology	7	3
		Business	6	3
		Total respondents	238	

If the assumption is made that those who responded under the category 'Education' are to some extent involved in the teaching of physics, then the results show that 77 percent of respondents are in some way involved in physics (physics plus education plus science or technology manager). Physics graduates do not seem to have moved into business or into the Information Technology field in any significant way, contrary to possible expectations. It is of course possible that those who had did not respond to the survey. While no detailed gender breakdown was carried out, it was noted that all the responses under the category 'Management' were male, i.e. **there are no female respondents in managerial positions.**

- **Physics specialisation (B4)**

Physics specialisation, ranked by primary field of specialisation is presented in Table 9-13. Based on other responses, it appears that respondents indicated their last physics specialisation, whether or not they were presently involved in physics related occupations. So Table 9-13 unfortunately does not necessarily reflect the current distribution of active workers in the different fields.

Table 9-13. Physics specialisation (ranked by primary field)

	Primary field		Secondary field	
	Number	Percent	Number	Percent
Other	29	13.1	13	8.7
Condensed matter	27	12.2	15	10.1
Nuclear physics	22	10.0	10	6.7
Material science and engineering, metallurgy	17	7.7	12	8.1
Physics education, tertiary	16	7.2	14	9.4
Physics education, school	14	6.3	8	5.4
Astronomy, astrophysics, cosmology	12	5.4	9	6.0
Medical physics	12	5.4	4	2.7
Optics	9	4.1	7	4.7
Radiological physics	9	4.1	11	7.4
Atmospheric sciences	7	3.2	3	2.0
Atomic and molecular physics	7	3.2	7	4.7
Chemical physics	7	3.2	5	3.4
Elementary particles & fields, high energy physics	6	2.7	3	2.0
Space physics	6	2.7	2	1.3
Electronics, electrical engineering	5	2.3	2	1.3
Crystallography	3	1.4	5	3.4
Fluid dynamics	3	1.4	3	2.0
Mathematical physics	3	1.4	4	2.7
Biophysics	2	0.9	3	2.0
Ocean sciences	2	0.9	3	2.0
Acoustics	1	0.5	1	0.7
Low temperature physics	1	0.5	1	0.7
Plasma physics	1	0.5	4	2.7
Total respondents	221		149	

The occurrence of combinations of primary and secondary fields of specialisation was examined. The following combinations occurred with frequency greater than two.

Table 9-14. Fields of specialisation occurring in combination

Primary field	Secondary field	Frequency of occurrence
Condensed matter	Material science and engineering, metallurgy	8
Material science and engineering, metallurgy	Condensed matter	6
Medical physics	Radiological physics	7
Nuclear physics	Other	4
Physics education, school	Physics education, tertiary	4
Physics education, tertiary	Physics education, school	3
Physics education, tertiary	Astronomy / Astrophysics / Cosmology	3
Nuclear physics	Physics education, tertiary	3
Condensed matter	Crystallography	3

It can be seen that the specialisation combinations ‘Condensed matter’ and ‘Material science and engineering, metallurgy’ occur in a total of 14 instances, and that physics educators tend to be active at both tertiary and pre-tertiary level (the combinations ‘Physics education, school’ and ‘Physics education, tertiary’ occur in a total of 7 instances).

- **Financial support while studying (B5)**

Of the 249 respondents who replied to this question, 73.4% (183) stated that they had received financial support (other than from self or family) during their physics studies. The percentage of those who received support, who were females was 17.8%, and the corresponding proportion in the group that did not receive support was 23.0%. A simple statistical test shows that there is no significant difference in the proportion of females in the two groups, i.e. there is no gender bias in financial support.

Source and extent of funding and degree funded

Of the 183 who indicated that they had received financial support, 179 respondents provided further information about the source of their financial support, albeit to a lesser or greater extent. This was because the intent and layout of the question (B5.b) was not fully grasped by many respondents and was only partially completed by most. The total number of instances of funding by source are shown in Table 9-15. In some cases more than one degree was funded by the same source.

Table 9-15. Funding by institution

Source	Instances	Percent of total
Public sector	65	22%
University / Technikon	60	21%
FRD / NRF	56	19%
Private sector	41	14%
Science Councils	38	13%
Foreign	15	5%
Other	15	5%
Total	290	

All in all, 473 degrees were financially supported, and the source of financial support by degree is presented graphically in Figure 9-9 and is shown in Table 9-16.

Figure 9-9. Source of financial support by number and type of degree

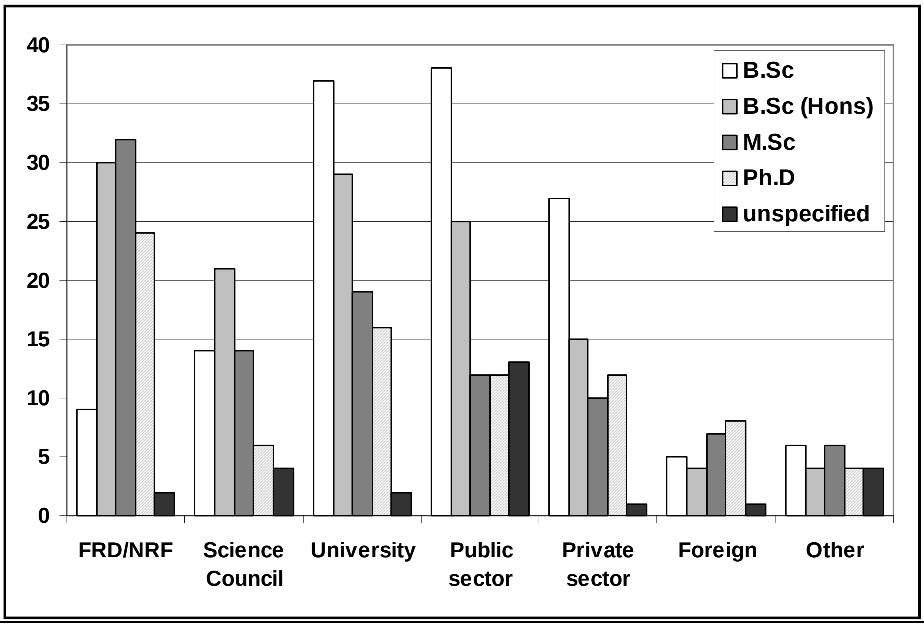


Table 9-16. Source of financial support by degree

	FRD/NRF	Science Council	University Technikon	Public sector	Private sector	Foreign	Other	Total
B.Sc	9	14	37	38	27	5	6	136
B.Sc (Hons)	30	21	29	25	15	4	4	128
M.Sc	32	14	19	12	10	7	6	100
Ph.D	24	6	16	12	12	8	4	82
Unspecified	2	4	2	13	1	1	4	27
Total	97	59	103	100	65	25	24	473

The main source of financial support for the first degree is provided by the public sector, the university and the private sector. There is some indication that education bodies, i.e. those concerned with teaching, are responsible for a good proportion of the public sector financial support, but this is at best a tentative conclusion, given the data.

These three sources of financial support (the public sector, the university and the private sector) also have a similar profile in the allocation of financial support for higher degrees.

The FRD/NRF notably extended its financial support to higher degrees, while other science councils favoured the Honours degree to some extent.

Multiple Sources

During their studies 53.6% of the 179 respondents who indicated that they had obtained financial support, obtained financial support from only **one** source, 33.0% obtained financial support from **two** sources, 11.2% obtained it from **three** sources and 2.2% obtained it from **four** sources.

Extent of funding

Of the 179 respondents who provided some details about funding received during the course of their studies, 110 indicated to what extent they had been funded. As noted earlier, the intent and layout of the question (B5.b) was not fully grasped by many respondents and was only partially completed by most. This meant that most of the 110 who responded did not indicate unambiguously which specific degree or degrees had received which level of funding.

The 110 respondents to this question provided a total of 305 responses. There were 74 responses indicating that funding had amounted to less than 1/3 of the cost, 47 responded that the funding had been between 1/3 and 2/3 of the cost and 184 had received funding to the extent of 2/3 or more of their costs.

Unfortunately the questionnaire did not ask what the costs compromised. The costs could have, in the respondents' minds, ranged from study fees alone, to the full cost of study which could include fees, study materials, travel, board and lodging, a living allowance and incidental expenses etc.

The only conclusion that can be reached with respect to the extent of funding, is that at least 43 percent of all respondents received financial assistance during their studies, and that when received, it was perceived in the majority of cases as being significant.

• Co-supervision of Masters (B6)

Out of the total of 254 respondents, 55 indicated that they would be prepared to co-supervise a Masters student, 115 responded that they would not be prepared to be involved in supervision, and 84 gave no answer. Implicit in the positive and negative responses was that the respondent was working outside a tertiary institution. When these replies were cross-checked with the respondent's employing body, it was found that of the 55 respondents who had responded positively, 11 were employed in tertiary education and thus only 44 had indicated a 'correct' positive response. Of the 115 who were not prepared to supervise, 24 were employed in tertiary education, thus only 91 had responded in a 'correct' and negative way. Of the 84 who did not answer this question, 22 were in tertiary education and the rest (62) worked outside a tertiary institution.

Thus we can conclude that of the eligible respondents (i.e. 197), 44 (22 percent) were prepared to co-supervise a Masters student, 91 (46 percent) were not prepared to do so, and 62 (31 percent) did not reply.

The positive response of 22 percent is an encouraging one and appears to show a commitment to post-graduate physics education by those at the time of the survey not in tertiary education.

- **The undergraduate physics curriculum in South Africa (B7) - preparation for the outside**

In the questionnaire it was stated that 'it had been suggested that South African tertiary institutions do not adequately prepare students for employment outside academia'. In this context, respondents were asked to comment on gaps in the undergraduate curriculum that needed to be filled, as well as curricular material that was perceived to be redundant.

Redundancies in the curriculum

Sixty respondents (24 percent) replied to the question, 'what material in the undergraduate curriculum do you perceive to be redundant?'. Some gave multiple responses, but interestingly, more than half of those responding i.e. 32 (53 percent) stated that there were no redundancies. The responses are summarised in Table 9-17.

Table 9-17. Perceived redundancies in the undergraduate physics curriculum

Redundant material	Count	Percentage
None	32	46%
Less theory / theoretical physics	8	12%
Quantum mechanics	5	7%
Fewer experiments	4	6%
(Advanced) nuclear/atomic physics	2	3%
(Classical) mechanics	2	3%
Learn less but better	2	3%
Less maths	2	3%
Memorisation	2	3%
Manual plotting of graphs	1	1%
Basic physics	1	1%
Some Newtonian physics	1	1%
Fluid mechanics	1	1%
Electromagnetism	1	1%
Thermodynamics	1	1%
Relativity	1	1%
Eliminate non-interesting material in 3rd year	1	1%
Add more	1	1%
That not applicable to the new SA	1	1%
Total	69	100%

The other general observation to be made is that the majority of the other respondents want less theory and not so much advanced physics in the undergraduate curriculum.

Table 9-18. Perceived gap areas in the undergraduate physics curriculum

Category	Percent	Count	Specific gap
Business skills	24%	27	Business
		10	Business management
		1	HR management
Physics	18%	9	Applied physics
		7	Computational physics & numerical modelling
		3	Modern physics
		2	Better teaching, instil more interest
		1	Radiological environment
		1	Medical physics/radiation physics
		1	Align lab work with research lab work
		1	Latest developments
		1	Broader base
		1	More content
		1	Experimental physics
		1	Analytical instruments
Industry	15%	8	Industry
		5	Industry related
		3	Industry skills
		2	Industry experience
		2	Practical work in industry
		1	Practical skills in co-operation with industry
		1	Industrial processes
		1	Industrial applications
		1	Visits to industry
Practical	10%	12	Practical skills
		1	Focus on local problems
		1	Job-related skills
		1	More non-structured project work
		1	Practical projects
Thinking skills and techniques	7%	3	Problem solving
		2	Systems engineering
		2	Critical thinking
		1	Thinking skills
		1	Systems approach
		1	Ability to do independent research
		1	Change student evaluation to test thinking
Communication	6%	8	Communications skills
		1	Writing & presentation
Career options and information	4%	6	Career information
		1	More job-market related
General	4%	2	Ethics
		1	Interdisciplinary
		1	Language and arts
		1	Soft skills
		1	Engineering
		1	Have science/maths/technology options
Computer literacy	4%	6	Computer literacy
Project control and management	3%	4	Project control
		1	Planning
Electronics	3%	4	Electronics
Teaching	1%	1	Science teacher training
		1	Understanding of 2005 school curriculum
None	1%	2	Specifically stated that there were no gaps

Gaps in the curriculum

116 (46 percent) respondents offered areas where there were perceived gaps in the undergraduate curriculum. Some respondents offered more than one area of deficiency. These responses are grouped by category in Table 9-18. Examination of the table indicates there is an overwhelming demand for non-core curriculum education and training. Together business, management, communications, thinking and project skills accounted for 63 of the 160 responses (39 percent). Industry-related and practical skills requirements accounted for a further 40 (25 percent) of responses. Eighteen percent of respondents felt that there were gaps in the physics content itself, with the emphasis being on applied physics and computational/numerical/modelling techniques.

Forty-nine respondents replied to both parts of the above two questions relating to the undergraduate physics curriculum. 23 felt that there were no redundancies, and wanted gaps to be filled i.e. they wanted the curriculum to be more comprehensive or longer. The rest (26) felt there were both gaps and redundancies and thus would give curriculum designers some leeway when restructuring the undergraduate physics curriculum.

Career

- **Present occupation (C1.a)**

The occupation of the respondents is shown in Table 9-19. Eighteen multiple responses were received which indicated that in addition to another occupation, 7 were also students and 11 who were retired were also employed in some way. There is an indication that a higher proportion of females work on a contract basis than do males.

Table 9-19. Occupation

Occupation	Count	Percent of total	Male	Female
Full-time	136	54%	110	24
Retired	51	20%	40	6
Self-employed	30	12%	26	4
Contract for 1 or more year	15	6%	8	6
Temporary employment less than 1 year	8	3%	6	2
Student	6	2%	5	1
Unemployed	6	2%	2	4
No response	2	1%		1
Total	254			

- **Job title (if employed) (C1.b)**

Table 9-20. Job Title

Broad area	Job Title	Count	Male	Female
No response (48%)		122	93	22
Responses (52%)		132	104	26
Science and technology 42 responses (32%)	Chief scientist	4	4	
	Manager	4	4	
	Medical Physicist	3	2	1
	Project manager	3	3	
	Thrust area leader	2	2	
	Astronomer	1	1	
	Centre manager	1	1	
	Chief director and professor	1	1	
	Chief physicist	1	1	

continued…

Table 9-20. Job Title (continued)

Broad area	Job Title	Count	Male	Female
Science and technology 42 responses (32%)	Consulting scientist	1	1	
	Deputy director	1	1	
	Development officer	1	1	
	Director medical physics	1	1	
	Director research unit	1	1	
	Division head	1	1	
	Head - laboratory	1		
	Head - research group	1	1	
	IP consultant	1	1	
	Principal research officer	1	1	
	Principal scientist	1	1	
	Professional officer	1		1
	Project head	1	1	
	Radiation scientist	1	1	
	Remote sensing specialist	1	1	
	Research assistant	1		1
	Research scientist	1	1	
	Researcher	1	1	
	Seismologist	1	1	
	Technical consultant	1	1	
	Technical manager	1	1	
	Technical officer	1	1	
Tertiary education 39 responses (30%)	Lecturer	23	13	10
	Professor	13	12	1
	Dean	1	1	
	Rector	1	1	
	Director, Centre	1	1	
Business 26 responses (20%)	Company director inc. CEO & MD	8	7	1
	Consultant	5	5	
	Farmer	3	2	1
	Business owner	2	2	
	Actuarial support	1	1	
	Advisor	1	1	
	Advocate	1	1	
	Business analyst	1	1	
	Management consultant	1	1	
	Priest	1	1	
	Project Manager	1	1	
	Quantitative Analyst	1	1	
Secondary and primary education 17 responses (13%)	Teacher (secondary)	10	4	6
	School principal (or deputy)	3	2	1
	Teacher (primary)	1		1
	Deputy chief education specialist	1	1	
	Educator	1		
	Science awareness presenter	1	1	
Information technology 8 responses (6%)	Customer support	1		1
	Instructor	1	1	
	IT consultant	1	1	
	Programmer	1	1	
	Software engineer	1	1	
	Specialist GIS	1	1	
	Systems analyst	1		1
	Systems programmer	1	1	

From Table 9-20 it may be seen that the most frequent occurring job titles are those of lecturer, professor, teacher and company director. 62% of all female job titles were lecturer and teacher. Grouping the job titles into broad categories once again showed that only a few respondents appeared to be active in the Information Technology sector (6 percent). Most were active in science and technology (32 percent), tertiary education (30 percent) and business (20 percent). Teaching related job titles accounted for 13 percent of the responses.

- **Unemployment (C2)**

Table 9-21. Respondents experiencing unemployment in the past 5 years (1995 -2000)

	Count	Gender		
		Male	Female	Unspecified
Total unemployed in past 5 years	41	31	7	3
For a period of:				
• Unspecified	24	16	5	3
• 0 to 6 months	6	4	2	
• 6 months to 1 year	4	4		
• 1 to 2 years	3	3		
• More than two years	4	4		

According to the data presented in Table 9-21, 16 percent of respondents had experienced unemployment in the five year period from 1995 to 2000. Unfortunately most respondents did not specify for how long they had been unemployed, which makes it impossible to ascertain whether the problem of unemployment for physics graduates is a serious one or not. By comparison, the overall official unemployment rate in South Africa in 1999 was 23.3 percent, ranging from a low of 4.4 percent for White males, 5.1 percent for White females, about 14 percent for male Indians and Coloureds, 17 percent for female Indians and Coloureds, 24.5 percent for Black/African males, to a high of 35 percent for Black/African females (StatsSA 2001)

.

- **Length of employment (C3)**

Table 9-22. Total length of employment

Total employment period	Count	Gender		
		Male	Female	Unspecified
For a period of:				
• 0 to 10 years	54	36	18	
• 10 to 20 years	54	39	14	1
• More than 20 years	121	110	8	3
No response	25	12	8	5
Total	254	197	14	9

It can be seen that the respondents are an experienced group, with 53 percent having been in employment more than 20 years. Once again the data show that the female respondents are a younger group than the males, as the female distribution of employment is weighted towards the shorter period of employment (cf. Tables 9-2 and 8-3).

- **Employing body (C4)**

Respondents had a choice of 18 employing bodies. Nevertheless this was insufficient as 47 responses were received indicating an ‘other’ employing body. The 47 ‘other’ responses were analysed further and were either reallocated into one of the given 18 categories of employing body, or were placed into 3 new categories of ‘employing’ body, viz. engineering, retired and student. The detailed results are presented in Table 9-23. 9 respondents indicated they worked for exactly 2 employing bodies each, thus there are 263 entries, (254 plus 9), in the table. Education bodies employed 45 percent of employed respondents.

Table 9-23. Employing body

Employing body	Count	Percentage
Education university	57	27%
Education secondary	26	12%
National research facility	21	10%
General business	18	9%
Research industrial	12	6%
Computer software / hardware	11	5%
Hospital or medical services	11	5%
Manufacturing	8	4%
Education other (tertiary)	8	4%
Legal services / consulting	6	3%
Financial / insurance / banking	6	3%
Mining extraction	5	2%
Education technikon	4	2%
Communications	3	1%
Government department	3	1%
Engineering	3	1%
Construction	2	1%
Services, maintenance	1	0%
Utilities	1	0%
Publishing	0	0%
Sub-total:	209	
No employing body		
No response	44	
Retired	12	
Student	1	
Sub-total:	57	
Total	263	

- **Aspects of work (C5)**

Table 9-24. Extent of involvement in various aspects (skill categories) in present work

Skill Category	Total	not at all	→	some	→	→	exten-sively
Physics content knowledge overall	85	20	16	8	10	9	22
Physics 1st year level	117	14	21	12	22	10	38
Physics 2nd year level	103	24	21	6	18	16	18
Physics 3rd year level	100	28	12	7	22	10	21
Physics Hons level	95	28	8	5	20	10	24
Physics MSc level	79	25	5	6	6	9	28
Physics PhD level	78	25	5	10	7	9	22
Computer	172	13	21	8	34	36	60
Lab/instrumentation	155	50	28	3	25	27	22
Mathematical	170	14	36	7	40	40	33
Modelling	160	41	25	4	30	27	33
Problem solving	178	9	12	11	21	40	85
Written communication	179	12	11	9	20	51	76
Interpersonal	168	7	12	8	34	39	68
Management	167	21	16	8	27	40	55
Verbal communication	177	8	8	11	19	47	84

Of the 254 respondents, 57 (22 percent). 13 (5 percent) answered every part of this multi-part question, while 30 answered all parts with the exception of the first skill category (physics contents knowledge overall) as they apparently assumed this was unnecessary as the subsequent 6 sub-questions broke this down by physics level). The remaining 154 respondents answered the various parts of this question to varying degrees of completeness. All responses are shown in Table 9-24.

So as to extract some useful information from Table 9-24, the responses were ranked in two tables. Table 9-25a ranks the aspects of work from most used to least used, while Table 9-25b ranks the aspects of work that are used extensively and quite extensively viz. the rightmost two columns of Table 9-24 (scale values 1 and 2 in the questionnaire), under the heading ‘used a lot’.

Table 9-25a. Skill category ranked by usage

Skill category	Used	Not used
Interpersonal	96%	4%
Problem solving	95%	5%
Verbal communication	95%	5%
Written communication	93%	7%
Computer	92%	8%
Mathematical	92%	8%
Physics 1st year level	88%	12%
Management	87%	13%
Physics 2nd year level	77%	23%
Physics content knowledge overall	76%	24%
Modelling	74%	26%
Physics 3rd year level	72%	28%
Physics Hons level	71%	29%
Physics MSc level	68%	32%
Physics PhD level	68%	32%
Lab/instrumentation	68%	32%

Table 9-25b. Skill category ranked by frequency of usage

Skill category	Used a lot
Verbal communication	74%
Written communication	71%
Problem solving	70%
Interpersonal	64%
Management	57%
Computer	56%
Physics MSc level	47%
Mathematical	43%
Physics 1st year level	41%
Physics PhD level	40%
Modelling	38%
Physics content knowledge overall	36%
Physics Hons level	36%
Physics 2nd year level	33%
Lab/instrumentation	32%
Physics 3rd year level	31%

The skills with the highest usage are:

- Interpersonal
- Problem solving
- Verbal communication

- Written communication
- Computer
- Mathematical

The skills that are ranked at the top of those used a lot i.e. extensively and quite extensively, are:

- Verbal communication
- Written communication
- Problem solving
- Interpersonal
- Management
- Computer

In both cases physics content knowledge at various levels and Lab / Instrumentation skills are ranked at the bottom end of the tables.

While it might be evident that in most occupations communications skills (both written and verbal) are required and enjoy a high usage, it is interesting to note that interpersonal, problem solving management, mathematical and computer skills were ranked ahead of any physics content knowledge.

• Evolution of career (C6.a)

A total of 199 unstructured responses were received in reply to the request to ‘summarise your employment history briefly’. There were a number which indicated that the respondent had followed a straightforward career path as a university lecturer or as a secondary science teacher or similar linear progression. Attempts to categorise, summarise or analyse the other responses were unsuccessful. The responses are presented in alphabetical order within career phase in Table 9-26 for the sake of interest and completeness.

Table 9-26. Evolution of career

Phase 1 →	Phase 2 →	Phase 3 →	Phase 4
Applied research	Technical manager		
Assistant	Projects / programmes	Managing	
Astronomer	Director of national facility		
Basic research	Industrial research		
Chemical analysis	Testing	Research	
Chemist	Chief chemist	Financial institution	General manager chemical complex
Chief chemist	Head R&D	Lecturer	
Computer science lecturer			
Construction industry	Cellular phone industry		
Consulting scientist	Self employed		
CSIR	AEC		
CSIR	Corporate planning	Computer Industry	
CSIR	Industrial research	Software	
CSIR	Lecturer		
CSIR	Lecturer	Insurance	
CSIR	Lecturer	Research	Self-employed
CSIR	Physics consultant	Lecturer	

continued…

Table 9-26. Evolution of career (continued)

Phase 1 →	Phase 2 →	Phase 3 →	Phase 4
CSIR	Private sector		
CSIR	Research	Property letting	
CSIR	Self-employed	Professor	
Engineer	Geomagnetist	Student	Astronomer
General medicine	Hospital management	Primary medical care	
Geoexploration			
Geophysicist	Computer systems	Lecturer	
Geophysics	Physics	TQM	Senior manager
Government	Researcher	Professor	CSIR
Hospital	Industrial research	Lecturer	Government
Hospital services	Physicist	Self-employed engineer	
Industrial research	CSIR	Lecturer	
Industrial research	Management consultant		
Industrial research	Private education	Self-employed	
Industrial research	Production design	Research manager	
Industry	Consulting	Manufacturing	
Industry	Research	Business	Consultant
Industry	Research	Lecturer	
Industry	Self employed		
Insurance	Banking		
Lab assistant	Lecturer		
Lab assistant	Medical practice	Government epidemiologist	
Lab assistant	Research		
Learner technician	Chief scientist	Chief scientist - industry	Senior technical manager
Lecturer	CSIR	HOD university	Scientific manager
Lecturer	Geophysics	Investment analyst	
Lecturer	HOD	Dean of faculty	
Lecturer	Industry		
Lecturer	Investment analyst	Business owner	Consultant
Lecturer	Primary school teacher		
Lecturer	Professor	Dean	
Lecturer	R&D	Public administration	
Lecturer	Research		
Lecturer	Research	Financial management	Financial director
Lecturer	Research	Industrial engineering	
Lecturer	Self-employed		
Lecturer	University administration		
Lecturer engineering	Private practise		
Materials engineering	Product development		
Medical technologist	Medical physicist	Project manager	Quality manager

continued…

Table 9-26. Evolution of career (continued)

Phase 1 →	Phase 2 →	Phase 3 →	Phase 4
Metallurgist	Lab manager		
Mining research	Semi-government	CSIR management	
Physicist	Computer systems		
Physicist	Researcher	CSIR	Head, national facility
Physics	Management	Research and management	
Plant metallurgist	Technical; manager	self-employed	
Plant superintendent	Lecturer (technikon)		
Process engineering	Instrument engineering	Manufacturing management	Company director
Research	Computer programmer		
Research	consultant		
Research	Farmer	Teacher	
Research	Financial market trading		
Research	Geophysical exploration	Petroleum engineering	
Research	Government dept	Self-employed	
Research	Government dept	Lecturer	
Research	Lecturer	Director national facility	
Research	Lecturer	University administration	
Research	Manager research		
Research	Materials science & manufacture		
Research	Medical school		
Research	Operations research	Information systems	Policy research
Research	Partner in manufacturing business		
Research	Product testing		
Research	Project management		
Research	Senior management		
Research	Student	Commerce	Lecturer
Research	Technical management	General management	
Research	Technology Management	Knowledge management	
Research	University		
Researcher	Technical manager	Own business	CEO
Scientist	Chief scientist		
Scientist	Chief Scientist	Business manager	Consultant
Scientist	Computer systems	Manager/ director	CEO
Scientist	Project manager	Business development	Sales
Seismic graphics	3G wireless communications		
Self employed	Industry	CSIR	
Studying economics			

continued…

Table 9-26. Evolution of career (continued)

Phase 1 →	Phase 2 →	Phase 3 →	Phase 4
Teacher	Computer instructor		
Teacher	CSIR		
Teacher	Laboratory assistant	Teacher	College rector
Teacher	Lecturer - this occurred 6 times		
Teacher	Lecturer	Government scientist	
Teacher	Lecturer	HOD	
Teacher	Metallurgist	Self employed	
Teacher	Principal	Education department	
Teacher	Principal	Education Dept	HSRC
Teacher	Rector of education college		
Teacher	Research	Head of National Facility	
Teacher	Research assistant	Lecturer	Senior manager
Teacher	Self employed		
Teacher	Administration	Management	
Technical computing	Information systems		
Technical officer	Teacher	HOD	Education dept
Technician	Scientist	Manager	Consultant
Theologian	Law		
Theological college	Teacher	Teacher training	Pastoral ministry
Unemployed	Teacher	Seismologist	

• Number of subordinates (C6.b)

122 (48 percent) of respondents replied to the question, with an indication that one or more persons reported to them in the workplace. The distribution of subordinates is shown in Figure 9-10a . It is apparent that the majority have 10 or fewer person reporting, and for clarity the distribution of subordinates in this subset is shown in Figure 9-10b . Interestingly the highest frequency occurs at 4 subordinates and in general most respondents have fewer than 7 subordinates.

Figure 9-10a. Distribution of number of persons reporting

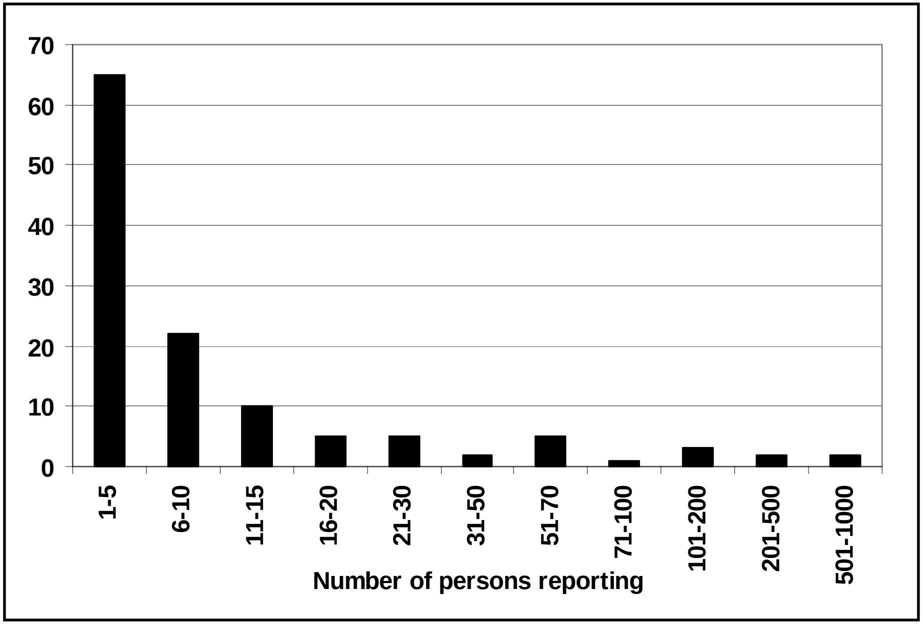
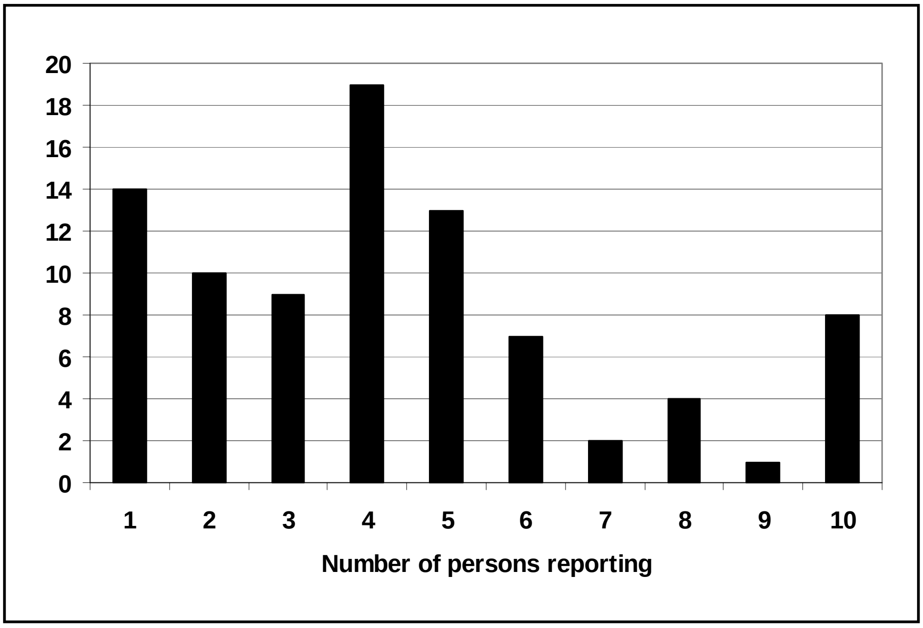


Figure 9-10b. Distribution of number of persons reporting (1-10)

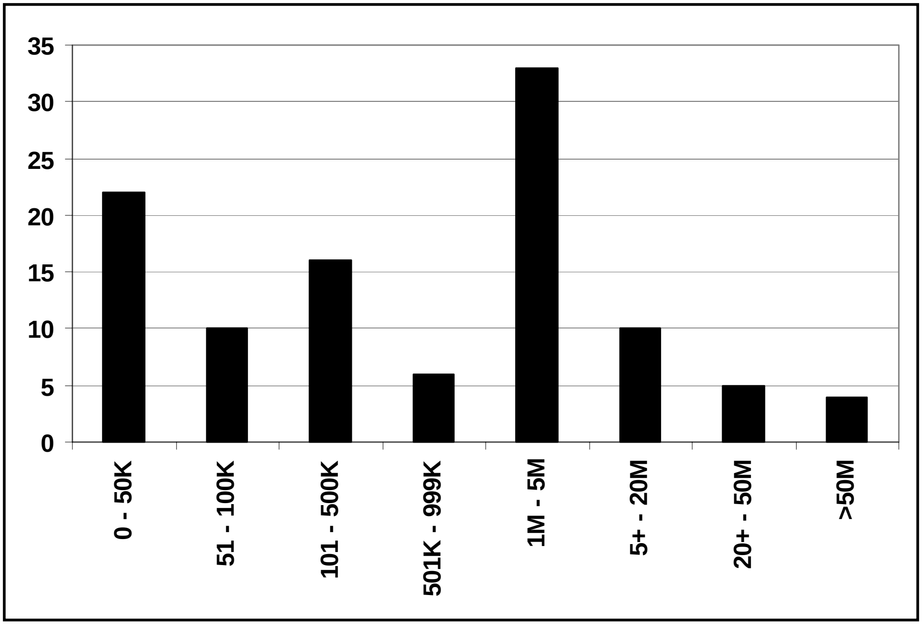


- **Total budget responsibility (C6.c)**

106 (42 percent) of respondents indicated that they were responsible for a budget, and the total budget amounts (assumed to be annual as this was not specially stated) ranged from R2 000 to R1.5 billion, for a combined total of R2.673 billion.

The distribution of the budget amounts is shown in Figure 9-11. Although the budget ranges were chosen somewhat arbitrarily, it is nevertheless interesting to note that 21 percent of the budgets are less than R50 000, and 31 percent of the budgets fall in the range R1 million to R5 million

Figure 9-11. Distribution of budgets

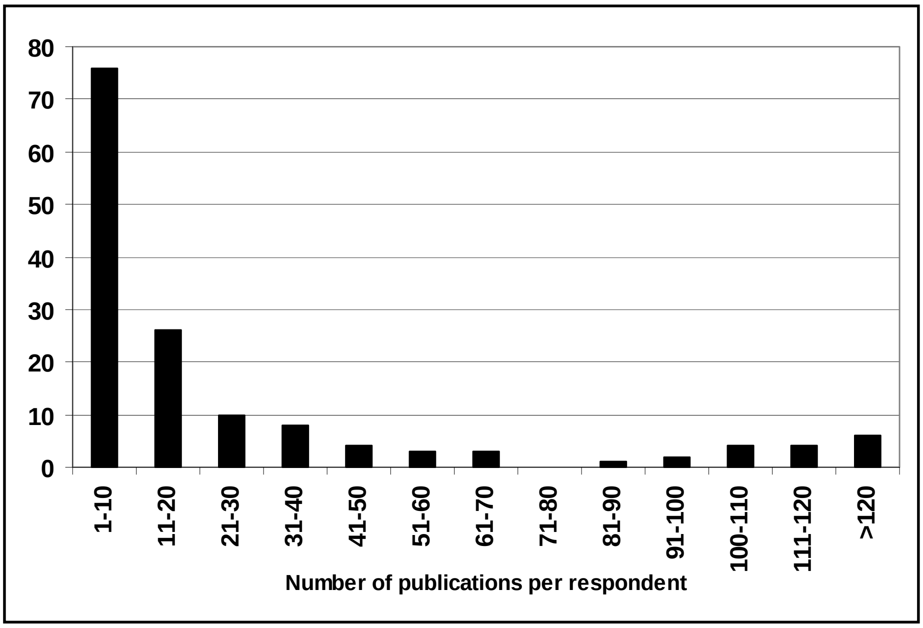


- **Publications (C6.d)**

147 (58 percent of respondents) indicated that they had been the (co)-authors of a total of 5 238 publications, including articles. The number of publications ranges from 1 per respondent to 1 000 per respondent and the distribution is shown in Figure 9-12. While there is a expected fall-off in the

number of respondents for higher numbers of publications, from 81 publications per respondent onwards there is a slight increase. This would seem to imply that these respondents are from a different sample to the rest, in that they are in a field where large numbers of publications can be achieved, that they have a different opportunity or mechanism for publication, or possibly, that they have been publishing for a long time.

Figure 9-12. Publications per respondent



- **Patents (C6.e)**

22 (9 percent) of respondents had been involved in a gross total of 54 successful patents (gross, because there is the possibility that two or more respondents are reporting the same patent) . The number of patents per respondent ranged from 1 to 8 patents. The distribution is shown in Table 9-27.

Table 9-27. Patents

Number of patents per respondent	Count	Percent of total patents
1	6	11%
2	7	13%
3	6	11%
4	2	2%
8	1	2%

- **Membership of professional societies (C6.f)**

138 (54 percent) of respondents indicated they belonged to professional societies or bodies. With the exception of the SAIP itself, there was little commonality discernible among the professional societies listed, and thus no further statistics apart from Table 9-28 below are presented. The table shows the distribution of the number of professional societies per respondent. As is to be expected, there is a Poisson distribution, with the majority belonging to 4 or fewer professional societies.

Table 9-28. Membership of professional societies

Number of professional societies by respondent	Count
1	59
2	39
3	20
4	11
5	5
6	1
7	1
8	1
12	1

Perceptions regarding the South African Institute of Physics (SAIP)

• Membership of the SAIP (D1)

Of the 254 respondents, 69 (27 percent) indicated they were members of the SAIP and 178 (70 percent) stated they were not members of the SAIP. Seven (3 percent) choose not to answer. The gender, age and race breakdown of the two groups is shown in Tables 9-29 and 9-30. The reader may wish to compare the data presented with the overall demographics for all respondents at the beginning of this chapter.

Table 9-28. Demographics of SAIP members

Gender	Count	percent	Median age	Average age	Count by race			
					African	Indian	Coloured	White
Female	10	15%	34.5	38.5	0	1	0	9
Male	58	85%	50.0	52.8	2	2	0	50

Table 9-29. Demographics of non-members of SAIP

Gender	Count	percent	Median age	Average age	Count by race			
					African	Indian	Coloured	White
Female	37	21%	40.5	43.3	0	2	0	35
Male	137	79%	53.0	50.7	6	3	4	122

The two groups have very similar demographic characteristics, viz. white males constitute the significant majority. Males have similar age characteristics, while females are significantly younger in both groups, with females members of the SAIP being much younger than their non-member female counterparts. The reasons for this difference are not clear, for if the difference was due to (female) members resigning from the SAIP on retirement, then this age difference should be apparent in the males respondents as well, which it is not. There is a hint that the SAIP is under-represented in terms of African and Coloured physicists. See also the responses regarding equity below.

• Joining the SAIP - yes or no? (D2)

Of the 178 non-member respondents, 37 (27 percent) indicated that they **would like** to become members of the SAIP. The demographics of this group is shown in Table 9-30.

Table 9-30. Demographics of potential SAIP members

Gender	Count	percent	Median age	Average age	Count by race			
					African	Indian	Coloured	White
Female	11	30%	34.0	33.9	0	1	0	10
Male	26	70%	36.0	38.8	5	1	2	16

For the SAIP the above statistics are encouraging, in that they indicate that younger physicists of all races are interested in becoming members of the SAIP.

Of the 141 non-member respondents who indicated that they would not like to become members of the SAIP, 103 provided reasons. Also included were reasons for not joining from 3 non-members who indicated they would like to join, and from 1 member and 2 non-members who did not indicate whether or not they would like to join the SAIP, for a total of 109 responses. These responses are summarised in Table 9-31. The two main reasons for not joining the SAIP (59,6% of all responses) were that the respondents were not active in physics or that they were retired. A further 15% of the respondents were not interested in the SAIP, felt it was irrelevant or that it offered no benefits. Judging from the other responses, cost of membership is not an issue, and a few (4,6%) respondents lacked information about the SAIP, which lack presumably held them back from joining. It appears that close to 20% of the respondents would consider joining the SAIP if more information was provided about the SAIP in general terms, and specifically about its relevance and benefits to physicists in South Africa.

Table 9-31. Reasons for not joining SAIP

Count	Percent	Reason
37	33.9%	Not in physics
28	25.7%	Retired
9	8.3%	Not relevant or not of interest
7	6.4%	No benefits to me
6	5.5%	No time for membership
5	4.6%	Lack of information about SAIP
4	3.7%	Cost or not affordable
3	2.8%	Scope of the SAIP is too broad
3	2.8%	Not in South Africa
3	2.8%	Not in research/too academic/teacher
2	1.8%	Conference date clash
1	0.9%	SA doesn't need physicists as it is 3rd world
1	0.9%	SAIP is too political
109	100%	

- **Perceived benefits of the SAIP (D3)**

Table 9-32. Benefits of SAIP membership

Category	Percent	Count	Specific reason
Contact	33%	27	Contact
		10	Contact with physicists
		2	Meet academics
Information	24%	17	Kept up to date
		4	Newsletter
		3	Info on career prospects
		2	Info
		2	Journal
		1	Web page
Events	21%	20	Conference
		5	Workshops/meetings
Negative perceptions	17%	11	No benefits
		9	Not aware of benefits
Other	5%	3	Represents physicists
		1	Support for younger physicists
		1	Looks good on CV
		1	Discounts
Total	100%	119	

There were 97 responses to the question ‘What benefits of SAIP membership do you regard as important?’ 47 (46 percent) were from members, 48 (47 percent) from non-members and two responses did not specify membership of the SAIP. 80 respondents specified one benefit only, while 17 specified two or more benefits. The benefits regarded as important have been binned under a number of specific benefits, and these have been grouped by five categories and are shown in Table 9-32. The most significant benefit is perceived to be contact (with other physicists) (33 percent), followed by various aspects of information provided (24 percent) and events held by the SAIP (21 percent). Seventeen percent of responses were negative in that respondents perceived there to be no benefits to SAIP membership, or were not aware of them.

- **Additional features/activities SAIP could provide to members (D4)**

Table 9-33. Additional benefits and features the SAIP could provide

Category	Percent	Count	Specific reason
Information dissemination	30%	13	More or regular info on physics (including e-mail, newsletters, or the Internet)
		3	Contacts between members or a member database
		2	Revive journal
		1	Publish conference proceedings
		1	More journal articles related to education
Employment	23%	13	Info about job opportunities
		2	Better incentives for physics teachers
Widen approach	15%	7	Promote greater involvement of physics in industry. Contact with industry problems and challenges
		1	Interest in medical physics
		1	Focus on young researchers
		1	Promote physics more widely
Promote and represent physics	11%	3	Professional identity or registration ensuring int'l acceptance of qualifications
		2	Have a vision of physics in SA -revitalise physics
		2	Links to int'l physics community
		1	Co-operation with other physics and scientific bodies and with industry
Conferences/ workshops	8%	2	More conferences/seminars
		1	Extended winter school
		1	Student participation at conferences
		1	Talks at local centres
Involvement at high schools	8%	2	Retrain high school teachers
		1	Local branches get involved
		1	Involvement at high schools
		1	Exhibition on inventions
Financial	5%	1	Free workshops or provide financial assistance
		1	Financial support for research in teaching physics
		1	Free motor cars
Total	100%	66	

58 responses to this question were received, 24 from non-members and 34 from members. The responses are shown in summarised form in Table 9-33, where they have been placed in seven broad categories. More than 50 percent of the responses were related to only two categories, information dissemination (30 percent) and employment opportunities/information (23 percent). Indeed, if the two

categories are merged, then the main additional benefit that physicists in South Africa require from the SAIP is information. Another significant area was that of the relationship between the SAIP and industry, with 11 percent of responses indicating that in some way there should be a closer or better linkage between the SAIP and industry.

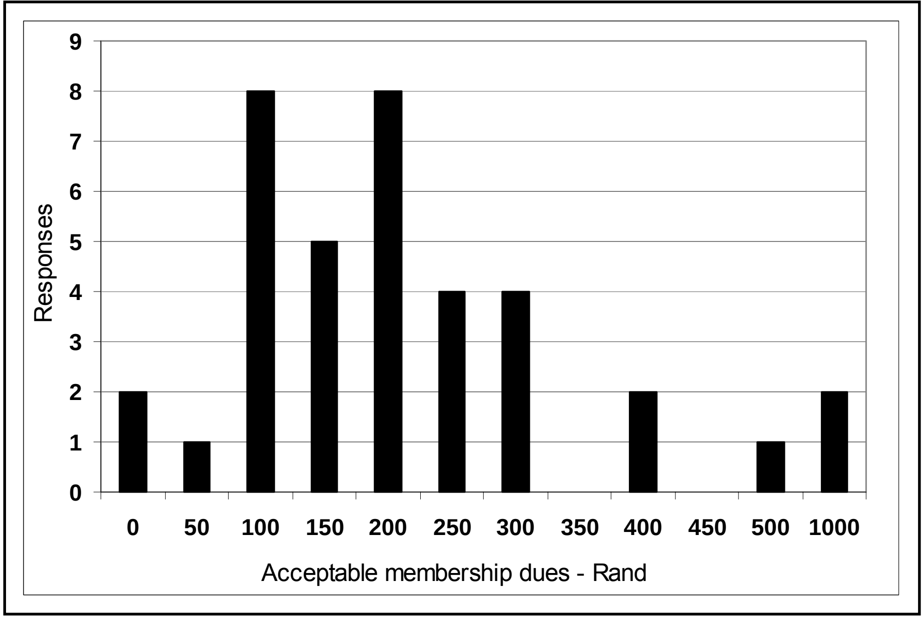
- **Should additional activities be available at an extra cost? (D5.a)**

There were 71 responses (28 percent of respondents) to this question, 48 from members and 21 from non-members. 70 percent of these responses indicated that they would like to have additional activities, at an extra cost, with the split in percentage terms between members and non-members about the same. Of the 183 who did not respond to this question, the majority were non-members of the SAIP (85 percent). Overall, 20 percent of the total sample of 254 wanted additional activities at an extra cost.

- **What is the acceptable level of SAIP membership dues? (D5.b)**

There were 71 responses (28 percent of respondents) to this question, 48 from members and 21 from non-members. The mean was R235 and a histogram of the responses is shown in Figure 9-13. One other respondent was prepared to pay 50 percent more.

Figure 9-13. Acceptable SAIP membership dues



- **Suggestions for making the SAIP more relevant to the wider physics community. (D6)**

The question stated that the SAIP has a relatively small fraction of members employed outside of academia, and went on to ask: ‘Do you have any suggestions as to how the SAIP can become more relevant to the wider group of physics graduates?’ 87 respondents replied to this question (34 percent of the total), with members and non-members of SAIP being equally represented.

The responses are summarised in Table 9-34. The responses have been grouped under a number of broad categories. Communication, publicity and events each accounted for about 16-18 percent of the responses. The suggestion of making SAIP conferences or seminars of wider appeal by having more general or industry related topics, and by inviting speakers from industry occurred the most (12 percent out of all the responses). Of the suggested actions, 6 percent of responses indicated that non-academics should be made more welcome in the SAIP.

Table 9-34. Suggestions for making the SAIP more relevant to the wider physics community

Category	Percent	Count	Specific reason
Total	100%	100	
Suggested actions	33%	6	Encourage non-academics to join and feel accepted, use members for this. Be more business like
		5	Communicate/collaborate/closer ties/liaison with industry
		4	Address their interests
		3	Be more interdisciplinary
		3	Form industrial branch/interest group. Special interest groups for industry / business
		2	Invite industry to state requirements
		2	Use students to solve industrial problems/internships
		2	Show where physics can add value in new SA/ make science more relevant/popularise physics
		2	Consult with other physics related societies/APS
		1	Write to them (get addresses from universities)
		1	Provide a service to them
		1	Extend activities of applied physics group
		1	Focus on young researchers
Publicity	18%	6	Publish/Publicise/Circulate info to industry/ media voice
		5	Publicise SAIP outside academia and to new graduates
		4	Publicise those physicists outside academia/get them to speak
		3	Advertise/send prospectus to major employers
Communication	18%	7	Newsletters of info/events/ job opportunities
		5	Provide practical info/emphasise applications/applied physics.
		4	E-mail newsletter or chat/user groups/forum or relevant website
		1	Encourage interaction/communication
		1	More articles on education
Conferences/work-shops/seminars	16%	12	Conferences/Seminars of more general and applied interest/relevant topics. Have industry speakers
		2	More regular meetings/conferences not in holidays
		1	SAIP more involved in industrial conferences
		1	Provide continuing education
Secondary education	6%	4	Involve physical science teachers/schools in SAIP
		2	Promote SAIP to high schools
Recognition	4%	3	Highlight professional status of scientists
		1	Protect the rights of physicists in industry
Other	5%	2	Not many physicists in industry. Physics graduates don't work in physics
		1	Involve amateur scientists
		1	Have attractive benefits
		1	Stop the move to one language in the SAIP

- **Does the SAIP embrace equity? (D7)**

A total of 36 responses to this question were received (14 percent of all respondents). Of these 36 responses, 29 were positive (14 with additional comments), 6 were negative and one was neutral. Assuming that any respondent who felt negatively about this subject would have responded, **only 2.4 percent of those in the survey felt that the SAIP was an organisation which did not embrace equity**. All 6 negative responses made comments as well. A breakdown of attributes of respondents is shown in Table 9-35.

Table 9-35. Does the SAIP embrace equity?

Response	Percent of total	Count	Members	Male	Female	White	Other race	Comments
Positive	11.4%	29	22	24	5	26	1	14
Negative	2.4%	6	5	6	0	4	1	6
Neutral	0.4%	1	1	1	0	1	0	1
None	86.8%	218	-	-	-	-	-	-

The comments received in response to this question are shown in Table 9-36.

Table 9-36. Comments regarding equity in the SAIP

Comment Type	Comments
Positive	Yes, for many years Yes, because of representation by academics SAIP represents the SA physics gender/race distribution Discard politics Politically correct at the cost of excellence - short-sighted Ask the previously disadvantaged Yes, but make members feel part of SAIP Concentrate on quality of work Yes, but little proactivity for change Yes, but male dominated Yes, but more participation of women and blacks Yes, but not enough women - are they interested? More efficient and visible outreach to young people Need physics in society and people development
Neutral	SAIP should be concerned with physics - then equity will take care of itself
Negative	White and male dominated council Geriatric whites Speciesism still rampant No, but changing in composition No, needs more priority, but do not supplant core mission with social agenda No, more promotion of physics to previous disadvantaged

It would seem from the above that equity is not a significant issue for South African physicists, whether or not they are members of the SAIP.

References

StatsSA. 2001. South Africa in transition. StatsSA.

A comparison of the two SAIP surveys

Introduction

This chapter makes some comparisons between the two surveys conducted by the SAIP in 1999 and in 2000 and which results have been presented in detail in Chapters 8 and 9. The intention is not to repeat that which has already been covered, but rather to juxtaposition the two surveys briefly to highlight differences. It is not intended to be a summary of the previous two chapters.

Are the two survey groups different?

The 1999 Electronic survey was sent to all SAIP members who had e-mail addresses (about 120), as well as to institutions and organisations that were likely to employ physicists, with a request to forward the questionnaire to others. The total number of questionnaires sent out is thus unknown. 122 responses were received. The HSRC 2000 postal survey targeted all persons who were registered as having at least an Honours degree, and half of those who had completed 3rd year physics. 254 responses were received. An examination of the returns showed that 23 respondents had responded to both surveys, so that the two surveys together are the responses of 353 unique individuals. By the nature of its distribution, the 1999 Electronic survey was obviously biased towards then employed physicists working in physics and with access to e-mail, whereas the HSRC 2000 covered a much wider spectrum of physics graduates.

Examination of the results presented in the earlier chapters show that the two survey groups are indeed different. The average age in the 1999 Electronic survey was 41, while in the 2000 HSRC survey, the average age was 49, with many more older respondents present. While the overall male/female ratios were similar, there were proportionally more younger women in the 1999 group. 20 percent of the 2000 group were retired, while, as expected, only a few (4 percent) who responded in 1999 were retired. The distribution of highest degrees was also markedly different, with 68 percent of the 1999 group having PhDs as their highest degree, while 46 percent of the 2000 group had PhDs. The comparative figures for a BSc as the highest degree were 2 percent and 15 percent.

Further differences and other remarks are noted below in columnar form for easier reference.

The differences between the two surveys

The 1999 Electronic Survey	The HSRC 2000 Survey
Race	**Race**
• 15 percent were African, Coloured or Indian. • 9 percent objected to being asked about their race.	• 8 percent were African, Coloured or Indian, and the majority of these respondents were younger than 40. • Only a very small number of objections to this question were noted.
Remuneration	**Remuneration**
• There was a strong peak at R100K-R150K per annum, with female remuneration peaking at R50K-R100K.	• Remuneration was more broadly spread, with a significant number reporting remuneration of more than R300K. Females earned significantly less than males.

continued…….

The 1999 Electronic Survey	The HSRC 2000 Survey
Retirees	**Retirees**
• 4 percent reported being retired.	• 20 percent reported being retired, and retirees had a significantly lower income distribution than did the rest of the group.
University career	**University career**
• In the first degree, if more than one major had been offered, it tended to be (pure) mathematics.	• Same.
• The most first degrees were obtained at Natal, Cape Town and Port Elizabeth universities.	• The most first degrees were obtained at Pretoria, Stellenbosch and Cape Town universities.
• 31 percent of respondents had higher degrees from overseas universities.	• 15 percent of respondents had higher degrees from overseas universities.
• 68 percent had PhDs as their highest degree.	• 46 percent had PhDs.
• Questions regarding financial aid were not asked.	• 73 percent had received financial aid while studying.
Employment	**Employment**
• 85 percent gave their occupations as physicists.	• 46 percent were employed as physicists, while education and 'other' occupations were also significant.
• None reported being self-employed.	• Retired and self-employed accounted for 32 percent of the responses.
• 10 percent had experienced unemployment.	• 16 percent had experienced unemployment.
• 89 percent gave a job title.	• 52 percent gave a job title.
• 53 percent were employed in tertiary institutions and 43 percent in S&T.	• 30 percent were employed in tertiary institutions and 32 percent in S&T, 20 percent in business and 13 percent in school education.
• 41 percent had been in employment for more than 20 years.	• 53 percent had been in employment for more than 20 years.
Field of physics specialisation	**Field of physics specialisation**
• The top three most frequent responses were condensed matter, 'other' and nuclear physics	• Same
Physics Curriculum	**Physics Curriculum**
• 58 percent perceived no redundancies in the physics curriculum	• 46 percent felt that there were no redundancies in the physics curriculum
• The two group had similar views on	• Same

the gaps in the curriculum • 23 percent were prepared to supervise an MSc	• Very similar (22 percent) continued…..
The 1999 Electronic Survey	**The HSRC 2000 Survey**
Societies	**Societies**
• The majority (83 percent) belonged to one or more professional societies, with about a third belonging only to the SAIP.	• Slightly more than half indicated they were members of one or more professional societies.
Membership of the SAIP	**Membership of the SAIP**
• 68 percent were members of the SAIP.	• 27 were percent were members of SAIP.
• 46 percent of the non-members expressed an interest in joining the SAIP.	• 20 percent of the non-members expressed an interest in joining the SAIP.
• Dominant reasons for not joining the SAIP were; no benefits and lack of information.	• The main reasons given for not joining the SAIP by 60 percent of non-member respondents were that they were not in physics or were retired.
• The majority were prepared to pay annual membership fees of R50-R100 (SAIP fees were R85 at the time).	• The majority were prepared to pay annual membership fees of around R200.
• The main benefits from membership of the SAIP were seen as contacts, events and information.	• Same.
• The most important additional benefits and features the SAIP could provide were to promote and represent physics, and more information.	• The most important additional benefits and features the SAIP could provide were additional information and to widen its approach.
• 20 percent of the total wanted additional activities from the SAIP at an extra cost.	• Same.
• There were no question on perceptions of equity in the SAIP.	• Only 2.4 percent of those in the survey felt that the SAIP was an organisation which did not embrace equity.

Conclusions and recommendations

The importance of physics and of science and technology

In the global market place, the most successful nations are those that have a culture and infrastructure for innovation, such as the United States and Japan. The nations that are least successful rely on exploiting natural resources to survive in the global market place. Thus, technology through innovation is the key to the economic development of a nation and the improvement of the quality of life of its citizens. At present technological innovation is occurring in four broad enabling technologies, viz. information and communications technologies (ICT), materials, energy and biotechnology, and it is in these areas that it is of national importance that appropriate investments both in infrastructure and human resources be made for future national well-being.

For a country to compete globally in these high-technology areas, the availability of a adequate pool of sufficiently skilled science and technology (S&T) practitioners is essential.

Within the above context physics is indispensable as it is both an enabling science and provides essential training for S&T practitioners. An enabling science is one that operates in a long-term framework, and developments in which underpin future developments and innovations in other sciences and technologies. It is without question that innovations in the four enabling technologies mentioned above have all been based in the first place on physics and physics-related advances, and that this will continue to be so. It is also clear that research and development in key areas such as the biological and medical sciences are increasingly reliant on people who are highly numerate and who have a background in physical sciences.

A decline in physics

In the past decade, the countries briefly reviewed in this report have all experienced, in one way or another, a decline in physics. At the secondary level there is a shortage of skilled mathematics and science teachers, with a concomitant decrease in learners who have the interest or aptitude to study physical science, particularly physics, at the tertiary level. The countries reviewed, with the exception of South Africa and New Zealand, have experienced declining numbers of physics graduates. Funding for physics is under pressure and universities and other physics establishments have been merged, downsized or even closed. Physics as such is not seen as an attractive career, and successful physics graduates are offered higher salaries in other occupations or are attracted to other countries for further studies or employment. Physics is especially not seen as a subject choice or career option by women, but to some extent this is slowly changing.

The reasons for this decline are not readily obvious, especially as physics is experiencing ongoing advances in both basic science and in the application of these advances. As noted earlier, there are many scientific challenges for physics to address. Factors which have probably contributed to the decline are the end of the cold war, with a consequent reduction in budgets for certain types of physics research; the shorter-term approach of governments to return on investments spurred on by privatisation and other policies initially expounded by Margaret Thatcher; the interest in careers in the dot.com, Internet and finance industries; poor pay and working conditions for teachers; and the physics' community inability 'sell' itself to the public at large, when compared with such S&T activities as genetics and space exploration.

Australia and the United Kingdom have recognised that action needs to be taken to reverse the declines that they are experiencing with regard to physics and S&T practitioners in the physical sciences. These actions are at present in the stage of being recommendations, as noted in an earlier chapter.

South Africa's S&T System

The 1990s saw the national science and technology system being examined, reviewed and restructured, and to a large extent this process has come to an end. It is now clear that government has recognised the importance of science and technology in the social and economic development of South Africa, most recently by the announcement of a separate Department of Science and Technology, formed from the S&T branch of the Department of Arts Culture Science and Technology (DACST). DACST, in its medium term expenditure framework strategic plan (April 2002 to March 2005) (DACST 2002), is implementing the main building blocks to enable South Africa to become an innovative and creative nation focused on its future rather than on its past. DACST feels that the national system of innovation (NSI) in South Africa is now capable, effective and well managed. It is, however, far too small for a country of South Africa's size and stage of economic development.

With respect to most indicators of S&T or R&D, South Africa does not fare well. DACST has recognised this and notes that some of the key indicators which will need to be addressed in the medium term are:

- The relatively large annual technology balance of payments deficit (R1.5 billion);
- The low number of researchers as a percentage of the workforce (0.07 percent) in comparison with international norms (Spain 0.3 percent, Australia 0.7 percent);
- The relatively low percentage of GDP spent on research and development (0.7 percent, against an OECD average of 2.15 percent);
- The low rate of formation of biotechnology companies.

The commitment by DACST is reflected in the funding for science, technology and meta-information, which has grown by 64 percent in the four year period ending in the financial year 2001/02 and reaching R685 million, and is projected to increased to R878 million in the next two years (to financial year 2003/04). Most of these funds are distributed to the various science councils and other S&T institutions, including the key Innovation Fund.

DACST has identified key objectives which need to achieved over a ten year or shorter time-frame to improve South Africa's S&T position and thereby its global competitiveness position. For a full list with commentary, see DACST (2002). Some of these objectives and actions are:

- The proportion of matriculants with university exemptions in mathematics and science should increase from the present 19 000 per annum to 36 000 per annum. In support of this more than 100 special schools have been identified.
- Proportion of tertiary students in SET (science, engineering, technology) to increase from the current 27 percent to 40 percent.
- University SET postgraduate output to increase from 3.4 percent to 12 percent of total student enrolment over the next decade facilitated by increased funding for postgraduate education and research.
- Number of SET practitioners per 1 000 of workforce to increase from 0.7 to 2.8 in 2012 by doubling every 5 years.
- Global share of research outputs to increase from the current 0.5 percent to 0.8 percent.
- Funding for SA technology centres of excellence to reach R150 million by 2005.
- Ensure 100 percent take up of S&T funds made available from sponsor countries.
- Business spending on R&D to increase more rapidly than Government spending.
- Proportion of the growth rate of the economy attributable to technical progress to increase from the present 10 percent to 30 percent by 2012.
- The number of US patents secured by South African inventors to increase from the present less than 10 to 100 per year.
- The net 'Intellectual property balance of payments' must become less negative from a present loss of R800 million per year to R300 million per year.

- New missions and focus areas for wealth creation in biotechnology, ICT, advanced manufacturing, smart transformation of resource based industries and smart agro-industries, to be supported to the extent of R200 million per annum per focus area via the Innovation Fund and other sources.

These developments in the national S&T system are indeed very encouraging, and while South Africa has a long way to go to catch-up to S&T levels in industrialised countries, and there are many difficult challenges to be dealt with, the situation for science in South Africa is more positive than it has been for many years.

Science education in South Africa

While government has recognised that there is a problem, if not a crisis, in secondary level education in physical science and mathematics as described in an earlier chapter, and is putting in place measures to address the low numbers of candidates and low pass-rates in these critical subjects, nevertheless the short term situation is bleak, as a correction will necessarily take some time to work its way through the system. Most critical is the shortage of skilled teachers in these subjects. Nevertheless, in general terms of actions, South Africa is slightly ahead of Australia and the UK.

At tertiary level the situation in South Africa is more positive and the trends in the number of graduates in the physical sciences have been upward at the first degree level, doubling over an 11 year period, and more or less flat at the PhD level. This is in contrast to the US, UK and Australia, where downward trends have been the rule. It must be noted that the growth in SA physical science graduates is off a very low base, and in 1997 only 0.55 percent of all first degrees awarded in South Africa were awarded to physical science graduates.

In the period 1987 to 1997 there was an increase in the proportion of bachelor degrees when compared to post-graduate degrees in all disciplines including the physical sciences. This means that bachelor graduates increasingly tended not to undertake further studies. Reasons for this could be that the job market became more attractive, i.e. a perception that further study would not significantly enhance career prospects, or that bachelor graduates increasingly could not afford to study further, or more of them did not qualify to study further. It could also be speculated that students chose to study further overseas.

The SAIP surveys

Physics in South Africa has experienced pressures in the past decade, and this is reflected in the reduced membership of the SAIP from about 550 in 1993, to some 440 at the time of the surveys. Particularly telling was the statistic that some 10 to 16 percent of physics graduates had experienced some form of unemployment in the two year period prior to the surveys i.e. in the time-frame 1997-2000.

The surveys indicate that the physics community is predominantly white and has a low proportion of women involved. This latter situation also occurred in the other countries reported on.

Key points that were made by respondents were that:

- Physics should make itself more relevant to industry and to South African society at large.
- Universities should review their curricula with a view to providing a broader educational experience, more relevant to the needs of industry and business.

Further details of the survey results are provided in chapters 8, 9 and 10.

The state of physics in South Africa

Based on what has been has been presented in this report, it can be said that while South African physics is in some respects in a state of crises in terms of the availability of potential tertiary students with the appropriate skills, the future of physics in South Africa has a greater positive potential than it has had in the past 10 to 15 years. It is up to the physics community to take the initiative and grasp the opportunities that developments in the national system of innovation are offering.

Recommendations

This review is intended to present the current environment of physics, and particularly that of the SAIP, in South Africa, so as to facilitate the ongoing process undertaken by the SAIP of examining and transforming physics in South Africa in the future. It is not the brief of this review to make any far-reaching recommendations regarding physics in South Africa. That is for the stakeholders to do.

Nevertheless, while a number of possible actions may be self-evident from the body of this report, the following recommendations are suggested for further investigation. The funding implications for these recommendations are beyond the scope of this report.

- The physics community, through the SAIP, should ensure that strong linkages are in place between itself and the national system of innovation, so that it can influence the developments that are occurring.

- Embark on a ‘marketing’ campaign to make physical science an attractive subject at school, and physics as a desired course of study at university. This could be in conjunction with DACST, the Department of Education or by private funding from a suitable sponsor. Strategies to particularly focus on young women, and on African, Coloured and Indian potential students should form part of this campaign.

- Provide support to the Department of Education initiative to train more science teachers and to increase the number of matriculants who are successful in higher grade physical science and mathematics. This should be done in a professional way, whether part-time or otherwise, and not in an ad hoc voluntary fashion.

- The physics community in academia and in the science councils should embark on a campaign to form linkages with industry and the business sector.

- University physics departments should review their curricula with a view to making their graduates more relevant to industry and the business sector, and with a view to increasing student numbers. It might also be appropriate to examine whether 21 university physics departments, with an involvement in the output of 348 physical science degrees at all levels in 1997, are not too many in the present situation.

- Request that the appropriate body compiles and maintains statistics regarding student numbers in physics at the tertiary level. Such figures are no longer available. The SAIP could consider becoming the custodian of these, and other relevant statistics regarding physics (e.g. education, industry, academic outputs, employment) so as to ensure that these statistics are collected, and so as to make them conveniently available for future planning, surveys and other investigations. In this regard it is noted that the excellent reference work, ‘SA science and technology indicators’, which was published by the Foundation for Research Development every three years, has not appeared since 1996.

- Examine why more students tend to leave university after obtaining their first degree. As this occurs across all disciplines, this is probably a matter for the university authorities.

- Should there be a requirement for more funds in the SAIP to support additional activities which were noted in chapters 8, 9, and 10, the membership fees could be raised to R200 per annum.

- The SAIP should more actively market itself to the wider physics community and industry and business with the view to increasing membership, funds and its influence.

- The SAIP should particularly concentrate on new female and African, Coloured and Indian members so as to ensure future long-term representivity.

- The SAIP should consider the requests of providing more information to members, particularly by electronic means.

- All SAIP council members should review the recommendations made in ‘SET for success’ (Roberts 2002) to see which might be appropriate and relevant to physics in the broad context in South Africa.

References

DACST. 2002. Department of Arts Culture Science and Technology Strategic Plan: 1 April 2002 - 31 March 2005. Available at http://www.dacst.gov.za

Roberts, G. 2002. SET for success: The supply of people with science, technology, engineering and mathematics skills. The report of Sir Gareth Roberts’ Review April 2002

Appendix 1. The 1999 Electronic Survey questionnaire

\---

Survey of Physicists in South Africa 1999

\---

The South African Institute of Physics is conducting a survey to investigate the present status of physics in South Africa with a view to assessing future directions in our discipline and its applications. It would be greatly appreciated if you could take 15 minutes of your time to complete this questionnaire and thereby play your part in helping to secure the future of physics in South Africa.

All information from the survey will be published only in anonymous, statistical form. No individual information will be released to any other party. Although we request that you supply personal details, it is important to stress that your name and contact details are required only to enable us to reach you for possible follow-up questions, for instance in connection with the open-ended questions. Should you nevertheless not wish to respond to one or two questions, we appeal to you to complete the rest of the survey and submit it to us.

It is important that the response to the survey represents a significant sample of our physics community, and hence we are appealing also to physicists who are not members of SAIP to participate.

Please also assist us by distributing the survey to all other physics graduates who may not have received a questionnaire, as they are not on our database.

Please complete this electronic survey only once, even if you should receive it from more than one source.

Thank you for participating, and responding timeously.

Professor Manfred Hellberg
President, SAIP

Please respond within the square brackets [ ] and place an X in [ ] to answer YES where appropriate. Please complete this electronic questionnaire once only even if you may receive it from more than one source.

PLEASE SEND YOUR RETURNS TO saip@roger.phy.unp.ac.za before 15 March 1999.

SECTION A: Personal Details

1. Surname [ ]
   Name [ ]

2. Institution or employer [ ]

3. Mailing address [ ]
   E-mail [ ]
   Telephone number [ ]
   Fax number [ ]

4. Membership of professional societies - please specify [ ]

SECTION B: Physics Background

1. Level of education
[ ] BSc
Major Subjects [ ]
[ ] BSc (Hons)
Subject [ ]
[ ] MSc
Field of specialization [ ]
[ ] PhD
Field of specialization [ ]
[ ] Other, please describe [ ]

2.a At which University did you obtain your Bachelors degree? If outside South Africa, in which country?
[ ]

2.b In which year did you obtain your Bachelors degree?
19 [ ]

2.c At which University did you obtain your highest degree? If outside South Africa, in which country?
[ ]

2.d In which year did you obtain your highest degree?
19 [ ]

3. Professional self-identification
[ ] Applied/ Industrial Physicist
[ ] Computational Physicist
[ ] Experimental Physicist
[ ] Scientific or Technical manager
[ ] Theoretical Physicist
[ ] Other, please describe [ ]

4. Physics specialization in (place a '1' next to your primary field of specialization and place a '2' next to your secondary field of specialization)

[ ] Acoustics
[ ] Astronomy/ Astrophysics/ Cosmology
[ ] Atmospheric Sciences
[ ] Atomic & Molecular Physics
[ ] Biophysics
[ ] Chemical Physics
[ ] Condensed Matter/ Solid State Physics
[ ] Crystallography
[ ] Electronics/ Electrical Engineering
[ ] Elementary Particles & Fields, High Energy Physics
[ ] Fluid Dynamics
[ ] Low Temperature Physics
[ ] Material Science & Engineering/ Metallurgy
[ ] Mathematical Physics
[ ] Medical Physics
[ ] Nuclear Physics
[ ] Ocean Sciences
[ ] Optics
[ ] Physics Education, School
[ ] Physics Education, Tertiary
[ ] Plasma Physics
[ ] Radiological Physics
[ ] Space Physics

[ ] Other, please describe [ ]

5. If you are working outside a tertiary institution would you be prepared to co-supervise a Masters student?
[ ] Yes
[ ] No

6. It has been suggested that South African tertiary institutions do not adequately prepare students for employment outside academia.
a What gaps in the undergraduate curriculum do you feel need to be filled?
[ ]

b Briefly, what material in the undergraduate curriculum do you perceive to be redundant?
[ ]

SECTION C: Career

1.a Are you currently
[ ] A student
[ ] Employed in a permanent capacity
[ ] Employed in a temporary capacity for less than 1 year
[ ] Employed on contract of 1 year or more
[ ] Retired
[ ] Unemployed

b If employed, what is your job title?
[ ]

2.a Have you been unemployed in the past 5 years?
[ ] Yes
[ ] No

2.b If you have been unemployed and seeking employment in the last 5 years, for how long were you seeking employment?
[ ] Less than 6 months
[ ] 6 months to 1 year
[ ] 1 to 2 years
[ ] More than 2 years

3. How long have you been employed in total?
[ ] Less than 10 years
[ ] 10-20 years
[ ] More than 20 years

4. What kind of employing body do you currently work for?
[ ] Communications
[ ] Computer Software/ Hardware
[ ] Construction
[ ] Education
    - [ ] University
    - [ ] Technikon
    - [ ] Other (tertiary)
    - [ ] Secondary
[ ] Financial/ insurance
[ ] Legal services/ consulting
[ ] Manufacturing
[ ] Mining/ extraction
[ ] Publishing
[ ] Research
    - [ ] Industrial

  - [ ] National facility
  - [ ] Other statutory research organization

[ ] General business
[ ] Hospital or medical services
[ ] Services, repair or maintenance
[ ] Utilities
[ ] Other, please describe [ ]

5. Please indicate the extent to which you are engaged in each of the following aspects of work in your present position (use a 5 point scale where '1' = "extensively" and '5' = "not at all")

[ ] Physics content knowledge, at what level?

  - [ ] First year
  - [ ] Second year
  - [ ] Third year
  - [ ] Honours
  - [ ] MSc
  - [ ] PhD

[ ] Computer skills
[ ] Interpersonal skills
[ ] Lab/ Instrumentation skills
[ ] Managerial skills
[ ] Mathematical skills
[ ] Modelling skills (numerical or physical)
[ ] Problem solving skills
[ ] Verbal communication
[ ] Written communication

6. Evolution of career (specifically those that have been employed for several years already - please summarize your employment history briefly)

EXAMPLE:
1982-1983 Lecturer at ML Sultan Technikon.
1983-1985 Research scientist at Eskom.
1985-1990 Technical advisor Eskom.
1990-1996 General manager, planning at De Beers.
1996-present Business and consulting in software development.

[ ]

Section D: South African Institute of Physics (SAIP)

1. Are you a member of the SAIP?
[ ] Yes
[ ] No

2.a If no, would you like to become a member?
[ ] Yes
[ ] No

b If you would not like to become a member, please give reasons [ ]

3. What benefits of SAIP membership do you regard as important?
[ ]

4. What additional features/ activities would you wish to see SAIP provide to its members?
[ ]

5. By comparison with a number of professional societies, SAIP

membership dues are low.
[ ] a Should additional activities be available, but only at a price?
b What level of membership dues would you deem acceptable?
[ ]

6. The SAIP has a relatively small fraction of members employed outside academia. Do you have suggestions as to how the SAIP can become more relevant to the wider group of physics graduates?
[ ]

Section E: General

Additional comments relating to physics in South Africa and to the SAIP in particular.

[ ]

Additional comments relating to this particular survey and how it could be improved for the future.

[ ]

Section F:INFORMATION FOR STATISTICAL PURPOSES:

Answers to the following questions will be used purely for statistical purposes, and will be separated from the rest of the questionnaire.

1. Gender
[ ] Male
[ ] Female

2. Are you
[ ] African
[ ] Coloured
[ ] Indian
[ ] White
[ ] Other, please specify.

3. Age [ ]

4. Remuneration per annum (full package)
[ ] Less than R 50 000
[ ] R 50 000 - R 100 000
[ ] R 100 000 - R 150 000
[ ] R 150 000 - R 200 000
[ ] R 200 000 - R 250 000
[ ] R 250 000 - R 300 000
[ ] More than R 300 000

Appendix 2. The HSRC Survey questionnaire

Survey of Physics Graduates, South Africa 2000

Please place an X in [ ] to answer YES where appropriate.

Please complete this questionnaire even if you have responded to a similar electronic survey.

PLEASE SEND YOUR RETURNS IN THE ATTACHED FREE-POST ENVELOPE TO THE HSRC BEFORE 31 OCTOBER 2000

SECTION A: Personal details

1. Surname:________________________
   Name:__________________Title:______
2. Institution or employer:__________________
3. Mailing address:______________________
   __________________ Postal code:_____
4. E-mail:__________________________
5. Telephone number:___________________
6. Cell pone:_________________________
7. Fax number:_______________________

SECTION B: Physics background

1. **Level of education:**

[ ] BSc Major subjects:___________________
[ ] BSc (Hons) Subject:___________________
[ ] MSc Field of specialisation:______________
[ ] PhD Field of specialisation:______________
[ ] Other, please describe:_________________

2.a At which university did you obtain your Bachelors degree? If outside South Africa, in which country? ____________

2.b In which year did you obtain your Bachelors degree? ______

2.c At which university did you obtain your highest degree? If outside South Africa, in which country?____________

2.d In which year did you obtain your highest degree? ______

3. **Professional self-identification**

[ ] Applied/Industrial Physicist [ ] Computational Physicist
[ ] Experimental Physicist [ ] Scientific or technical manager
[ ] Theoretical Physicist
[ ] Other, please describe:_________________

4. Physics specialisation (place a ‘1’ next to your primary field of specialisation and place a ‘2’ next to your secondary field of specialisation)

[ ] Acoustics
[ ] Astronomy/Astrophysics/Cosmology
[ ] Atmospheric Sciences [ ] Atomic & Molecular Physics
[ ] Biophysics [ ] Chemical Physics
[ ] Condensed Matter/Solid State Physics
[ ] Crystallography [ ] Electronics/Electrical Engineering
[ ] Elementary Particles & Fields, High Energy Physics
[ ] Fluid Dynamics [ ] Low Temperature Physics
[ ] Material Science & Engineering/Metallurgy
[ ] Mathematical Physics [ ] Medical Physics
[ ] Nuclear Physics [ ] Ocean Sciences
[ ] Optics [ ] Physics Education, School
[ ] Physics Education, Tertiary [ ] Plasma Physics
[ ] Radiological Physics [ ] Space Physics
[ ] Other, please describe:___________________

5.a Did you receive financial support during your physics studies?

[ ] Yes [ ] No

5.b If yes, please indicate phase and source of support:

Codes:
During B degree = 1
During Honours degree = 2
During MSc/Mtech = 3
During PhD = 4
Less than ⅓ of cost = a
Less than ⅔ = b
Equal/more than ⅔ = c

FRD/NRF______________
Other science council________
University of technikon_______
Other public sector support_____
Private sector support________
Foreign support___________
[ ] Other______________

6. If you are working outside a tertiary institution would you be prepared to co-supervise a Masters student? [ ] Yes [ ] No

7. It has been suggested that South African tertiary institutions do not adequately prepare students for employment outside academia.

7.a What gaps in the undergraduate curriculum do you feel need to be filled?_________________________
____
____

7.b Briefly, what material in the undergraduate curriculum do you perceive to be redundant?____________________
____
____

SECTION C: Career

1.a Are you currently

[ ] A student [ ] Employed in a permanent capacity
[ ] Employed in a temporary capacity for less than 1 year
[ ] Employed on contract of 1 year or more
[ ] Self employed
[ ] Retired [ ] Unemployed

1.b If employed, what is your job title?______________

2.a Have you been unemployed in the past 5 years?

[ ] Yes [ ] No

2.b If you have been unemployed and seeking employment in the last 5 years, for how long were you seeking employment?

[ ] Less than 6 months [ ] 6 months to 1 year
[ ] 1 to 2 years [ ] More than 2 years

3. How long have you been employed in total?

[ ] Less than 10 years [ ] 10-20 years
[ ] More than 20 years

4. What kind of employing body do you currently work for?

[ ] Communications [ ] Computer Software/hardware
[ ] Construction [ ] Education University
[ ] Education Technikon [ ] Education Other (tertiary)
[ ] Education Secondary [ ] Financial/insurance/banking
[ ] Legal services/consulting [ ] Manufacturing
[ ] Mining/extraction [ ] Publishing
[ ] Research industrial [ ] National research facility
[ ] General business [ ] Hospital or medical services
[ ] Services, maintenance [ ] Utilities
[ ] Other, please describe:______________________________

5. Please indicate the extent to which you are engaged in each of the following aspects of work in your present position (use ea 5 point scale, where'1' = "extensively", and '5' = "not at all").

[ ] Physics content knowledge. At what level?
    [ ] First year [ ] Second year
    [ ] Third year [ ] Honours
    [ ] MSc [ ] PhD
[ ] Computer skills [ ] Interpersonal skills
[ ] Lab/Instrumentation skills [ ] Managerial skills
[ ] Mathematical skills
[ ] Modelling skills (numerical or physical)
[ ] Problem solving skills [ ] Verbal communication
[ ] Written communication

6.a Evolution of career (specifically those that have been employed for several years already – please summarize your employment history briefly)

____
____
____
____
____

6.b How many persons report to you in the work environment?
____

6.c What is the total budget that you are responsible for? R_____
6.d In how many publications are you the author/co-author?____
6.e In how many successful patents have you been involved?___
6.f Membership of professional societies – please specify:

____
____
____
____
____

SECTION D: South African Institute of Physics (SAIP)

1. Are you a member of the SAIP? [ ] Yes [ ] No

2.a If no, would you like to become a member? [ ] Yes [ ] No

2.b If you would not like to be a member, please give reasons

____

3. What benefits of SAIP membership do you regard as important?

____
____
____

4. What additional features/activities would you wish to see SAIP provide to its members?

____
____
____

5. By comparison with a number of pr0fessional societies, SAIP membership dues are low.

5.a Should additional activities be available, but only at a price?
[ ] Yes [ ] No

5.b What level of membership dues would you deem acceptable?

____

6. The SAIP has a relatively small fraction of members employed outside academia. Do you have suggestions as to how the SAIP can become more relevant to the wider group of physics graduates?

7. Do you see the SAIP as an organisation that embraces equity (gender, race, etc)? Please comment:

SECTION E: Statistical information

Answers to the following questions will be used purely for statistical purposes, and will not be linked to your name.

1. Gender: [ ] Male [ ] Female

2. Are you [ ] African [ ] Coloured
[ ] Indian [ ] White
[ ] Other, please specify:___________________________

3. Age:_____________________

4. Remuneration per annum (full package):

[ ] Less than R50 000 [ ] R50 000-R100 000
[ ] R100 000-R150 000 [ ] R150 000-R200 000
[ ] R200 000-R250 000 [ ] R250 000-R300 000
[ ] More than R300 000