

A comparative analysis of school physics curriculum content in selected countries

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Abstract. Meaningful curriculum reform is central to the provision and acquisition of globally relevant scientific skills. A globally competitive curriculum fosters the cultivation of skills required for sustainable economic growth and development. In addition, it is imperative to harness the affordances associated with the provision of intellectually stimulating school physics curriculum content in order to foster the development of cognitive and reflective skills. In response to this key imperative, a comparative analysis of school physics curriculum content in selected countries was carried out with a view to identify levels of commonalities and the depth up to which each curriculum extends. Analysis of school physics curriculum content in selected countries revealed striking inherent characteristic features that serve to provide the structural differentiation between these curricula. The level of economic growth and development in selected countries appeared to be a function of the quality and depth of the school physics curriculum content. Theoretical implications for meaningful curriculum reform are discussed.

1. Introduction

Curriculum reform has been a key area of concern for both developed and developing countries in a bid to consolidate the structural imperatives that characterise their education systems. The development of cognitive and reflective skills is central to a coherent overhaul of any education system as a key outcome of a globally competitive curriculum. While most countries have made substantial progress in overhauling their education systems, secondary education in particular remains a weak link in the education chain in many countries [1]. This study provides a comparative analysis of school physics curriculum content in selected countries with a view to identify levels of commonalities and the depth up to which each curriculum extends.

2. Secondary education reform

Secondary education reform ought to serve as a key pillar for strengthening sustainable economic growth and development. The democratic breakthrough in South Africa engendered significant curriculum reforms as a means to adequately and innovatively respond to the constantly changing global environment. Given the centrality of global imperatives in shaping education systems in various countries, South Africa undertook rigorous and far-reaching curriculum reforms with a view to fully embrace profound ramifications associated with the fourth industrial revolution. The introduction of Curriculum 2005 [2] was in many ways an ambitious enterprise to radically reform education in South Africa and outcomes-based education was the underlying principle of this curriculum reform. Inherent problems associated with the implementation of Curriculum 2005 necessitated its review culminating in the promulgation of the National Curriculum Statement [3]. The National Curriculum Statement underwent a further metamorphosis resulting in the promulgation of the Curriculum and Assessment Policy Statement [4].

Curriculum reform was in a global sense also underpinned by significant and fundamental transformative evolution. Secondary education in the Asia-Pacific region has been characterised by rapid expansion in response to an increasing demand for skilled manpower, economic growth and strong private requirements [1]. Consequently, some of the varied approaches adopted by different countries in this region in developing the structure of secondary education included diversifying the curriculum, financing institutions and student support and assessing student-learning performance. Curriculum reform was the major driving force in the improvement of the quality of secondary education in the Asia-Pacific region. Some of the detailed strategies that were developed to adequately address curriculum reform include the improvement of the quality and scope of vocational education, strengthening science and technology education, developing competence in information technology skills by introducing or expanding the use of information technology in the classroom, as well as focusing on the teaching of a wide range of cognitive, social and personality skills so as to develop the capacity for flexibility, problem-solving, creativity, initiative and life-long learning [5].

While secondary education reform process in Eastern Europe was largely influenced by political and economic factors, the rules of the game that resulted in good educational outcomes changed significantly [6]. In the main, educational change in this region can be described in terms of four key characteristics [7]: (a) depolarization of education (i.e., the end of the ideological control of the system); (b) breaking down of the state monopoly in education by allowing private and denominational schools to be established; (c) increased choices in schooling options; and (d) decentralization in the management and administration of the education system (in particular the emergence of school autonomy). Although the education systems in Latin America and the Caribbean reflected relatively high enrolment rates at the primary and secondary levels during the latter part of the 20th century, there were significant problems with regard to quality and relevance of instruction [8]. In fact, the system was bedevilled by a bimodal distribution of enrolment [9], which provided a skewed picture in terms of both school and university attendance and completion. The revamping of secondary education in this region primarily focused on aspects such as curriculum structure, teacher training, student evaluation, development of technological infrastructure and management [10].

Arab States also undertook a series of educational reforms to overhaul their education systems. While educational reform in the Arab States was previously aimed at the elimination of high illiteracy rate, the education reform policies have of late been geared towards quality and equity in education [11]. In addition, educational reforms in this region reflected different sources of funding for education [12]. This scenario is in stark contrast with educational reform initiatives in other countries. Secondary education reform in Sub-Saharan Africa has also been an area of increased focus over many years. The quality of education in this region was eroded by a skewed provision of resources in favour of basic and higher education at the expense of secondary education [13]. Suffice to indicate that substantial growth in secondary education in this region was characterised by a general shift in emphasis from vocational training to general secondary education [14].

3. Theoretical framework

Comparative analysis of school Physics curriculum content in selected countries was underpinned by a Product-Process Framework [15] as the underlying theoretical framework illustrated in Figure 1 below. This framework consists of three continuums. The first continuum, [Product (Dimension 1): Broad conceptual content versus Descriptive factual content], is used to identify the organisation of content. The second continuum, [Product (Dimension 2): Pure content versus socially applied content], is used to identify the nature of Physics content. The third continuum, [Process dimension: Intellectual process skills versus Practical process skills], is used to identify the skills valued in the Physics curricula.

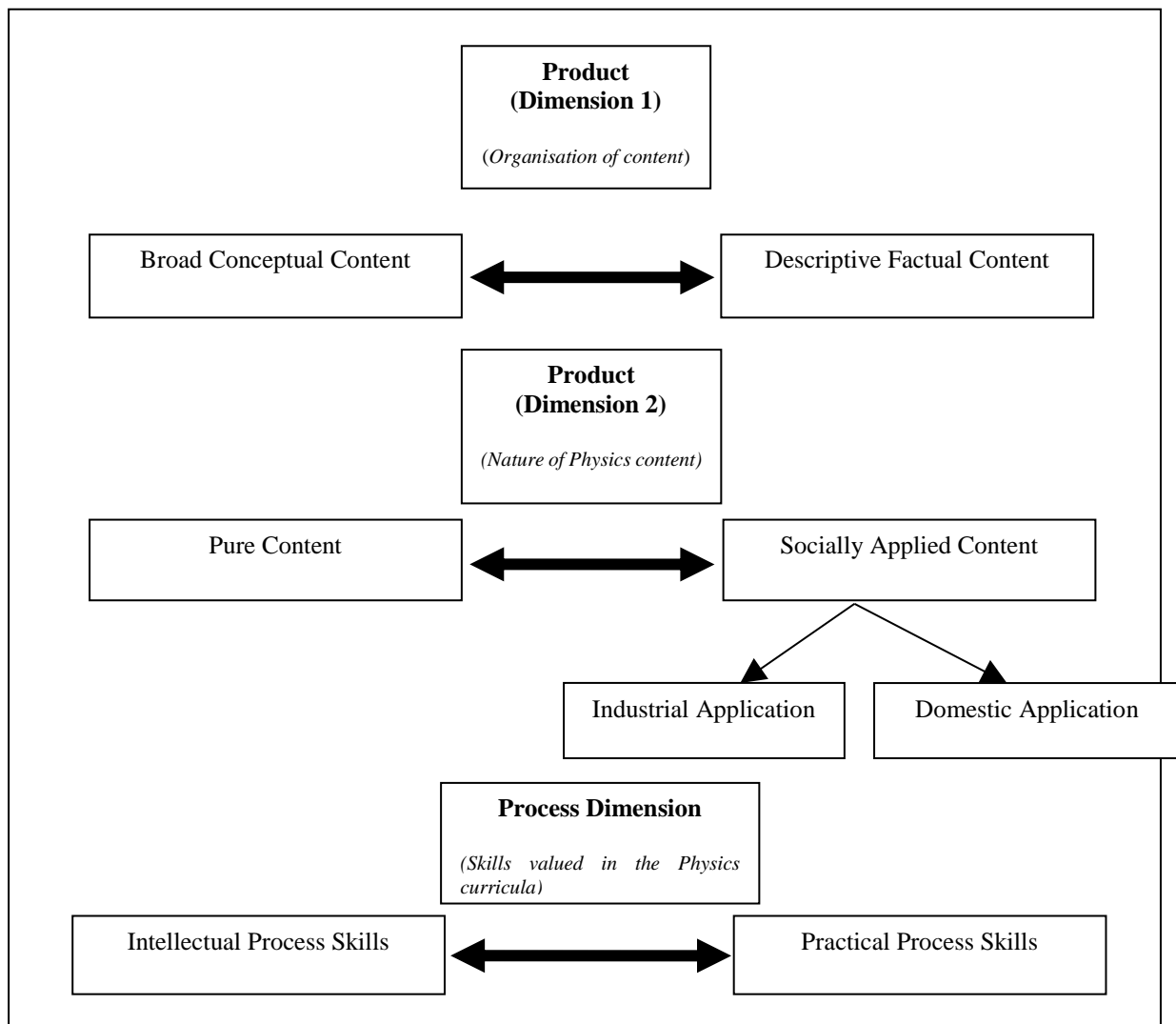


Figure 1: Bailey's (1978) Product-Process Framework

4. Comparative analysis of school Physics curriculum content in selected countries

The countries selected for comparative analysis of secondary education Physics curriculum are India, Ghana and South Africa. Ghana represents in this particular context West African countries which have historically embraced the Cambridge A Level and O Level Physics curricula [16, 17]. The structure of the Indian secondary education Physics curriculum [18] is illustrated in Table 1 below. In terms of broad conceptual content, the curriculum provides more emphasis on basic conceptual understanding of the content through detailed description of factual content. Furthermore, the curriculum exposes the learners to different processes used in Physics-related industrial and technological applications (Industrial Application). The Domestic Application component of the curriculum is not clearly articulated though. The curriculum provides opportunities for Intellectual Process Skills as it promotes the development of process-skills and experimental, observational, manipulative, decision making and investigatory skills in the learners. In terms of Practical Process Skills, every learner is afforded the opportunity to perform 10 experiments (5 from each section) and 8 activities (4 from each section) during the academic year. In addition, two demonstration experiments must be performed by the teacher with participation of learners with learners maintaining a record of these demonstration experiments. This is augmented by a Practical Examination based on a clearly defined evaluation scheme. The striking characteristic feature with regard to the Indian secondary education Physics curriculum is that Physics and Chemistry are treated as two separate components and this is in stark contrast to the South African Further Education

and Training Physical Sciences Curriculum. On close scrutiny, the level of depth of the Indian secondary education Physics curriculum reveals that Physics topics taught at university in South Africa are covered at secondary school in India.

Table 1: Indian secondary education Physics curriculum content

STRUCTURE OF THE SYLLABUS: INDIAN SECONDARY EDUCATION PHYSICS CURRICULUM	
CLASS XI	CLASS XII
Physical World and Measurement Kinematics Laws of Motion Work, Energy and Power Motion of System of particles and Rigid Body Gravitation Properties of Bulk Matter Thermodynamics Behaviour of Perfect Gas and Kinetic Theory of gases Oscillations and Waves	Electrostatics Current Electricity Magnetic effect of current and Magnetism Electromagnetic Induction and Alternating current Electromagnetic Waves Optics Dual Nature of Matter Atoms and Nuclei Electronic Devices Communication Systems
Practicals: Every student performs 10 experiments (5 from each section) and 8 activities (4 from each section) during the academic year.	

The structure of the A Level and O Level Physics curricula is provided in Table 2 below. The only difference between AS levels and A levels is that AS levels can be taken as a stand-alone qualification, or as the first part of an A level course. The first level of A levels is called AS level, the normal duration of which is one year. The A Level and O Level Physics curricula make provision for a Practical Assessment (Practical Process Skills) designed to assess the learner's competence in those practical skills which can realistically be assessed within the context of a formal test of limited duration. The learners pursue a comprehensive course in practical Physics during which they are being taught theoretical content. In line with broad conceptual content imperatives, the curriculum provides a thorough introduction to the study of Physics and scientific methods through detailed description of factual content. In addressing the need for Intellectual Process Skills, these curricula make provision for the development of skills (such as accuracy and precision, objectivity, integrity, the skills of inquiry, initiative and inventiveness) and abilities that are relevant to the safe practice of science and to everyday life (Domestic Application). In addition, these curricula also strive to enable learners to become confident citizens in a technological world (Industrial Application) and to take an informed interest in matters of scientific importance such as the promotion of the use of Information Technology (IT) as a tool for the interpretation of experimental and theoretical results (Practical Process Skills). The A Level and O Level Physics curricula demonstrate some level of adequate depth as compared to the South African Further Education and Training Physical Sciences Curriculum. As is the case with the Indian secondary education Physics curriculum, the A Level and O Level Physics curricula make provision for Physics and Chemistry to be taught as two separate components.

Table 2: A Level Physics and O Level Physics curriculum content

A LEVEL PHYSICS AND O LEVEL PHYSICS CURRICULUM CONTENT		
AS LEVEL PHYSICS	A LEVEL PHYSICS	O LEVEL PHYSICS
Physical quantities and units Measurement techniques Kinematics Dynamics Forces, density and pressure Work, energy and power Deformation of solids Waves Superposition Electric fields Current of electricity Direct current circuits Particle and nuclear physics	Motion in a circle Gravitational fields Ideal gases Temperature Thermal properties of materials Oscillations Communication Capacitance Electronics Magnetic fields Electromagnetic induction Alternating currents Quantum physics	General Physics Newtonian Mechanics Energy and Thermal Physics Waves Electricity and magnetism Atomic Physics
Practical assessment	Practical assessment	Practical assessment

The structure of the curriculum content in relation to the South African Further Education and Training Physical Sciences Curriculum [4] is depicted in Table 3 below. The South African Further Education and Training Physical Sciences Curriculum seeks to prepare learners for future learning, specialist learning, employment, citizenship, holistic development, socio-economic development and environmental management by developing competences in the following three focus areas: scientific inquiry and problem solving in a variety of scientific, technological, socio-economic and environmental contexts (Intellectual Process Skills); the construction and application of scientific and technological knowledge (Practical Process Skills); and the nature of science and its relationship to technology, society and the environment (Industrial Application and Domestic Application).

Table 3: South African Further Education and Training Physical Sciences Curriculum content

SOUTH AFRICAN FURTHER EDUCATION AND TRAINING PHYSICAL SCIENCES CURRICULUM CONTENT		
Mechanics	Grade 10	Introduction to vectors & scalars, Motion in one dimension, Energy
	Grade 11	Vectors in two dimensions, Newton's Laws and Application of Newton's Laws
	Grade 12	Momentum and Impulse, Vertical projectile motion in one dimension (1D) Work, Energy & Power
Waves, Sound & Light	Grade 10	Transverse pulses on a string or spring, Transverse waves, Electromagnetic radiation
	Grade 11	Geometrical Optics, 2D & 3D Wave fronts (Diffraction)
	Grade 12	Doppler Effect
Electricity & Magnetism	Grade 10	Magnetism, Electrostatics, Electric circuits
	Grade 11	Electrostatics, Electromagnetism, Electric circuits
	Grade 12	Electric circuits, Electrodynamics
Matter & Materials	Grade 10	Matter and classification, States of matter and the kinetic molecular theory, Atomic structure, Periodic table, Chemical bonding
	Grade 11	Molecular structure, Intermolecular forces, Ideal gases
	Grade 12	Optical phenomena and properties of materials, Organic chemistry, Organic macromolecules
Chemical Systems	Grade 10	Hydrosphere
	Grade 11	Lithosphere (mining; energy resources)
	Grade 12	Chemical industry (fertilizer industry)
Chemical Change	Grade 10	Physical and chemical change, Reactions in aqueous solution
	Grade 11	Stoichiometry, Energy and chemical change, Types of reactions
	Grade 12	Reaction rate, Chemical equilibrium, Acids and bases
Skills for practical investigations	Grade 12	Skills for practical investigations in physics and chemistry

The South African Further Education and Training Physical Sciences Curriculum consists of six core knowledge areas: two with a Chemistry focus – Chemical Systems and Chemical Change; three with a Physics focus – Mechanics; Waves, Sound and Light; Electricity and Magnetism; and one with an integrated focus – Matter and Materials. A major structural deficiency of the South African Further Education and Training Physical Sciences curriculum is that it does not make provision for Physics and Chemistry to be taught as separate components as is the case in West African countries. While the curriculum provides opportunities for learners to perform practical work, this is not augmented as a logical imperative by a clear practical assessment process to evaluate the practical skills acquired by the learners.

5. Economic growth levels in selected countries

Economic considerations paint a rather interesting picture with regard to the countries selected. More specifically, the South African economy grew 0.8% year-on-year in the first quarter of 2018 [19]. The gross domestic product (GDP) growth rate in India was 7.36% in 2018 [19]. Ghana's economy grew 6.8% year-on-year in the first quarter of 2018 [19]. Clearly, South Africa's demonstrated inadequate economic performance during the period under review as compared to India and Ghana. South Africa faces a real challenge to generate adequate levels of economic growth and development in order to reassert its place within the global community of nations. The gross domestic product of any country is crucially dependent on the quality of human capital development which is the outcome of the provision of quality education. It is imperative for South Africa to conceptualise and implement a globally competitive Further Education and Training Physical Sciences Curriculum geared towards strengthening sustainable economic growth and development on a broader scale.

6. Conclusion

The South African Further Education and Training Physical Sciences Curriculum appears to be inherently shallow as compared to curricula offered in other countries. South Africa has a moral obligation to harness the potential of its education system in order to develop and strengthen its competitive edge in the global arena. This can possibly be accomplished through epoch-making and crucial steps such as undertaking significant and far-reaching curriculum reforms with a view to develop much needed human capital for meaningful competitive advantage. The need for South Africa to provide a globally competitive curriculum for meaningful enhancement of human capital development is paramount.

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