Learning from Africa: Science

A report of Umalusi's research comparing Science syllabuses and examinations in South Africa with those in Ghana, Kenya, and Zambia

An Umalusi Research Report
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Introduction

This short subject report is an addendum to the report emanating from an Umalusi study aimed at understanding how the South Africa senior secondary school certificate compares with those of three other African countries. The full research report is entitled *Learning from Africa: A report of Umalusi's research comparing syllabuses and examinations in South Africa with those in Ghana, Kenya, and Zambia*. The research, in comparing South Africa's Matric certificate with the senior secondary school certificates of Ghana, Kenya, and Zambia, explored various aspects of the curriculum and examinations systems, including the intended and examined curriculum in four subjects.

The aim of the research was to learn from English-speaking African countries in different regions, in order to contribute to improving the intended and examined curricula in the Further Education and Training band in South Africa. Umalusi believes that it is valuable to understand our systems better by considering those in other countries, and hopes that this kind of comparative analysis will allow South Africans to stand back and achieve a distance from our internal debates. The research also cautions South Africa not to assume that our education system is superior to those found elsewhere in Africa.

The South African context of the research is a new curriculum which is in the process of being implemented in the Further Education and Training (FET) phase (senior secondary school). The FET phase, which covers the final three years of secondary schooling (Grades 10 to 12), culminates in the National Senior Certificate, the certificate which is to replace the current Senior Certificate. The implementation of the new curriculum began in Grade 10 in January 2006, and the first cohort of

Grade 12 learners will write the new National Senior Certificate in 2008.

The research aimed to understand how South Africa compares with the other countries, in terms of both the old the curriculum and examinations, which were still in use at the time of conducting the research, as well as the new curriculum. It attempted to understand what we can learn from the other countries with regard to systemic issues, as well as lessons for our new curricula and examinations on the basis of the subject comparison.

The study was conducted through meetings and open-ended interviews with officials in all four countries, supplemented by documentary information. Syllabus—and 2004 examination documentation was collected from each country and analyzed by groups of South African experts.

The full report provides a synthesis of what was learnt from the comparative study. It deals mainly with three issues:

- An overview of aspects of the education systems in the four countries. i.e. years in school, examinations and certification;
- A brief overview of comparisons of the intended and examined curriculum in four subjects at school-exit level, i.e. Biology, Science, English and Mathematics;
- Some reflections on the new curriculum in South Africa.

This short subject report, which provides a more detailed analysis of what evaluators found in their comparison of the Science courses across the four countries, should ideally be read in conjunction with the main report.

The draft base report, which contains more detailed elaborations of the findings, is available on Umalusi's website as *Evaluating syllabuses and examinations: An Umalusi technical report comparing the syllabuses and examinations from Ghana, Kenya, South Africa and Zambia*, and may be of interest to subject experts.

Science courses in the four countries

Table 1 below shows the Science courses offered for each of the four senior secondary school certificates in the study, the requirements for learners with regards to these subjects, and which of them are included in the analysis of Science courses in this study. The text below the table provides further explanation and elaboration.

Table 1: Science courses in the four countries

Certificates	Courses in the study	Science subjects excluded from this study	Rules of combination for science subjects
Ghana Secondary Senior School Certificate	Physics Chemistry	Integrated Science	Integrated Science is compulsory for all learners, Physics and Chemistry are elective.
Kenya Secondary School Certificate	Chemistry Physics	Biology (addressed in Biology report)	Learners must select two Science courses.
Zamiba School Certificate	Science Physics Chemistry		Learners must select one Science course.
South Africa Senior Certificate (old)	Physical Science, Higher Grade Physical Science, Standard Grade		Elective
South Africa National Senior Certificate (new)	Physical Science		Elective

Ghana and Zambia both have an integrated Science course. In Ghana, the subject is called Integrated Science and covers a broad range of topics which are not readily comparable to those studied in physical science-related courses, and evaluators felt that it was not appropriate to compare this course to the Physical Science, Physics, or Chemistry courses of other countries. For completeness, a table of the content of this course is available on Umalusi's website (www.umalusi.org.za). This course is compulsory for all learners in Ghana, but in addition they can choose to enroll for elective Physics and/or Chemistry as final examination subjects.

In Zambia, the system offers learners three options, one of which learners are obliged to choose for matriculation. The Chemistry and Physics courses are taken by relatively small numbers of learners. The combined course, simply called Science, is taken by far the majority of Zambian learners. The curriculum documentation supplied by the Zambian education authorities on their Physics course was incomplete and Umalusi was unable to obtain complete documentation. Solely for this reason, this course has been excluded from the analysis.

In Kenya, learners must enroll for two Science subjects, choosing from Physics, Chemistry, and Biology. There was originally a Kenyan Secondary School Certificate subject that combined the three. Biology was then made into a separate subject, and about ten years ago, Physics and Chemistry were split because higher education institutions complained that learners were not sufficiently exposed to the necessary content in the subjects. The current belief in Kenya is that the new system is more appropriate.

In the old South African system, there were two science courses, one at Higher and one at Standard Grade, both of which included Physics and Chemistry. Neither course was compulsory, so learners could matriculate without a science subject in their certificate. Biology functioned as a separate subject, and was not included in the South African Physical Science curriculum. The Physical Science course was taught over three years, and consisted of a Physics and a Chemistry component, each of these being given an equal weighting. The same topics were taught in both Higher and Standard Grades, but the depth at which they are taught differed slightly.

The new South African curriculum currently being phased in consists of a Physics and a Chemistry component, each of which is given an equal weighting. In contrast to the old system where the course was offered at two levels, namely Higher grade and Standard grade, the new course is only offered at one level.

While South Africa had 161 214 candidates write the Science examination in 2004 (that is, almost 28% of all who wrote matric that year), 40% more candidates than Ghana, and 48% more than Zambia, these absolute numbers do not tell the whole story. Ghana's figure represents 100% of all the learners writing their matriculation examination in that year, while Zambia's 76 904 represents 91% of the high school leaving candidates for that year. The remaining 9% of Zambian school leavers (barring the absentees) also wrote a science subject, but this time a specialized elective in either Physics or Chemistry. Given that all Kenyan candidates are required to do at least two science subjects, these figures suggest that all school leavers in Kenya, Ghana and Zambia will have had exposure to some form of science as a subject right up to their last year in school, while this is patently not the case in the South African education system. While it is clear that the majority of learners in the countries north of South Africa are exposed to a more general, integrated science curriculum, these learners also have the opportunity to choose to study Physics and/or Chemistry in greater detail while still at school. This is not the case in South Africa, where not even the general science curriculum is compulsory in the last years of school.

Even this very brief overview of the four sets of courses suggests that there are significant differences in terms of:

- Whether some form of science course is compulsory or not;
- Whether the compulsory course has options from which the learners themselves select;
- Whether additional elective science subjects are available as alternatives to the integrated science subject;
- Whether, as is the case in South Africa, there are different levels at which the subject can be taken, and different boards which examine the same curriculum;
- The proportion of the total senior high school-leaving

population which has one or more science subjects as a part of the senior high school certificate.

The four sets of Science courses are not easily comparable, since some incorporate the natural sciences while the others do not. Some of the courses are compulsory, but may retain an element of choice. Others, as in the South African case, are entirely optional. These and other variations prevent a simple, direct comparison of the courses. The Physical Science component of this research consists of an analysis of nine sets of curriculum documents of very different courses, and as a result did not achieve the depth of comment that could otherwise be achieved if a fewer number of courses were to be studied.

Nevertheless, the analysis of the different courses raises issues which are both pertinent and interesting.

The intended curriculum

Overview

The general structure of the curriculum documentation is similar, in that they all have a fairly traditional approach with regard to the aims, coherence, sequence and progression and organizing principle. The pacing on the whole is not sufficiently spelled out by any of the courses to give teachers an idea of the depth expected in each of the topics.

Aims

All the curricula contain lists of general objectives, and all have specific objectives as well, except the new South African curriculum statements, where outcomes play a similar role. There is a focus on application in Kenyan syllabuses, as well as a focus on the development of practical skills.

The Kenyan Physics and Chemistry syllabuses both contain a clear list of general objectives, as well as a list of specific objectives associated with each content topic. Application of each topic is explicitly mentioned. The general objectives also make a connection between the knowledge acquired and further education and training. The general objectives of the Physics syllabus place strong emphasis on application of Physics to the environment, society and industry, which is also reinforced in the content specification, where application of each topic is explicitly mentioned. An emphasis on the development of practical skills, and on integrity and positive attitudes towards science are also consistent elements of the syllabus. The Kenyan Chemistry syllabus introduces Chemistry as a subject and indicates why knowledge of Chemistry is necessary in relation to the environment, everyday life and industry. The introduction also places emphasis on the development of practical skills and projects which link the subject with the physical environment, everyday life and industry. The projects are intended to enhance creativity, critical thinking and the ability to make logical decisions.

The Zambian Chemistry syllabus contains a clear list of general aims which clearly specify knowledge, skills (including the required mathematical skills), values, and attitudes that learners need to acquire by the end of the course. The Zambian Integrated Science syllabus also contains a clear list of general aims, specifying knowledge, skills (together with the required the mathematical skills), values and attitudes that learners need to acquire at the end of the course. In both courses, specific objectives are also given in the form of a table.

Ghana has two Physics syllabuses, a teaching syllabus and an examination syllabus, both of which give clear statements of aims/objectives. However, a number of these aims are not realized in the actual content of the syllabuses. For example, one of the objectives in the teaching syllabus is that students should be able to 'make reasonable estimations', but this is not mentioned anywhere in the detailed syllabus outline. Overall, there are 16 objectives listed in the teaching syllabus, of which 5½ are not realized in the syllabus outline. The introduction to the teaching syllabus includes a Needs Assessment Summary, which addresses the question, 'Why study Physics in the Senior Secondary School' (p. ii). The reasons given fall broadly into two categories: Ghana's technological and economic needs, and the need for scientific literacy of its citizens.

The rationale of Chemistry in Ghana places emphasis on Chemistry as the study of matter and its changes, and how it relates to everyday life, for example in terms of food preparation, preventing environmental disasters, clothing, medicine, household items etc. The Chemistry syllabus is built on the science learnt at Junior Secondary school. The syllabus is designed to provide enough Chemistry knowledge to students who will exit at the Senior Secondary school level; continue with vocational studies; or continue with their studies at tertiary institutions. The syllabus contains a clear list of general objectives, as well as a list of specific objectives associated with each content topic, where application of each topic is explicitly mentioned. The general objectives place strong emphasis on Chemistry as a practical subject where students acquire experimental design (practical skills) and problem solving skills, and also demonstrate how Chemistry is related to other disciplines.

The old South African Physical Science syllabus has a clearly outlined list of aims which place strong emphasis on acquisition of knowledge, skills, techniques and methods of science. They also emphasize science in industry and everyday life. There is explicit mention of the need to develop in learners a reverence for the Creator and an appreciation for the many bounties He has provided. In this sense, this syllabus document still contains elements of the old Christian National Education.

Evaluators felt that in the new South African curriculum in particular, many of the broad aims of the curriculum are explicitly followed through in the science curriculum statement and other documentation, providing an integrity and coherence to the curriculum statement.

Content coverage

It is difficult to draw a direct comparison between the content coverage of the various curricula, because the length and time allocations of the courses differ, and while some courses combine Physics and Chemistry into one course, others have them as separate subjects. It was found, however, that the major content areas are covered by all the curricula, but some have more detail than others, and some inevitably cover particular topics which are not covered by others.

The Kenyan *Introduction to Physics* is the only clear example of a discussion of Physics in the syllabus documentation in this study, and appears to be very useful. Something similar could well be considered for the South African syllabus. All the Chemistry curricula apart from the South African ones have an *Introduction to Chemistry*, though the content of the introductions varies considerably. Elements from each of the introductions should be considered for inclusion in a comparable introduction for the South African syllabus: Chemistry as an experimental science with its own methodology; safety in the laboratory; the particulate nature of matter; role of Chemistry in modern societies—practical uses and applications.

In general, there is a high level of consonance among the curricula in terms of the topics covered, though the Kenyan syllabuses, which cover four years of learning, are the most comprehensive. The old South African syllabuses, despite the fact that they are effectively two half courses made into one, cover similar ground to the Ghanaian and Kenyan syllabuses, though in slightly less detail. It certainly is considerably broader in scope than the Zambian combined science course, which is in one respect, the most comparable course in the study. However, the Zambian course is taken by a far greater percentage of learners.

In terms of specific content covered, the Ghanaian and Kenyan Physics and Chemistry courses are most directly comparable to one another. Although the South African curricula, both the old syllabus and the new curriculum statements, represent a combined Physics-Chemistry curriculum, these courses are nonetheless comparable in scope and cognitive demand to the specialized Physics and Chemistry curricula in the other countries studied.

The spread of topics in the new curriculum in South Africa was seen, in fact, to be more extensive than the separate Physics and Chemistry courses of both Ghana and Kenya. Each of these courses, however, is a full course in both Ghana and Kenya, whereas in South Africa they are intended as half-courses. This may mean that too much content is expected to be covered in the new South African curriculum. The net result may be that learners and teachers are overwhelmed, resulting in a superficial, cursory understanding of concepts, with little development of scientific skills such as reasoning, practical and problem-solving skills. Evaluators commented that, in an attempt to attain international standards, the curriculum designers seem to have overlooked the nature of the Physical Science course as comprising two half components, requiring the content to be selected accordingly.

By contrast, the Zambian General Science is less cognitively demanding, and seems to be intended as scientific literacy courses rather than as preparatory courses for future scientific studies.

This raises two important questions for South Africa. Firstly, should we focus our Physical Science course around the broader aims of raising the scientific literacy of the general population, or around the needs of learners who wish to pursue tertiary studies in the sciences? Perhaps it is possible to do both, through differently designed courses, or by making it compulsory for learners to do at least a basic science course, as is the case in Zambia.

Secondly, the question of whether it is preferable to have Physics and Chemistry as separate courses instead of two components of a single course is raised. The opinion of the evaluators in this project is that separating these two into single courses limits the exposure of learners to various fields of learning. It is better for their broad education to be exposed to a greater number of subjects, rather than in-depth subjects which take the place of other possibilities. It is also important for learners to have as many options open to them as possible for selection of future career paths once they have completed their secondary schooling, since most learners are unable to make clear and informed career choices at the end of Grade 9. Keeping Physics and Chemistry as two components of a single Physical Science course also keeps a place open for an additional subject.

However, evaluators also argued that a concern with regard to such a demanding Physical Science course is that, where the country should be encouraging more learners into this field, learners will instead be frightened away from the course (which already has a negative image in terms of its level of difficulty). They felt that it would be more beneficial for the learners to be taught less content, with more of a focus on depth of conceptualization and sound skill development. Despite these comments on the overload of content in the Science curriculum, evaluators argued that a notable oversight in the new South African Physics curriculum is the absence of thermal physics and calorimetry, which is included in each of the other Physics syllabuses. Evaluators suggested that the six broad topics that are covered in the curriculum (namely mechanics; waves, sound and light; electricity and magnetism; matter and materials; chemical change; chemical systems) are appropriate, but that the expanse of content that is covered within each topic could be more limited. They further suggested that some of the more advanced and less core concepts could be removed, for example, electronics and the mechanical properties of materials, allowing more room for depth of conceptual development of the remaining core content.

They felt that a positive aspect of the content is that there is an emphasis on links with everyday life, society, and the environment. This makes for a more interesting and holistic course, and teaches learners that the relationship between science, society and the environment is important. It also encourages life-long learning, as learners have been encouraged to reflect critically on their every-day experiences and observations.

Evaluators also pointed out that much of the content at the Grade 11 and 12 levels is new to the school curriculum, and is usually associated with a first-year University Physics course. Many teachers will be ill-equipped to teach this content, and extensive in-service training is therefore required to enable implementation of this new curriculum. They argued, based on anecdotal experience, that at present, many of the departmental workshops aimed at preparing teachers for the new curriculum focus more on the philosophy and values of the new curriculum, and that there is generally insufficient focus on the content.

Coherence

Evaluators argued the provision of an organizing principle for a curriculum helps to create a unified picture for both educators and learners alike, and thus is likely to make learning and teaching easier. In this regard, they criticized all curricula in the study, arguing that the idea of an organizing principle to help create internal coherence within the curriculum appears to be poorly understood by syllabus designers, and certainly is seldom used as a means of unifying the curricula into integrated learning processes. Evaluators found no particular organizing principle evident in the Kenyan Physics syllabus, the Kenyan Chemistry syllabus, the Zambian Chemistry and Integrated Science syllabuses, and the Physics component of the old South African syllabus. Sometimes the preoccupations of the curriculum writing teams are reflected in repeated references to, say, the practical applications of scientific knowledge, but these do not always translate into a framework for organizing the learning process or the order in which content is taught.

They argued, however, that in most Physics syllabuses there was an implicit organizing principle: the idea that the physical behaviour of inanimate objects can be predicted, by considering systems of objects, and using reductionist models and 'bottom-up' explanations. This principle allows for logical progression, insofar as the starting point is simpler systems (for example, ignoring friction during the study of linear motion), moving on to more complex systems.

A thread which runs throughout the Kenyan Physics syllabus is the importance of experimental work, and the application of scientific knowledge. However, this does not appear to guide the organizational framework or selection of content within the document. Similarly, in the Kenyan Chemistry syllabus there is no particular consistency in the way that the curriculum is organized. As with the Physics curriculum, the emphasis on the practical work, projects and the application of scientific knowledge is again evident. The document states that the learning/teaching experiences have been chosen to ensure proper development of the cognitive, psychomotor, and affective skills, but this approach does not appear to guide the organizational framework or selection of content within the document.

The preamble to the Ghanaian teaching syllabus sees Physics as organized around the concepts of energy and the nature of matter. Energy is a thread which runs through all areas of Physics, but the nature of matter is usually considered the domain of Chemistry. Within the teaching syllabus, there is coherence with regard to the reasons given for studying Physics, which emphasize the application of science, and its content. Many applications of Physics principles are given, for example 'suitability of position of Ghana for harnessing solar power for rural use' (p. 12) and 'curved mirrors used in shops to check shoplifting' (p. 18), but the syllabus is not fully internally coherent. In the teaching syllabus, for example, lightning is used as a significant example of a natural phenomenon which Physics can explain. The preamble states that

> a sound knowledge and understanding of the concepts in Physics will help the average citizen to explain natural phenomena like lighting (sic) and will greatly reduce unhealthy superstitions and cultural practices … (p. ii)

However, lightning is not mentioned at any point in the syllabus outline. The section on electrostatics (year 2, p. 14) deals only with electroscopes and capacitors—it does not even include sparks or discharges through air. They also noted that topics included in the examination syllabus were not found in the teaching syllabus (e.g. Coulomb's Law (p. 8); the photo-electric effect (p. 10), and X-rays (p. 11)), signaling a lack of coherence between the two syllabuses.

Evaluators argued that in the old South African syllabus, the relationship between different topics in Physics is often not well articulated—electricity tends to get treated separately from gravity, although both involve particles moving in response to force fields.

They felt that the new Physical Science curriculum in South Africa, designed in such a way that the same broad content topics are covered each year, but in ever-increasing depth and conceptual demand, provides excellent coherence through the senior high school phase, and ensures a conceptually developmental nature to the course as a whole. It also allows for clear organization of knowledge by the learners. Additional coherence is brought about as a result of key concepts being explicitly woven through the curriculum. One such example is that of fields, which is introduced in a number of different topics, and addressed in depth in the final year. In addition, the continual emphasis at all grade levels on the link between science, the environment and society lends further coherence to the course. The integration between various learning areas is clearly spelled out and supported throughout the curriculum documentation. There is a strong focus on the link between theory, practice and reflection.

The organizing principle for the new curriculum as a whole is that of outcomes-based education. In this sense the learning outcomes and assessment standards are very clearly explicated, and are designed to be more demanding with each year of study. However, some of the learning outcomes are possibly too generic, and some important scientific skills are not explicitly mentioned where they merit individual mention, for example, diagrammatic representation and interpretation, is a key scientific skill that needs to be developed at secondary education level.

The evaluators in the study pointed out that the curriculum structure makes it necessary that learners have access to Grade 10, 11, and 12 textbooks. This has funding implications for the Department of Education. In addition, they argued that some teachers may prefer to teach an entire topic in one year, and another entire topic in a later year—which is how the old South African curriculum was organized. Both approaches have their merits, and a flexibility in teaching approach should be encouraged. However, with the imposition of standardized tests at the end of each grade, this kind of flexibility is prohibited.

Evaluators felt that the syllabus documents of two of the countries had been typed by someone not familiar with science, and there are thus frequent typing errors which could create confusion for the reader without a strong Physics background. Some errors were argued to be undecipherable, even for a physicist, and evaluators felt that errors such as these seriously detract from the coherence and credibility of the syllabus.

Sequence, and progression

It is clear that sequencing and progression are to some extent naturalized concepts in the discipline and that it is largely assumed that educators have the ability to make the connections between content areas where needed, and across years if a topic is dealt with at more advanced levels in later years. Certainly there is very little that is explicitly said in this regard in any of the curricula examined.

The only curriculum to state an explicit principle for sequencing and progression is the Ghanaian Physics curriculum which says it uses a spiral approach, which presumably means re-visiting the same topics in different years but each time at a cognitively more demanding level, while making an attempt to connect the topics meaningfully in a sequence at the same time.

In Ghana, Zambia, and South Africa, the senior secondary curriculum is taught over three years, and in Kenya, over four years. The Chemistry course in Ghana includes both theory and practical components. The order of arrangement of topics in the syllabus takes into consideration the psychological, maturing needs of the student. Teachers are not expected to rigidly follow the order of the topics at all times. They are encouraged to use their own discretion to re-order for more effective teaching. There is no particular consistency in the way that the curriculum is organized, and no explicit coherence within the course.

For the Kenyan Physics and Chemistry syllabuses, although it seems that some of the topics covered in later years build on the concepts that have been developed in earlier years, these links are not explicitly outlined in the document. No explicit mention is made of the reason for the sequence of topics, or of relevant links to previously covered content. Although it is clear that the topics increase in conceptual demand from one year to the next, it is not clear that the course progresses developmentally within each year. The order in which the topics are to be taught within each year is not specified, although it is assumed that most teachers will follow the topics in a linear sequence.

From the Kenyan Chemistry syllabus, it is clear that the topics increase in conceptual demand from one year to the next, but it is not clear that the course progresses developmentally within each year. There is no clear specification in the syllabus that the teachers should follow the order of arrangement of topics within each year.

In the Zambian Chemistry syllabus, the topics are organized according to units, and it is not stipulated which units are to be covered in each of the Grade 10, 11 and 12 years of study. It is not clear whether the sequence of the topics (units) was intended to be a teaching order, or whether teachers should be flexible in their planning. The content topics are arranged in order from less conceptual demand to greater conceptual demand. The Zambian Integrated Science syllabus similarly does not contain any information on which units are to be taught in which years of study. The contact time for this course is also not stipulated in the documentation. It is clearly stated in the document that the sequence of the topics (units) is not intended to be a teaching order, but that teachers should be flexible in their planning. The content topics are arranged from less conceptual demand to greater conceptual demand, it is thus assumed that teachers will generally follow these topics in a linear fashion, although it is unclear in which year each of the topics will be covered.

The Ghanaian Physics syllabus explicitly claims to follow a spiral progression (p. vi) with most topic areas being revisited at least once. The cognitive demand increases with the years, for example, geometric optics is done with plane surfaces in the first year, and with curved surfaces in the second year. The sequencing of content within a year is generally logical (though with inevitable disjunctures), and generally starts with easier topics. However, there is no rationale given for the sequencing of the content.

The Ghanaian Chemistry syllabus has topics which increase in conceptual demand from one year to the next, but it is not clear whether the course progresses developmentally within each year. In Year 1, topics introduced are mainly basic (introductory), and some of these topics are then repeated at a more advance level in later years. There are no guidelines on the sequencing of the topics within each year. Teachers are encouraged to use their own discretion to re-order topics for more effective teaching.

The old South African syllabus outlines the topics to be covered in Grades 10, 11 and 12 on a year by year basis. It clearly demarcates the length and breadth of the topics to be covered in each year. The document reflects a progression of topics with regard to concept formation and depth of understanding and application, but there is no clear specification of the sequence or order in which topics must be dealt with in a particular grade. This is left to the educator's discretion.

In the new curriculum statement in South Africa, the sequencing within each year is not necessarily developmental in terms of the content, although some topics explicitly build on basic concepts covered in previous topics. As mentioned above, the curriculum is structured so that the same topic is taught each year in ever-increasing depth. There is thus a clear progression in terms of the content as learners progress through the grades. However, evaluators felt that there was a problematic discontinuity between the curriculum for General Education and Training and the FET curriculum. In the GET curriculum, the content specification is very loose and open to interpretation. In practice, this means that learners are not used to the demands of a content-heavy course. On the other hand, the FET phase, as discussed earlier, covers a very large amount of content, which is very clearly outlined. This content has been explicated in even greater detail in a subsequent document from the Department of Education (*National Curriculum Statement—Physical Sciences content*, June 2006). Learners have not been prepared in the lower years to cope with the rigour and conceptual depth that is demanded of them in this later phase. It should be noted, however, that in all other countries evaluators did not have access to the syllabuses for primary or junior high school.

Pacing

Pacing, evaluators argued, is one of the features of a syllabus which can significantly help inexperienced teachers to cover the syllabus. It also serves as a guide to more experienced teachers as to the relative weighting of different content areas in the curriculum. As a feature, pacing differs from being radically underspecified—as in the case of the Zambian curricula—to being reassuringly explicit, as is the case in the Ghanaian Chemistry curriculum. Teachers need to know that time allocation need not be regarded as rigidly prescriptive, but as an aid to making sure the content is covered in the time available.

The Physics and Chemistry courses in Ghana are taught over a period of three years at Senior Secondary school. The syllabuses are built on the science learnt at Junior Secondary School. The Ghanaian Physics teaching syllabus indicates clearly the total number of contact hours for each year, and which topics should be covered in which years, but does not specify how the years should be broken down. There is no time breakdown for theory and practical work (as the Ghanaian Chemistry syllabus does), for the syllabus explicitly intends to integrate the two. In the Ghanaian Chemistry syllabus, on the other hand, specific objectives associated with each topic guide both the teacher and the learner on the depth of treatment of content. Within each grade, there is a suggested number of periods (practical and theory) allocated per week for each level. For the first and second year period allocation for theory is 4 and that for practical is 3. In the third year, theory periods are increased to 5 and that of practical still remain the same. The order of arrangement of topics in the syllabus takes into consideration the psychological maturing needs of the student. For the three years, a total of 10 topics is taught with other topics being repeated at the advanced level.

The Kenyan Physics course is taught over f*our* years. In the first and second years, 132 contact sessions are prescribed in each year. In the third year there are 165, and in the final year there are 148 sessions. The syllabus covers the 41 identical topics in the four years of secondary education.

In Kenya, Chemistry is introduced to the learners for the first time at secondary school level. The course is also taught over *four* years. In the first year there are 104 prescribed contact sessions, in the second there are 128, in the third year there are 155, and in the final year there are 140 sessions.

The Kenyan Physics content is very clearly specified in terms of grades. In addition, within each grade there is a clear indication of the amount of time to be spent on each topic. The specific objectives associated with each topic in the Kenyan Chemistry syllabus guide both the teacher and the learner on the depth of treatment of content. The content is clearly specified in terms of grades and within each grade, a suggested time allocation for each topic is provided.

The Zambian Chemistry course is taught over a period of three years of study, and there are five teaching periods of 45 minutes each per week.

The Zambian Chemistry syllabus does not clearly stipulate which content topics are to be covered in each of the Grade 10, 11 and 12 years of study. The topics are merely listed as a set of units, which makes it difficult for teachers to pace the teaching for each year of study. Similarly, the Zambian syllabus does not clearly stipulate how much time should be spent on each topic, or which content topics are to be covered for Grades 10, 11 or 12. The curriculum documentation therefore does not provide any guidance for pacing within and across years.

In the old South African syllabus, the amount of contact time for this subject is not specified in the curriculum document, and there is no specification of the amount of time to be spent on practical work. This is problematic, since with this being left to the school's discretion, it is likely that implication is that there are huge discrepancies between different schools. A typical well-organized school would offer six periods of Physical Science per week, where each period is 35 to 40 minutes in length.

In the old South African Physical Science Syllabus the content is clearly specified in terms of grades, but a time allocation for each topic has not been suggested, and is left to the teacher's discretion. Work schedules are available from the Department of Education, however, to assist with guiding teachers in this regard.

The new Curriculum Statement for Science in South Africa is a course taught over three years.

Evaluators felt that the *Learning Programme Guidelines* document for the new South African curriculum gives teachers a clear idea of how to structure the learning programme for Physical Science at each grade. The guidelines include exemplars of work schedules, as well as suggestions for learning support material which may be useful. In addition, the provincial education departments supply teachers in their regions with year-plans outlining a suggested teaching programme. It is not required that teachers rigidly adhere to this, but it is a helpful guide in terms of the amount of time spent on each topic. A concern was raised, however, that this time allocation was done with hindsight, rather than during the curriculum design phase. There is thus no guarantee of whether this is a realistic timeframe in which to cover each topic. In fact, anecdotal evidence suggests that teachers are struggling to pace their teaching so that they cover all of the required content of the Grade 10 Physical Science course, which was first implemented in 2006, indicating that the pacing is not well structured, and the content demands of the course are probably too extensive. Where a previous version of the *Learning Programme Guidelines* document (April 2005) provided exemplars of lesson plans, these have been omitted from the January 2007 version for some reason. Evaluators felt that this was a pity, as teachers do generally need guidance on how to design their lessons.

Content coverage by cognitive demand

In general, evaluators felt that cognitive demand was not something that could usefully be dealt with in curriculum documentation, and argued that it is only in examinations where the levels of cognitive demand of an intended curriculum can be realized. This issue is discussed in more depth in Umalusi's report reflecting on the methodology of the research, Umalusi (2007), *Making Educational Judgements: Reflections on judging standards of intended and examined curricula*. Nonetheless, evaluators did explore attempts made in curriculum documents to deal with levels of cognitive demand.

Evaluators argued that the syllabuses under discussion all attempt to spell out the cognitive demands embedded in the curriculum, although some do this much more explicitly than others. The range of demands expressed in the various syllabuses vary considerably: some remain chiefly within the realms of the two lowest levels of Bloom's taxonomy, while some of the syllabuses are much more ambitious in their expectations of learners' achievements. The Kenyan matrix and the IEB's documentation were seen as the most sophisticated attempts to reflect levels of cognitive complexity within the curricula.

In the Kenya Physics syllabus, specific objectives associated with each topic give clear guidelines as to the cognitive operations expected of the learners. There is a wide range of cognitive demands required, which includes simple recollection, description and explanation of phenomena, experimental determination of scientific quantities, experimental verification of scientific laws, construction of apparatus, problem solving, construction and interpretation of diagrams and other representations, and derivation of scientific equations. These cognitive operations become more demanding with each successive year.

In the introduction to the Kenyan Chemistry syllabus, it is stated that the learning and teaching experiences have been appropriately chosen to ensure proper development of the cognitive, psychomotor and affective skills. The indicators of cognitive demand, time spent on a topic, and emphasis placed on a topic are used to develop a content matrix. This is shown by time allocated to various topics and the emphasis placed on a particular subject area.

In the Zambian Chemistry and the Integrated Science syllabuses, specific objectives associated with each topic give clear guidelines as to the cognitive operations expected of the learners. However, since the sequencing and progression of the units is not spelt out in the documentation, it is not guaranteed that the required cognitive operations become more demanding with each successive year.

The Ghanaian Physics teaching syllabus mostly tells teachers what students should be able to do with each item of content (list, state, define, explain, understand, calculate etc). The cognitive level is mostly at the first two levels of Bloom's taxonomy (knowledge and comprehension), with forays into the third level (application).

In the Ghanaian Chemistry syllabus, it is stated in the general objectives that the learners should demonstrate the following levels of cognitive demand:

- Observation and recalling of facts, patterns, principles and theories.
- Design experiment to solve problems (problem-solving).
- Communicating and understanding of scientific concepts.
- Interpreting scientific data (experimental data).

In the curriculum document, the specific objectives state the main generalizations, skills, competence, and attitudes to be developed by learners in order to be able to understand the level of cognitive demand related to each topic. There is a wide range of cognitive demands required, which includes simple recalling of facts, description and explanation of phenomena, experimental determination of scientific quantities, experimental verification of scientific laws, construction of apparatus (experiment design), problem-solving, construction and interpretation of diagrams, graphs, and derivation of scientific equations. These cognitive operations become more demanding with each successive year.

The old South African syllabus largely outlines the content to be covered with a description of what cognitive demands are expected. The IEB documentation contains an additional supporting document, namely Resource Materials for Physical Science, which outlines in detail the cognitive demands expected for every aspect of every topic.

In the new South African Curriculum Statement, the course progresses clearly from year to year in terms of conceptual demand, both of the content, and of the outcomes. However, evaluators felt that some of the topics at specific levels are too advanced for the learners at this level. For example, the topic of "Graphs of motion" is conceptually very demanding (particularly for accelerated motion), and beyond the scope of Grade 10 learners. In addition, learners are required to apply this to particle motion due to a wave. This is most certainly beyond the reach of Grade 10 learners. Some of the topics included in the Grade 12 course are extremely complex, and therefore require learners to simply accept and apply equations whose origins and derivation they are not able to understand. This is undesirable in a discovery-based science course.

In addition, there are pockets of topics which are not required in a

Physical Science course at this level, and which make the curriculum far too complex. An example is the VSEPR theory, which is thrown in without the underpinning concepts which are needed for an understanding of this topic. Evaluators argued that certain parts of the curriculum give the impression that certain peoples' favoured fields have been pushed into the curriculum without consideration being given to the educational basis for this content.

Assessment specification

In general, this aspect of curriculum description appears to be poorly thought through. Certain syllabuses provide lists of contents which are examinable (and these are sometimes not entirely consistent with the teaching curriculum) and cognitive abilities that could be assessed using a particular content area, but often without giving any indication of the relative importance or the weighting of these learning areas, in terms of what ought to be assessed. In addition, some of the examination syllabuses provide basic information (such as the number of exams to be written) but then say nothing about how the individual exams should be structured.

While certain curricula make reference to the practice of continuous assessment, it appears not to be factored in to determining the learners' final marks. In other words, it is a 'nice to have', but is not regarded as integral to the learners' final assessment.

The Zambian curricula, however, provide very specific information about the number of exams, the time and marks allocated to each, and some indication of the type of assessment required in each (multiple-choice, choice of questions from a limited range, practical examination). There is no indication, however, whether each paper covers the whole syllabus or whether the different papers cover different content areas. The Zambian specification thus provides a standardized framework or 'skeleton' for the three respective examination papers to be set each year.

Although a separate examination syllabus exists for Kenyan Physics, it does not specify the structure or weighting of the various components of the examinations. There may, however, be separate documentation providing this information which is disseminated to the schools. The examination syllabus contains a Table of Specifications which is in the form of a rubric. All of the content topics are listed in this table, with columns for cognitive operation types. These are listed as knowledge, comprehension, application, analysis, synthesis and evaluation.

For Kenyan Chemistry, the following assessment methods are proposed: Oral questions, observation of individual groups, short answer questions, practical test/assignments, written assignments, project work, and field trips. How much weight should be allocated to each proposed assessment method is not given. The separate examination syllabus provides no clarity on whether the final examination carries the total weight of the course, or whether the continual assessment contributes to the final mark. Three examination papers are written at the end of the course but no comment is made on the specific structure or weighting of the various components of the examination papers. A Table of Specifications in the form of a rubric lists all the content topics, with columns for cognitive abilities related to the topic. These are listed as recall knowledge, comprehension, application, analysis, synthesis and evaluation.

The Zambian Chemistry syllabus specifies that the examination is divided into three papers: an hour-long, multiple-choice paper (40 marks), a 2-hour theory paper (95 marks) and a practical lasting an hour and a half, worth 40 marks. The Zambian Integrated Science syllabus specifies that the examination is divided into three papers: an hour-long, multiple-choice paper (40 marks), and two 2-hour theory papers (65 marks each). The two theory papers are each allocated 1 hour and 15 minutes.

The Ghanaian Physics examination syllabus specifies the duration, mark allocation, and type of question for each of the 2 examinations, but does not give the weighting of the different content sections of the syllabus. The examination syllabus indicates that there will be a Continuous Assessment component (comprising tests, assignments/projects and practical), but does not give the weighting of this relative to the examinations. The examination syllabus states the purpose behind the practical examination and the aspects for which marks are awarded; this is not done for the theory examination. There are no exemplars or rubrics of difficulty levels provided.

There is a separate examination syllabus for Ghanaian Chemistry, but there is no clarity whether the examination carries the total weight of the course or whether the continual assessment is considered for the final mark. Two examination papers are written at the end of the course but there is no specific structure or weighting of the various components of the examination papers. There is a Table of Specifications which is in the form of a rubric. All of the content topics are listed in this table, with columns for cognitive operations. These are listed as recall knowledge, comprehension, application, and analysis.

For the old South African Physical Science Syllabus, the South African Department of Education supplied a *National Guideline Document* (Department of Education, 2000), which provides clear guidelines with respect to the mark allocation applicable to the different examinable topics of the syllabus. With regards to the differentiation of questions into "levels of difficulty", the Guideline Document also prescribes a weighting according to a "taxonomy of cognitive level". The cognitive demands required are knowledge, recall, low demand, comprehension, explanation, application, problem solving and higher ability synthesis. The curriculum documentation which was made available for this research project does not specify any of this information.

The required assessment tasks for the new South African curriculum are clearly spelled out in the *Subject Assessment Guidelines* document. A Programme of Assessment is included in the document, where the number of tasks and their relative weighting is clearly specified. The relative weighting of the various learning outcomes is also clearly stipulated. Formative assessment is explicitly encouraged, with examples provided of daily assessment tasks for assessing the various learning outcomes. The document also contains a suggested weighting of the various cognitive levels, namely recall, comprehension, analysis or application, and evaluation or synthesis. Suggested weighting of the various content areas is also provided. An assessment taxonomy describing the various cognitive levels and their associated skills is included as an appendix to the subject assessment guidelines. A helpful list of action verbs associated with each cognitive level is included in the taxonomy provided.

In South Africa, continuous assessment (in the form of the learner's portfolio) contributes 25% toward a learner's total mark, and the end-of-year exam comprises the remaining 75%. The reliability of this examination mark is ensured through the process of common testing. The reliability of marks allocated to the school-based assessment is not guaranteed. Cluster moderation could ensure this to some extent, but schools in a particular cluster are likely to be similarly resourced, and therefore will require similar standards to one another. Different clusters might have very different standards of assessment. Provincial moderation could make up for this. External moderation is only mentioned for Grade 12, but it should perhaps apply to Grades 10 and 11 as well so that schools can have a realistic sense of their achievement, and whether additional assistance is required.

The list of examinable content in the assessment guidelines document implies that learners are required to know the content from all three years of the FET phase, which is different to the old South African system. Interestingly, the document states that no multiple choice questions will appear in the examination. Evaluators felt that this is an improvement over the previous examination system, where multiple choice-type questions counted for 3 or 4 marks each, which doesn't allow for partial attainment of a concept or skill. The assessment guidelines document refers to a webpage containing exemplars of research tasks, exams etc. Subsequent examination guidelines, however, indicate that only parts of the Grade 11 curriculum will be assessed along with that of Grade 12.

Practical tasks

Practicals form a component of assessment in some of the curricula analyzed, and, in the cases of the Kenyan Physics and both Ghanaian curricula, the practical forms a substantive part of the final assessment. While the South African curriculum does not include a practical examination, certain practical tasks are required for the Programme of Assessment. Although the following point is made cautiously, it would seem that the nature of the practicals is generally quite highly determined. In other words, the tasks tend to be closed rather than open, and learners are required to 'follow the recipe' rather than to devise something a little more novel.

In the Kenyan Physics syllabus, practical tasks are clearly outlined throughout the document. In addition, a number of possible projects are described. These projects are intended for enrichment, and, although this is not clearly stated, it appears that they do not contribute to the overall assessment of the learners. In the Kenyan Chemistry syllabus, it is stated clearly in the syllabus aims that Chemistry is a practical subject where scientific concepts, principles and skills are developed through experimental investigations. This is further demonstrated by the practical tasks that are clearly outlined throughout the syllabus document. The learners are also required to do projects at the end of each topic. A separate practical exam is written, which explicitly assesses these practical skills.

Similarly, the Zambian Chemistry practical syllabus clearly stipulates what should be covered in the Chemistry practical sessions, although the Zambian Integrated Science syllabus does not specify practical work.

The Ghanaian Physics teaching syllabus clearly specifies the practical work to be performed for each topic. The examination syllabus refers to Appendix B which contains a guide to 'the practicals and project works', but the researchers did not receive this appendix. The practical examination is weighted as 30 % of the total examination mark. There is no guideline as to the weighting of practical work in the continuous assessment component. There is a mismatch between the aims/objectives relating to practical work, and the way in which the practical work is presented in the syllabus outline. Stated objectives of the teaching syllabus are that students should 'acquire the skills for *making hypotheses*, for *devising experiments* to test hypotheses' (p. iv), and should be able to 'isolate variables' (p.5), i.e. control variables. However, none of the practical tasks specified in the syllabus requires the making of a hypothesis or the design of an investigation.

The syllabus outline in the teaching syllabus does start by stating, 'It is recommended that the mode of instruction be the activity and *guided discovery method*' (p. vi), but presents the practical work in a deterministic manner. For example, instead of requiring students to investigate the relationship between potential difference and current, the outline states 'Demonstration of Ohm's law by using simple circuits and plotting graphs' (p, 24). There is no suggestion of open-ended investigations. On a related note, one of the teaching syllabus objectives requires that students should be able to 'undertake projects in science.' (p. v)—this aim is only achieved if 'projects' are defined narrowly as constructions (referred to above) and do not include investigations. Another stated objective is that students should have the 'ability to improvise basic learning materials' (p. v). However, there is only one reference to improvisation: that of making a 'water-lens microscope' and improvising a lens with a 'small polythene bag filled with water' (section 19.3, p. 20). For the rest, the equipment mentioned is specialized laboratory apparatus.

In the Ghanaian Chemistry syllabus, the general objectives place strong emphasis on Chemistry as a practical subject, where students acquire the skill of experimental design (practical skills). Practical tasks are clearly outlined throughout the syllabus, for an example, a conductivity experiment. There is a separate practical examination. It is stated under the course objectives that students should do a wide range of activities which include projects. It is not stated anywhere in the course content what kind of projects should be carried out by learners, and there is no clear indication whether the projects contribute to the overall assessment of the students.

In the old South African Physical Science Syllabus, practical or experimental work is mentioned as a matter of fact rather than being specified. The amount of practical work done is therefore left up to the educators' discretion. There are, however, other supporting documents with regards to Portfolio requirements wherein a minimum number of practical tasks need to be completed. (This is discussed further in the "Examined Curriculum" section of this report.)

The curriculum statement for the new South African curriculum spells out the importance of practical investigations and research projects, and the skill of performing a scientific investigation is included in the list of assessment standards. The *Subject Assessment Guidelines* document suggests that practical investigations should contribute 40% toward the continuous assessment mark (hence 10% toward the overall mark). However, the practical tasks to be included in the continuous assessment mark are not explicated at all. This is problematic in that it is open to a great deal of interpretation, although the positive side to this is that flexibility is given to under-resourced schools to select practical tasks according to the equipment that is available. A possible solution would be to suggest a bank of possible assessed practical tasks of similar scope and depth, but utilizing a wide range of practical equipment (including items readily available in under-resourced communities). In addition, where the curriculum document is extremely detailed in some aspects, it is not sufficiently explicit with regard to the practical tasks to be carried out in each topic area. Again this is possibly because consideration has been given to variable availability of resources, but this allows for too much interpretation, and the possible exclusion of practical work.

The examined curriculum

Ghana, Kenya, and Zambia all have three question papers in each of their Science courses; South Africa has only two, as it does not have a practical examination. However, practical reports contribute 50% of the continuous assessment mark, and since the continuous assessment mark contributes 25% of the final mark, practical work contributes 12.5% towards a learner's final Physical Science mark.

The analysis of the South African Higher Grade papers (state and IEB) indicated that they were challenging. They both contain the greatest percentage of difficult questions (38% and 42% respectively), indicating that the South African Higher Grade examinations may be more demanding than any of the other Physics or Chemistry examinations studied, despite each being taught as only half a Science course. The South African Standard Grade examinations are considerably less challenging, with very few questions set at difficulty level 3 (that is, at the most difficult of three levels, see below). However, a combination of higher grade and standard grade results (as shown in Table 2 on the following page) gives a similar spread in terms of difficulty level to the Kenyan Physics and Chemistry examinations. This suggests that it is possible to assess the range of cognitive demands assessed in the separate grade system through one set of exams. One can also conclude from this that the South African Physical Science examinations as a whole appear to be comparable to the Kenyan examinations as far as difficulty is concerned. By contrast, the Ghanaian and Zambian examinations appear to be less demanding, with a much greater emphasis on questions set at level 1 in both of these sets of examinations. The Zambian examinations contain the highest proportion of factual recall questions, particularly in the Chemistry course.

Cognitive levels

The Science evaluators allocated categories of cognitive operations to the examination questions of the various science papers. Evaluators then categorized questions into three levels of difficulty, with level one being the easiest, and level three the most difficult. According to the evaluators' analysis, both the South African Higher Grade Physics examinations (state and IEB) are more demanding than any of the other Physics examinations studied in this research. The Kenyan Physics and Chemistry examinations were also seen to be of a high standard.

It is apparent from the results of the examinations analysis that the South African Physics examinations contain a sufficient spread of questions at different difficulty levels. It is clear that there is an emphasis on problem solving, at both the Standard Grade and Higher Grade levels. This is appropriate, since Physics is largely a problem-solving discipline. For the Chemistry examinations, both the state and IEB Higher Grade courses also have a large percentage of problem-type questions. It is clear that the South African Standard Grade courses are much less demanding than the Higher Grade courses, with no questions aimed at assessing difficulty level 3, and a greater percentage of questions aimed at factual recall (particularly in the Chemistry examinations).

The difficulty level of a combination of higher grade and standard grade is compared in the following table with that for the Kenyan Physics and Chemistry exams:

Table 2: Average of difficulty levels for SA HG and SG compared with Kenyan examinations

	Level 1	Level 2	Level 3
PHYSICS			
SA Department of Education Physics (HG+SG)	25%	56%	19%
SA IEB Physics (HG+SG)	22%	58%	21%
Kenya Physics	16%	58%	26%
CHEMISTRY			
SA Department of Education Chemistry (HG+SG)	20%	73%	8%
SA IEB Chemistry (HG+SG)	21%	65%	15%
Kenya Chemistry	23%	62%	15%

It is interesting to note that the combination of higher grade and standard grade results gives a similar spread in terms of difficulty level to the Kenyan Physics and Chemistry examinations. One can conclude from this that the South African Physical Science examinations as a whole appear to be comparable to the Kenyan examinations as far as difficulty is concerned.

There is, however, greater breadth of content coverage in the Kenyan Physics examination, as it covers four years of schooling. As a result, the examination questions are not able to assess a great depth of conceptual knowledge of each area, since there is a broad range of content areas to be assessed. This approach would also possibly encourage learners to "cram" before their final examination, since there is so much content to be recalled, some from a number of years in the past. Similarly, with regard to Chemistry, evaluators argued that the South African examinations appear to be quite comparable to the Kenyan Chemistry examinations as far as difficulty is concerned. The content, broadly speaking, is similar in these two courses, but this means that the South Africa course is more demanding, because the complexity of material has to be covered in less time (since it is a half-course covered in only three years). Comprehension is then more difficult to acquire when the time devoted to the concept is reduced. On the other hand, Kenyan learners have to study a greater amount of material to prepare for examinations.

The Zambian Physics examination is similar to the Ghanaian Physics examination in level of difficulty, and neither were seen to be as challenging as their Kenyan and South African counterparts. The Zambian examination tests content knowledge, understanding, problem solving abilities and practical skills, but enough of the questions are at a sufficiently simple level for any diligent student to pass, with very few questions requiring learners to apply their knowledge in new contexts.

The Zambian Chemistry examination was seen to be the least challenging in the study, with only 1% of challenging questions. As nearly 50% of this examination assesses rote recall of factual information, evaluators argued that it assesses a very superficial level of knowledge and understanding of the subject, and is not comparable with the South African, Kenyan, or Ghanaian Chemistry examinations. The Ghanaian

Chemistry examination was not seen to be of the same standard as either the South Africa Higher Grade or Kenyan Chemistry courses, since it had a greater emphasis on assessing easy questions than either of these courses. It did, however, test more conceptual knowledge than factual recall, and was seen to compare most favourably with both of the South African Standard Grade Chemistry courses

The Zambian Integrated Science examinations were also seen to mainly test easy questions, with a great emphasis on factual recall. Evaluators concluded that the course is not comparable to the South African Physical Science course, or to any of the Physics or Chemistry courses that have been studied in this research. Nonetheless, it should be pointed out that it is compulsory for all learners in Zambia to take a Science course, necessitating that such a course should be accessible to weaker learners, and it may be an advantage in this country that all learners at least acquire some scientific knowledge.

Syllabus coverage

In general, evaluators felt that examinations reflected good syllabus coverage. There were minor criticisms. For example, they felt that radio-chemistry and energy changes were under-represented in the Kenyan examination compared with teaching time specified for them. With regards to the Ghanaian Physic paper, evaluators felt that a couple of questions are beyond the scope of both the teaching and examination syllabuses: in Paper 1, section A, question 26 asks about FM and AM signals, but the syllabus does not deal with these terms or radio waves in any way. Paper 1, section B, question 7b requires calculation of the electric field between parallel plates, whereas the syllabus is explicitly limited to electric fields around point charges. In addition, section B, question 10b asks the candidate to sketch an X-ray spectrum, but, while the syllabus includes X-rays, it does not extend to X-ray spectra.

They pointed out that the breadth of the Ghanaian Physics examinations makes it difficult for a candidate to 'spot' questions, although it should be noted that a candidate could choose to have 60 % of section B of paper 1, based entirely on final year work, by choosing questions 2 and 8.

In general, evaluators favoured the South African approach whereby the final examination does not include many years work, as opposed to the Ghanaian courses which are spread over three years, and the Kenyan over four. They argued that in order for the examination papers to be able to cover all of the material covered in these three/four years, the questions tend to be superficial.

However, they also pointed out problems with the South African approach. In the South African system, not all content covered in Grades 10 to 12 is covered in the final examination. In fact, none of the content topics from the Grade 10 year are covered, although some of the content in this year forms foundational understanding for the topics dealt with in later years, and is thus implicitly assessed (for example, the periodic table, atomic structure and bonding, and acids and bases). Also, most, but not all of the Grade 11 topics are examined, such as light. By focusing just on the topics dealt with in Grade 11 and 12, the South African examinations are able to probe a deep level of understanding of these topics. The drawback of this system is that, in the Physics component, only content relating to mechanics and electricity and magnetism are examined. Since most energy in secondary school learning is focused around the final examination, this gives learners the incorrect perception that these are the only important topics in a Physics course. They may leave school with a well-developed understanding of these topics, and of no others.

Choices with respect to questions

Evaluators did not theorize about whether having choices in an examination paper is better than having to answer everything, or examine the relative advantages and disadvantages of the two approaches. The discussion below focuses mainly on whether choices in the different question papers are comparable with each other.

None of the South African papers provide for choices in questions. All questions are compulsory. This is also the case for the Kenyan Chemistry paper. All other papers offer learners some choices. The Kenyan Physics paper 2 offers learners a choice between two questions in Section II of the examination. Although these questions cover different topics from the syllabus, both of the questions assess similar skills at similar difficulty levels.

In the Zambian Physics paper 2, section A contains one choice, worth 7 marks (out of 50 for the section). The choice is between a question on electronics and a question on a generator. The generator question is slightly more difficult, perhaps to compensate for the fact that the electronics content is more challenging. Section B contains 4 questions (15 marks each), out of which a candidate must choose 3. The questions are significantly different in approach: questions 10 and 11 (electricity and density) test practical skills, whereas questions 11 and 12 (radioactivity and optics) do not. There is also a significant difference in the levels at which the questions operate. In Zambian Chemistry paper 2, Section B, offers candidates an opportunity to answer three out of four questions. All of these questions are of a similar standard. This also applies to papers 2 and 3 in Zambian Integrated Science.

In the Ghanaian Physics examinations, the long questions in the theory paper comprise two choices for each of the five sections into which the syllabus is delineated. These choices do not all test the same skills. The choices are also dissimilar in terms of the breadth of content covered. The practical tasks are comparable in the three alternate practical papers and in the choices contained within those papers. However, the last 6 marks of each practical task is designated 'theory', and there is quite a discrepancy in the levels of these questions. Perhaps this is meant to level out differences in the challenges in the practical tasks.

In the Ghanaian Chemistry papers, evaluators noted that in Paper 1 B, where a choice is allowed, the different questions are not of equivalent rigour. In fact, some questions tested only at the conceptual level whereas the remaining optional questions partially test at the problem-solving level.

In two instances, evaluators found examples of question papers which contained choices which were not given the same mark allocation.

Mark allocation and marking memoranda

Clearly how question papers are marked influences the standard of the paper. However, this is something that is difficult to comment on at a distance, and the discussion below simply indicates comments based on an analysis of marking memoranda and mark allocation.

Evaluators commented favourably on the South African marking memoranda, arguing that there was broad provision made for alternative problem-solving methods, with clear marks associated with each. In terms of mark allocation, due consideration has been given to the time it would take to answer each question, and for the paper as a whole, for example, in some cases a greater time is needed in reading of the question and interpretation of diagrams, and marks are allocated accordingly. There is evidence of the fact that due consideration is given to assessing partial achievement of concepts or skills. This is possible due to the fact that most questions are structured into sub-questions or leading questions. In the problem-type answers, half-marks are allocated as well. The state and IEB memoranda are both accurate, with all answers corresponding to the questions.

Evaluators' main criticism of mark allocation in South Africa was that the multiple choice questions are in some cases very searching and demanding, but are only worth 3 marks per question in the national Standard Grade examination, and 4 marks per question in the Higher Grade examinations, with no provision made for part understanding of a concept.

In the Kenyan Chemistry papers, the marking memoranda do not allow for variation in the approach to solving problems—usually only one method is shown. The marking memorandum for Chemistry Paper 2 has had numerous handwritten amendments made to it—presumably made in the meetings to finalize the memoranda. The mark allocations for each question seemed reasonable for the work expected. The mark allocation for partial achievement of the concept or skill seems reasonable. In the marking memoranda for the Kenyan Physics paper, where a question is allocated a number of marks, it is not specified what these marks should be awarded for. There is also no provision made for alternative problem-solving methods. This is likely to lead to a great deal of discrepancy in mark allocation. This issue could be overcome if the marking process is centralized and well managed.

In the Zambian Physics memoranda, most of the questions in Paper

2 require short answers, and the mark allocation is appropriate. However, the mark allocation for longer questions is very lean. For example, only one mark is allocated for a ray diagram (12b), and reading of Vernier calipers also only receives one mark (1c ii). The memorandum for paper 2 does not indicate the mark allocation at all, so it is not possible to tell whether it is possible to get half marks. A simple calculation (involving three steps) is always awarded 2 marks—it is impossible to tell how these marks are allocated. The memorandum for Paper 2 offers more than one possible answer for many of the questions. Where candidates are required to read a value off a graph (question 9a i), a range of values is given in the memo.

In the Zambian Chemistry, the marking memoranda do not allow for variation in the approach to solving problems—usually only one method is shown. Evaluators commented that the marking memoranda emphasized how little numerical work is examined. The mark allocations for each question seemed reasonable for the work expected, but the mark allocation for partial achievement of the concept or skill is inadequate. In many instances, the mark is assigned to the final answer, and it was not clear whether or not individual markers can decide whether to give part marks.

In the Ghanaian Physics paper 1, the mark allocation is lean—there are many lines of working in the memo which are not allocated marks at all. The mark allocation is also inconsistent: sometimes a mark is allocated for giving the equation used, and sometimes no marks are given. (This, evaluators felt, is harsh, given that candidates are expected to learn equations by rote—there is no mention or evidence of an information sheet.) The mark allocation does not give a guide as to the depth required for each question, as only the total marks for every two or three questions are shown on the question paper. In contrast, the mark allocation for the practical exam is more generous, and does allow occasionally for ½ marks.

The time allocation for the paper 1 is also lean: candidates are expected to complete multiple choice questions at a rate of one every 1,5 minutes—compared to 2,4 minutes in the South African examinations. Some of the multiple choice questions involve two part calculations or two stage selections (of the form: 'Which of the following statements are correct?').

This means that the right answer is not immediately apparent, and candidates have to spend time on the question.

The memorandum offers alternative options for a few questions, but for most only allows one solution, and there no indication that other solutions may be admissible. However a memorandum is always a working document and markers may well be briefed to accept other valid solutions. Some inaccuracies were found on one of the memoranda.

For Ghanaian Chemistry, the marking memorandum allows for some variation, as when examples are required, but not for different approaches to solving problems—usually only one method is shown. The mark allocations for each question seem reasonable for the work expected. The allocation of marks for partial achievement of the concept or skill seems reasonable within Paper 1B. In the Ghana theory paper, 60 marks out of a total of 160 are assigned to multiple choice questions. In this case 60 questions are asked, for 1 mark each. Evaluators felt that this mark allocation is better than that used in the South African examinations, where 60 out of 200 marks are allocated to 15 multiple choice questions. For the practical examination no memorandum is supplied, and the breakdown of the marks in each of the 3 questions is not shown, so it is difficult to assess what the ratio for practical work versus calculations using the collected data might be. It should also be noted that the seven questions in Paper 1B are not assigned the same mark value each (20 marks) which should be the case, as learners choose to answer 5 of the 7 questions.

Overall quality of examinations

In South Africa and Kenya, no mistakes were detected in either of the question papers or the memoranda. The mark allocations indicated in the memoranda are very clearly laid out, and the overall presentation is clear and readable. Some mistakes were found in both the Zambian and Ghanaian Physics examinations and in the Zambian marking memoranda. Evaluators also criticized the quality of some questions in these papers.

Evaluators questioned whether the approach followed in the Kenyan and Zambian Chemistry papers, which were set in such a way that the learners are not required to write much language, was desirable. By contrast, the Ghanaian Chemistry papers are set in such a way that the learners are required to write quite a lot of sentences—they are language intensive as compared with the other countries' Chemistry exams. The Zambian Chemistry examination is not biased towards numerical work as one sees in the South African and Kenyan exams. Evaluators felt that this is probably a short-coming since Chemistry is a numerical as well as a descriptive discipline.