The story of a physical science curriculum: transformation or transmutation?

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Abstract

Recently Curriculum and Assessment Policy Statements (CAPS) were introduced in South Africa in response to confusion precipitated by previous curriculum documents. The purpose of this paper is to explore that confusion in the subject 'Physical Sciences' and consider the nature of the transformation from the previous curriculum by looking at curriculum documents and examination papers. We present a two phase curriculum change model which suggests that congruency between curriculum documents and examinations is critical for effective curriculum change. We analyse the pre-CAPS curriculum, the National Curriculum Statement (NCS), on its own terms by using the stated outcomes as our reference point. Our analysis reveals that the weighting and conceptualization of the outcomes shifted through successive documents, which undermined congruency between the documents and meant that content-oriented science masqueraded as inquiry-oriented science. This led to a retreat from the original vision of weighting skills and relevance equally with content. The examinations took this retreat a step further. Evidence of the retreat is that the nature of the questions asked in the 2008 examinations on the NCS was similar to that of the 2007 examinations on the previous curriculum which had not changed since apartheid. However, in the NCS examinations there was a small shift towards contextualisation and inquiry oriented science. The retreat means the vision of transformation which was the rationale for the NCS curriculum was eroded – instead of transformation, there was transmutation back to the old apartheid curriculum. The Physical Sciences CAPS cements the retreat and creates new confusion by changing the syllabus again without signposting the change.

Keywords: assessment; examinations; curriculum analysis; curriculum change; learning outcomes; physical science; transformation; National Curriculum Statement; Curriculum and Assessment Policy Statement

Introduction

A new curriculum for the final three years of schooling was introduced in South Africa from 2006, with transformation as one of its key objectives. This curriculum, expressed in a National Curriculum Statement (NCS), claimed to provide the foundation for fulfilling the South African constitution's aim of establishing a democratic nation by means of nine principles underpinning the curriculum. The first of these was 'social transformation' (Department of Education (DoE), 2003). In 2008 the first cohort of learners completed the NCS curriculum. However, in 2009 a ministerial committee was appointed "to investigate the nature of the challenges and problems experienced in the implementation" of the new curriculum (DoE, 2009b, p. 5). One of their 'high-level' recommendations was a new document for each subject:

> that will be the definitive support for all teachers and help address the complexities and confusion created by curriculum and assessment policy vagueness and lack of specification, document proliferation and misinterpretation. (DoE, 2009b, p. 7)

Acting on this, the minister of Basic Education appointed project committees to develop a Curriculum and Assessment Policy Statement (CAPS) for each subject. These were finally published in 2011 and replace the previous documents (Department of Basic Education, 2011). This major policy change suggests that the original aim of transformation was undermined by the way in which the NCS curriculum was communicated. In addition to 'document proliferation', a problem not noted in the above quote is a lack of congruency between the various curriculum documents. In other words the documents were not in agreement with each other. The purpose of this paper is to explore that problem in the subject 'Physical Sciences' and consider the nature of the transformation from the old curriculum (known as NATED 550) which had not changed since apartheid, by examining NCS curriculum documents and examination papers.

The NCS curriculum was outcomes-based. All subjects except mathematics had three Learning Outcomes: one about skills, one about content knowledge and one about relevance. These Learning Outcomes were central to the curriculum and are central to our analysis – we thus evaluate the curriculum on its own terms. We do this through three research questions. First, how congruent was the conceptualization of the Learning Outcomes in the various NCS documents? Second, how did the weighting of the Learning Outcomes in exemplar and actual examination papers align with the weightings specified in the curriculum documents? Third, how did the first examination on the NCS compare with the last examination on the previous NATED 550 curriculum? We address these questions by analysing first the curriculum documents and then the examinations in terms of the Learning Outcomes. We begin by developing a model of curriculum change for framing our study.

Conceptual Framework

Curriculum change is never straightforward, and so we need a framework for understanding this process. Our conceptual framework is illustrated in Figure 1. Curriculum theorists typically distinguish between the intended curriculum, the implemented curriculum and the attained curriculum. These three aspects can be further broken down: the intended curriculum comprises the ideal or vision underpinning the curriculum, and the version communicated in writing, which we will call the published curriculum; the implemented curriculum comprises the perceived curriculum understood by teachers and the operational curriculum which happens in their classrooms; and the attained curriculum comprises the curriculum as learners experience it as well as their learning outcomes (van den Akker, 2003).

Of relevance here is Bernstein's (1996) theory of how the privileged text of curriculum is produced, transmitted and acquired. He identifies four players in the process of implementation of a curriculum: producers, recontextualisers, reproducers and acquirers. The producers create the privileged text of curriculum. The recontextualisers are the government officials, academics and teachers who formulate the realization rules of the curriculum. The reproducers are the teachers who implement the curriculum in their classrooms, and the acquirers are the learners in these classrooms. Curriculum theory relates to Bernstein's players insofar as the producers write the intended curriculum; the reproducers enact the implemented curriculum and the acquirers achieve the attained curriculum. But this three stage process does not take into account Bernstein's recontextualisers who flesh out the realization rules of implementation and assessment. Thus we also need to consider what we will call the illustrated curriculum and the examined curriculum produced by the recontextualisers.

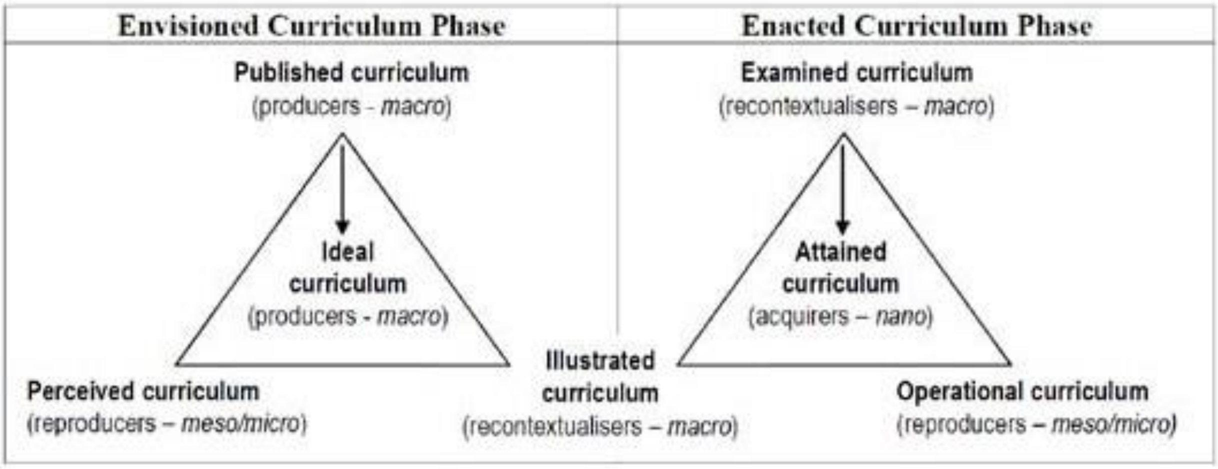

Figure 1: Two phase curriculum change model

The different elements of curriculum operate at different levels. For a curriculum which is examined nationally or provincially, the published, illustrated and examined curricula operate at the national or provincial / macro level whereas the perceived and operational curricula occur at school / meso level and classroom / micro level, and the attained curriculum occurs at individual / nano level (van den Akker, 2003). The curriculum at meso, micro and nano levels differs from one context to another, so these elements can be seen as multidimensional.

In summary, at the macro level the producers have a vision which they communicate through the published curriculum. The recontextualisers then provide the illustrated curriculum, which teachers – the reproducers – apprehend as the perceived curriculum and implement as the operational curriculum at meso school level and micro classroom level. The learners acquire the attained curriculum at nano level, assessed through the macro level examined curriculum generated by the recontextualisers.

We see curriculum implementation as occurring in two phases: the envisioned phase and the enacted phase, represented by the triangles in Figure 1. The illustrated curriculum serves as a bridge between the two phases. There is some overlap between these phases as the first cohort of learners progresses through a new curriculum. Only after the first national examinations on a new curriculum is the envisioned curriculum phase complete and the enacted curriculum phase fully operational. For the envisioned phase, the published curriculum communicates the ideal curriculum by providing a lens on it. By communicating the curriculum, the published curriculum serves as the main driver for that phase and hence is at the apex. Similarly the examined curriculum provides a lens on the attained curriculum. In addition, the examined curriculum has a backwash effect into the classroom: where schools are rated according to their pass rate as happens in South Africa, teachers tend to teach towards the examination, and focus on the aspects of the examination that have the greatest return on investment (Biggs, 1996). This was powerfully demonstrated by Barnes, Clarke and Stephens (2000) who found alignment between the examined curriculum and the operational curriculum in two Australian states with the same published curriculum but whose examined curricula embodied radically different values – one content-driven and the other inquiry-based. Thus while the published and illustrated curricula should drive the enacted curriculum phase, the examined curriculum effectively becomes the main driver for this phase, and hence its position at the apex of the enacted curriculum triangle is appropriate.

In an ideal world the two triangles of Figure 1 would be mirror images. The attained curriculum would mirror the ideal curriculum; the operational curriculum would mirror the perceived curriculum; and the examined curriculum would align with the published curriculum. But in the real world the translation involved in each step of the curriculum process shifts the curriculum. The producers do not capture their vision exactly in the published curriculum, and the teachers / reproducers then read the published curriculum through their own contexts and experiences. In addition the operational curriculum is both facilitated and constrained by local circumstances, and so there are inevitably disjunctures between the perceived curriculum and the operational curriculum. Similarly the way learners experience the curriculum and what they learn is not a perfect mirror of teachers' intentions, so there may be a significant gap between the original vision of the producers and the learning outcomes of the acquirers. The examined curriculum provides a lens on these outcomes, but it is a lens which distorts, emphasising some aspects and failing to notice others. Overall the cumulative effect of small shifts with each translation may be significant curriculum drift. Yet van den Akker claims that "careful alignment between assessment and the rest of the curriculum appears to be critical for successful curriculum change" (2003, p. 5). Likewise Barnes et al. (2000) emphasise the role which alignment between the published and examined curricula plays in enhancing the credibility of a curriculum. This resonates with Stake's (1967) Contingency-Congruency model which suggests there should be congruency between all the curriculum elements in Figure 1.

Overall our model suggests that congruency between the macro elements of a curriculum, i.e. the published, illustrated and examined curricula, is critical for effective curriculum change. This means that the messages communicated by the illustrated curriculum should be consistent with the published curriculum, and the examinations should align with the illustrated and published curricula. Hence our first research question asks about congruency between the published and illustrated curricula, and our second research question considers alignment between the examined and illustrated curricula. In both cases we consider congruency in respect of the Learning Outcomes, since these were central to the curriculum under scrutiny, i.e. the Physical Sciences NCS for grades 10 to 12. But it should be kept in mind that the overall goal of these congruencies is alignment between the ideal and attained curricula, i.e. between the two triangles of Figure 1.

The South African Physical Sciences curriculum

In this section we describe the macro elements of the pre-CAPS Physical Sciences curriculum for grades 10 to 12, i.e. the published, illustrated and examined curricula. The published curriculum was the NCS document (DoE, 2003). This was the only document which had legal status, having passed through the national government. Table 1 gives the documents which constituted the illustrated curriculum. In 2005, Learning Programme Guidelines (LPG) and Subject Assessment Guidelines (SAG) were first published. In these first versions, it was indicated that they would be revised and a final version printed in 2008, which is what happened. In addition, a 'Content' document was published in response to complaints that the Physical Sciences content was underspecified. Then in the year of the first grade 12 examinations (2008), a further document came out, the Examination Guidelines, which was slightly modified in 2009. Overall these documents were published over a period of five years. In addition various exemplar examinations were published. There were also provincial documents, for example the portfolio guidelines, as well as textbooks which formed part of the illustrated curriculum, but in this analysis we will consider only the national documents. The examined curriculum comprised the examinations: Paper 1 (Physics) and Paper 2 (Chemistry). In order to address our second and third research questions, we looked at the papers for 2008, which were similar in nature to the subsequent papers.

Table 1: The national illustrated curriculum for NCS Physical Sciences

Document	Abbreviation used in this paper	Date published	Main content
Learning Programme Guidelines (e.g. DoE, 2008a)	LPG	2008, with draft versions from 2005 onwards.	How to plan for teaching
Subject Assessment Guidelines (e.g. DoE, 2008b)	SAG	2008, with draft versions from 2005 onwards	Weighting of examinations and other assessment
National Curriculum Statement Grade 10-12 (General) Physical Sciences Content (DoE, 2006)	Content document	June 2006	Syllabus (elaborated content description)
Physical Sciences Examination Guidelines (DoE, 2008c, 2009a).	Exam Guidelines	2008 and 2009	Examinable syllabus
Exemplar Examinations for grades 10, 11 and 12 (e.g. DoE, 2007, 2008d).	Exemplar	2006-2008	Sample examinations

We are not the first to analyse the NCS Physical Sciences curriculum. Green and Naidoo (2006) used various lenses to compare the grade 10 content in the NCS document to the NATED 550 curriculum. Lubben and Bennett (2008) looked at the use of contextualisation in chemistry in the NCS document, in textbooks and in examinations and compared this with the NATED 550 curriculum. Clerk and Naidoo (2010) focussed on what they saw as the demise of problem solving in the examined curriculum. Umalusi (the statutory body responsible for setting and monitoring school standards in order to ensure continued quality improvement) concluded in a report that the 2008 examined curriculum met an appropriate standard: "The quality of the 2008 examination papers is commendable, given the newness of the curriculum, and the fact that these papers have been set for the first time." (Umalusi, 2008, p. 59). The Physical Sciences examination papers were also found to be acceptable in terms of difficulty level, cognitive demand, and content coverage (Koopman, 2010; Umalusi, 2009b). While these different studies have provided useful analyses of different aspects of the curriculum, none has considered congruence across the macro elements of the curriculum.

The conceptualization of the Learning Outcomes

We will look at the published and illustrated curricula in order to answer our first question: how congruent was the conceptualization of the Learning Outcomes (LOs) in the various curriculum documents? The Physical Sciences LOs were:

- LO1: Practical Scientific Inquiry and Problem-solving Skills
- LO2: Constructing and Applying Scientific Knowledge
- LO3: The Nature of Science and its Relationships to Technology, Society and the Environment (DoE, 2003).

LO1 is in line with international trends towards inquiry-oriented science education (Minner, Levy & Century, 2010), and LO3 with the Science, Technology and Society (Solomon, 1993) and Nature of Science movements (Abd-El-Khalick & Lederman, 2000). We will consider first the weighting and then the content of these three LOs.

With regard to weighting, the NCS document required that both teachers and examiners pay equal attention to each of the LOs. Under the heading “Weightings of the Learning Outcomes” it instructed:

> The three Learning Outcomes and the Assessment Standards are of equal importance. This implies that the Learning Outcomes require the same prominence in terms of teaching and assessment time. (DoE, 2003, p. 15).

However, subsequent documents gave greater prominence to LO2 at the expense of LO1 and LO3, as illustrated in Table 2. This prominence became more exaggerated in subsequent documents. For example, LO3 had a weighting of 33 % in the NCS document but by 2009 could be weighted as little as 5 % in the final examinations.

Table 2: Specified weightings of the Learning Outcomes for examinations

	Paper 1 Physics				Paper 2 Chemistry			
	SAG (gr. 10-12)		*Exam Guidelines (Gr. 12)*		*SAG (gr. 10-12)*		*Exam Guidelines(Gr. 12)*	
	2005	2007+8	2008	2009	2005	2007+8	2008	2009
LO1	30 %	40 %	35 – 45 %	35 – 45 %	30 %	30 %	25 – 35 %	30 – 40 %
LO2	40 %	45 %	40 – 50 %	45 – 55 %	40 %	45 %	40 – 50 %	40 – 60 %
LO3	30 %	15 %	10 – 20 %	5 – 15 %	30 %	25 %	20 – 30 %	5 – 15 %

One could argue that examinations are not well suited to assessing LO1 and LO3 and so they should be assessed in other ways, such as the two practical investigations and one 'research project' required by the SAG for each grade. However, the SAG requirement was that 85% of the final mark in grade 10-12 be derived from tests and examinations, with 75 % from the end-of-year examination and 10 % from tests and midyear examinations. In contrast only 10% came from the two practical investigations and 5 % from the research project. Moreover, according to the SAG, the practical investigations were required to assess all three LOs though "with a greater focus" on LO1 (p. 10). Furthermore, the SAG example of a research project was a pen-and-paper exercise which tested understanding of concepts associated with LO1 (e.g. hypothesis, control of variables) and did not in fact require any research. Overall, in contrast to the published curriculum, LO3 was severely neglected in assessment weightings in the illustrated curriculum, with LO1 better off, and LO2 leading the field with a clear margin.

We have described the assessment weighting, but what of the weighting of the operational curriculum in the classroom? According to the NCS quote above, the teaching time should have been equally weighted. We did not investigate the operational curriculum, but note two points. First, as explained earlier, the examined curriculum drives the operational curriculum phase. Second, a content overload for LO2 meant that LO2 tended to eclipse LO1 and LO3 in the classroom. An Umalusi (2009a) study concluded that the NCS included about 30 % more topics than the previous physical science curriculum and estimated that the time required to teach this LO2 content would be about 31 % more than that required for the old Higher Grade[1] syllabus.

We now turn to look at the actual content of the LOs, which were fleshed out further in Assessment Standards (AS) given in Table 3. Here we ask the question, what counts as LO1? In other words, what counts as 'conducting an investigation', 'interpreting data to draw conclusions', 'solving problems' and 'communicating and presenting information and scientific arguments'? We will consider the interpretation of all of these except the first.

The explanation for LO1 in the NCS document started with:

> The thrust of this Learning Outcome is on the doing aspects and the process skills required for scientific inquiry and problem solving. Learners' understanding of the world will be informed by the use of scientific inquiry skills like planning, observing and gathering information, comprehension, synthesizing, generalizing, hypothesizing and communicating results and conclusions. (DoE, 2003, p. 13)

In the context of this description, AS 1.2 – 'Interpreting data to draw conclusions' – suggests the data analysis phase of an investigation, for example plotting measurements on a graph to find a relationship. Indeed the NCS document described AS 1.2 as "seek patterns and trends, represent them in different forms, explain the trends, use scientific reasoning to draw and evaluate conclusions, and formulate generalizations." (p. 19). But according to the final document of the illustrated curriculum, the Exam Guidelines, any question involving a graph counted for AS 1.2, even if the question tested content understanding, for example sketching or interpreting a graph of motion.

1 Previously South African learners had the option of doing Physical Science on Higher or Standard Grade.

Table 3: Learning Outcomes and Assessment Standards (DoE, 2003, pp. 13-14,17)

Learning Outcomes	Assessment Standards
LO1: Practical Scientific Inquiry and Problem-solving Skills The learner is able to use process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts	AS1.1: Conducting an investigation AS 1.2: Interpreting data to draw conclusions AS 1.3: Solving problems AS 1.4: Communicating and presenting information and scientific arguments
LO2: Constructing and Applying Scientific Knowledge The learner is able to state, explain, interpret and evaluate scientific and technological knowledge and can apply it in everyday contexts.	AS 2.1: Recalling and stating specified concepts AS 2.2: Indicating and explaining relationships AS 2.3: Applying scientific knowledge
LO3: The Nature of Science and its Relationships to Technology, Society and the Environment The learner is able to identify and critically evaluate scientific knowledge claims and the impact of this knowledge on the quality of socio-economic, environmental and human development.	AS 3.1: Evaluating knowledge claims and science's inability to stand in isolation from other fields AS 3.2: Evaluating the impact of sciences on human development AS 3.3: Evaluating science's impact on the environment and sustainable development

The skills listed in the opening quote of the last paragraph are the elements of the so-called scientific method, thus AS 1.4 – 'communicating results and conclusions' – appears to refer to a report on an investigation. But the NCS document examples for AS 1.4 were broader than such practical reports and included e.g. "formulates and defines scientific arguments for wearing seatbelts" (p. 23). The Exam Guidelines broadened this further and interpreted AS 1.4 as "Explain/describe /argue using scientific principles" (p. 16) – thus counting as LO1 any question which tested content knowledge by requiring an explanation or description.

'Solving problems' can mean the solving of 'real life' problems but is also used for mathematical 'problems'. The NCS linked problem solving with the scientific method: in describing the 'scope' of LO1, the NCS document claimed that the skills "which learners use and develop in the study of Physical Sciences are similar to those used by scientists at work" (p. 10) and gave this definition in the explanation of LO1: "Problem solving involves identification and analysis of the problem at hand, and the design of procedures to reach solutions". (p. 13). In contrast, the Exam Guidelines included the following interpretation of AS 1.3: "Solving problems using calculations with two or more steps." (p. 15). Thus any calculation involving more than one ‘formula’ from the ‘Formulae’ table provided on the examination paper counted as LO1.

If we return to the statements of LO1 and LO2 in Table 3, we can see that the Exam Guidelines’ interpretations of the last three Assessment Standards for LO1 are more in line with LO2 than the ‘Practical Scientific Inquiry’ of LO1. Thus over time the original inquiry-oriented focus of LO1 morphed into the content knowledge focus of LO2. We liken this situation to that of nitrogen which when bombarded with neutrons in the upper atmosphere changes into carbon-14, but over time transmutates back into nitrogen. In the same way, the old curriculum was dramatically changed in the rarefied atmosphere of the curriculum producers, but over time transmutated back to being similar in nature to the original. Effectively the Exam Guidelines provided a framework in which traditional science examination content masqueraded as inquiry oriented science.

In response to our first research question, we have shown that there was a considerable drift in the conceptualization of the Physical Sciences LOs in successive documents, both in weighting and meaning: the assessment weightings migrated in favour of LO2 while aspects of LO1 transmutated into LO2. The vision of having skills and relevance count equally with content, espoused in the published curriculum, was eroded in the subsequent documents of the illustrated curriculum. This resulted in a substantial lack of congruency between the published and illustrated curricula, and within the illustrated curriculum.

The examination papers

Having considered the shift in conceptualisation of the LOs, we now consider their actual weightings in the exemplar and actual examination papers, thus addressing our second research question. We analysed the Physical Sciences Grade 10-12 exemplar examination papers and the 2007 and 2008 Grade 12 examinations using the elaboration of the Assessment Standards given in the Exam Guidelines. The questions were classified by two physicists and one chemist and then cross validated: the physicists checked the chemist’s classifications and vice versa.

Despite this crosschecking, we note that such classification is not straightforward. Our totals disagree significantly with Koopman’s (2010), who seems to have done his analysis using the original interpretation of LO1. In particular, classification of LO3 requires careful judgement. Many physics questions requiring LO2 knowledge are asked about everyday objects (for example a wheelbarrow in the grade 11 exemplar paper) but we judged that this did not make the questions eligible for categorization into LO3. The chemistry examiners are prone to using what we consider to be pseudo contexts, for example:

> Most modern cars are equipped with airbags for both the driver and the passenger. An airbag will completely inflate in 0,05 s. This is important because a typical car collision lasts about 0,125 s.
>
> The following reaction of sodium azide (a compound found in airbags) is activated by an electrical signal:
>
> $2NaN_3$ (s) ® 2Na (s) + $3N_2$ (g)
>
> 7.1 Calculate the mass of N_2(g) needed to inflate a sample airbag to a volume of 65 dm^3 at 25 °C and 99,3 kPa. Assume the gas temperature remains constant during the reaction.
>
> 7.2 In reality the above reaction is exothermic. Describe, in terms of the kinetic molecular theory,

> how the pressure in the sample airbag will change, if at all, as the gas temperature returns to 25 °C. (DoE, 2007, p. 8).

This question is framed as a contextualised question but in reality the first paragraph is not necessary for answering the question and merely provides additional reading for the candidates. Hence we did not consider such a question as an example of LO3.

We will first present the overall totals for the LOs, and then break these totals down into the individual Assessment Standards. Table 4 shows the percentage of marks allocated to each LO, according to our analysis. The numbers in brackets show how these percentages differ from those specified in the Exam Guidelines (grade 12) or the SAG (grade 10 and 11) – see Table 2. Note that for the grade 12 papers, the specified percentage was a range over 10 % (e.g. 35 - 45 %), whereas for the 10 and 11 papers, the specified percentage was a single number (e.g. 40 %) which made the target narrower for an examiner. For LO1, the physics examinations were above the specified percentages, but the chemistry examinations were below, despite the fact that from 2007 the specified percentages for chemistry were lower than those for physics. For both papers, the examinations contained more than the specified percentages of LO2 questions, and less than the specified percentages of LO3 questions, despite the already substantial increase and decrease respectively in the specified weightings of these two LOs described in the last section. The proportional allocation across the LOs of the physics papers was fairly consistent with a maximum range for any LO of 9 %, but more variable in chemistry, with a range of 14 – 16 % for each LO. Particularly noticeable is the shift towards LO2 in the grade 12 chemistry papers. Overall all but one of the examination papers took the emphasis on LO2 even further than the already inflated weightings specified in the illustrated curriculum.

Table 4: Percentage distribution of marks across Learning Outcomes

	Physics (Paper 1)				Chemistry (Paper 2)			
	Illustrated Curriculum: Exemplars			Examined Curriculum	Illustrated Curriculum: Exemplars			Examined Curriculum
	Gr. 10	Gr. 11	Gr. 12	Gr. 12	Gr. 10	Gr. 11	Gr. 12	Gr. 12
	2006	2007	2008	2008	2006	2007	2008	2008
LO1	41 (+11)	44 (+4)	50 (+5)	43	21 (-9)	31	15 (-10)	21 (-4)
LO2	55 (+15)	42 (+10)	45	52 (+2)	49 (+9)	49 (+4)	65 (+15)	64 (+14)
LO3	3 (-27)	13 (-2)	5 (-5)	5 (-5)	29	19 (-6)	19	15 (-5)

Figure 2 and Figure 3 below show the breakdown by Assessment Standards for the exemplar papers and the actual grade 12 papers, for physics and chemistry respectively. For physics the distribution across Assessment Standards was fairly consistent across the papers, which meant the final paper was not a radical departure from the exemplars. However, AS 1.4 only featured in the last two papers, and AS 3.1 and 3.3 each featured only once overall. With regard to inquiry-oriented science, AS 1.1 'investigating relationships' decreased while AS 2.2 increased, consistent with the move away from inquiry oriented science towards content knowledge which we saw in the conceptualisation of the LOs. In addition the biggest contributor to LO1 was AS 1.3, 'solving problems', which we argued in the last section is really LO2 in disguise. Thus the reason the physics examinations were above the specified percentages for LO1 overall is not because of a focus on scientific inquiry, but because of a significant proportion of calculations involving more than one step. With regard to content knowledge, AS 2.2, ‘Indicating and explaining relationships’ consistently contributed less to LO2 than the Assessment Standards involving recall and application.

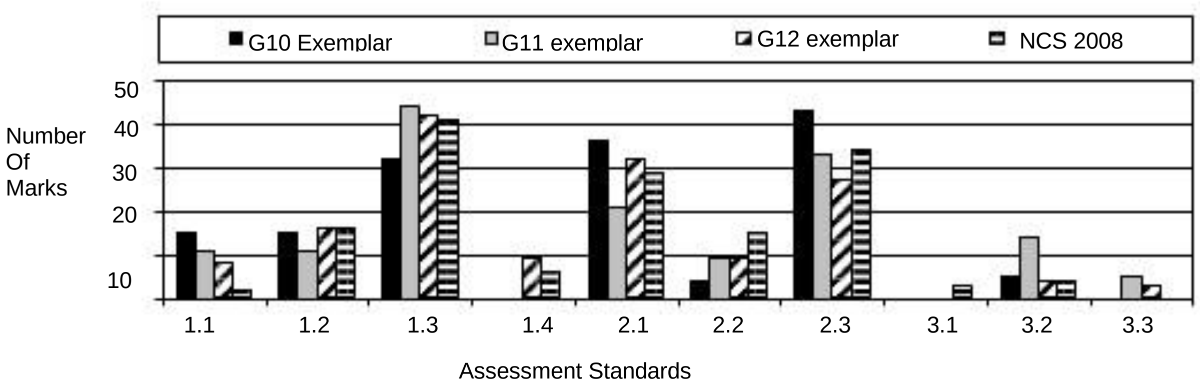

Figure 2: Distribution of marks across Assessment Standards for Physics Examinations

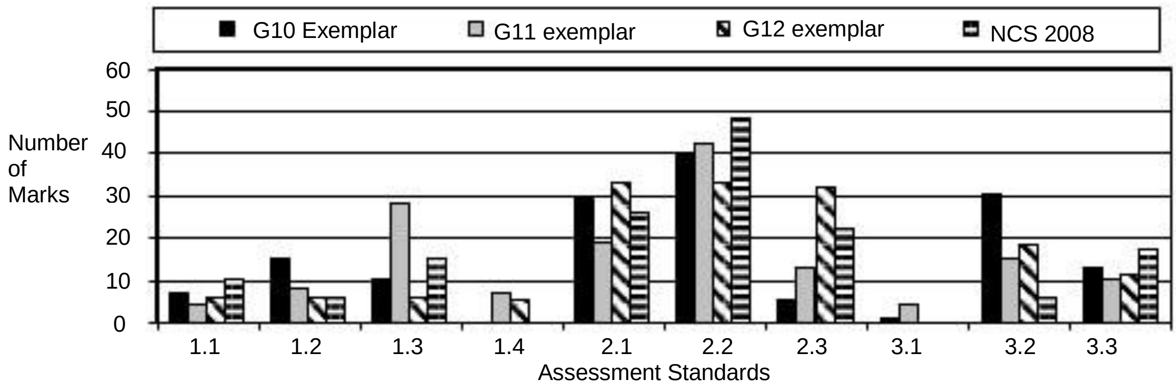

Figure 3: Distribution of marks across Assessment Standards for Chemistry Examinations

The chemistry papers show distinctly different distributions across the Assessment Standards from the physics papers. AS 1.3 only contributed disproportionately to LO1 in the grade 11 exemplar. Except for the grade 12 Exemplar, AS 2.2 contributed more than the other two Assessment Standards for LO2 – implying that recall was more significant in the chemistry examinations than the physics examinations. Although chemistry had more marks allocated to LO3, Figure 3 shows that AS 3.1 was neglected – the contribution came instead from questions which involved evaluating the impact of science on human development and the environment. The distribution across Assessment Standards is less consistent than that of physics, making the exemplars less helpful as indicators of the final paper. The grade 12 exemplar had the most equitable distribution.

Overall both physics and chemistry papers reflect a focus on content, and so the question naturally arises: how do these grade 12 examinations compare with the content-focussed examinations of the previous curriculum? This brings us to our final research question. The comparison between the 2007 grade 12 examinations on the old curriculum (NATED 550) and the 2008 NCS papers are shown in Figure 4 and Figure 5 below.

The previous curriculum was not outcomes-based and so it is not surprising that the 2007 papers hardly included LO1 and LO3. The exception is AS 1.3 but this simply indicates that both 2007required more two-step calculations than their 2008 counterparts. The relative proportions for the three Assessment Standards of LO3 are similar for the 2007 and 2008 paper, for both physics and chemistry. Overall the 2008 examined curriculum was similar to the 2007 examined curriculum in the nature of the questions asked, with a small shift towards contextualisation (LO3) and inquiry oriented science (AS 1.1). But the effect of these changes is minimal and the balance of question types in the new paper is not fundamentally different from before.

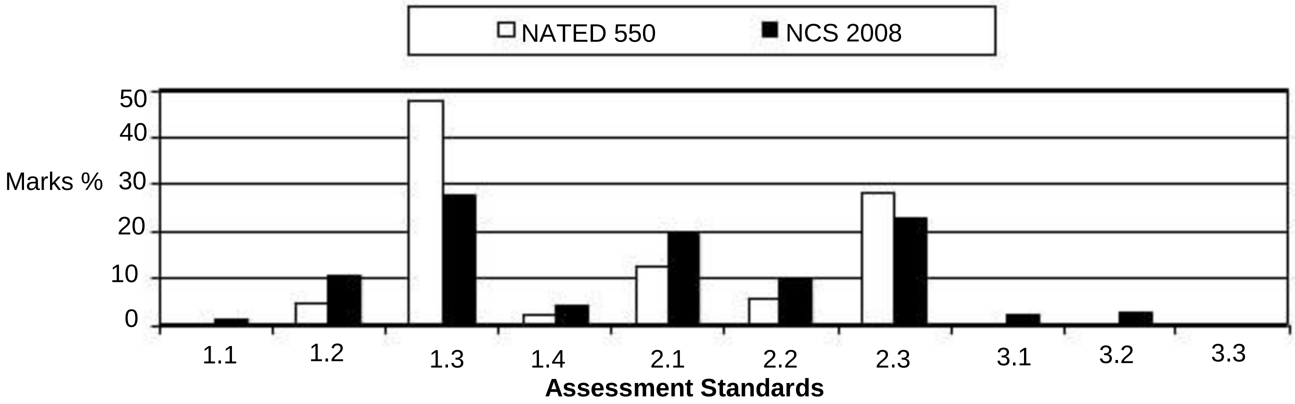

Figure 4: **Marks** distribution for Assessment Standards for Physics Gr. 12, 2007 and 2008

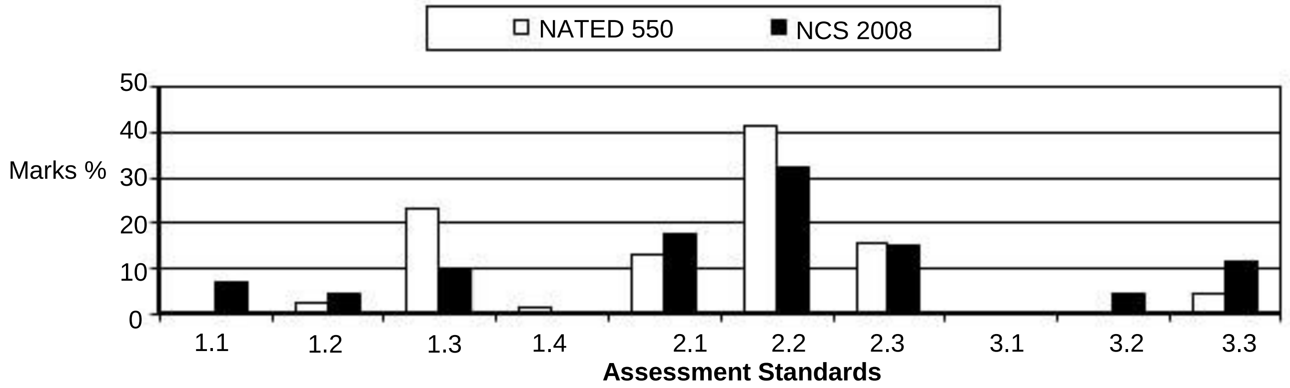

Figure 5: **Marks** distribution for Assessment Standards for Chemistry Gr. **12, 2007 and** 2008

Discussion

We have witnessed a retreat from the original NCS vision of weighting skills and relevance equally with content. How does this retreat talk back to the principle of transformation upon which the curriculum was supposedly based? With regard to this principle, the LPG made the claim that:

> Physical Sciences contributes to social transformation by ensuring the development of scientifically literate citizens who are responsible and can critically debate scientific issues and participate in an informed way in democratic decision-making processes. (DoE, 2008a, p. 8)

According to the NCS document, LO3 addressed scientific literacy by a focus on science, society and environmental issues. So using the published curriculum's own logic, diminishing the importance of LO3 detracts from scientific literacy and undermines the principle of social transformation. Hence we conclude that the curriculum producers' vision of transformation which was the rationale for the new curriculum was eroded by the recontextualisers who wrote the illustrated and examined curricula. Instead of transformation, we see transmutation.

The retreat from the vision also led to a lack of congruency between the published, illustrated and examined curricula. We note though that even the original NCS document reflected conflicting voices. Green and Naidoo concluded it:

> appears to be hybrid product that intersects different ideological traditions, different discourses, a range of competences and a range of complexities. It is probable that the voices of a diverse range of role-players are reflected in the structure, nature, content and goals of the curriculum. (2006, p. 79).

This situation is not unusual: Van den Akker cautions that the "result of adding up all kinds of wishes is that curricula tend to get overloaded and fragmented" (2003, p. 7). Bernstein's (1996) notion of classification helps explain some of the diverse voices. Strong classification means that there are strong boundaries between science and other subjects. Thus students are given epistemological access to the disciplines of science, and are able to work powerfully with the paradigm which science offers. On the other hand, weak classification means porous boundaries between science and other subjects, and between school knowledge and home knowledge. Thus students are able to make connections between science and other subjects, and between school and home. The two main goals of science education, "a scientifically-based workforce and a scientifically literate citizenry" (Fensham, 1988, p. 3) sit in tension because 'science for scientists' needs strong classification whereas 'science for all' involves weak classification. The focus on traditional content in the examinations makes for strong Bernsteinian boundaries which detract from the goal of science literacy expressed in LO3.

The extent of the retreat from the original vision is reflected in the similarities between the examinations on the NCS and NATED 550 curricula. We recognise that examiners faced a tension between setting an examination learners (and their teachers) would find familiar and hence cope with, and using examinations to push for transformation. But instead of "gradual iterative approximation of curricular dreams into realities" (van den Akker, 2003, p. 8) subsequent examinations followed the same broad pattern and so entrenched the emphasis on LO2.

Overall our analysis of curriculum documents confirms the ministerial committee's conclusion that there was confusion created by document proliferation. We further showed how incongruency between the documents led to continually shifting goalposts. The question we now ask is: does the CAPS solve the problem? The Minister of Basic Education stressed in a Government Gazette that the CAPS: "must not be seen as a new curriculum but only as a refined and repackaged" NCS (Motshekga, 2010, p. 7). We dispute this claim: while it may be true of other subjects, it is not true of Physical Sciences. Firstly, the content has changed significantly: various topics have been removed, moved between grades or considerably reworked. This immediately renders current textbooks obsolete, indicative of a new curriculum. Secondly, while the statements of the Learning Outcomes remain as ‘Specific Aims’ in subjects such as Natural Sciences and Life Sciences, in the Physical Sciences they have disappeared. In other words the central pillars of the NCS curriculum have been excised. Instead a section from the LPG entitled ‘What is the purpose of Physical Sciences?’ has been renamed ‘Specific Aims of Physical Sciences’ in the CAPS. However this section does contain an echo of the Learning Outcomes insofar as it foregrounds investigation: “The purpose of Physical Sciences is to equip learners with investigating skills”, and claims that “Physical Sciences promotes knowledge” and “an understanding of the nature of science and its relationships to technology, society and the environment” (p. 8).

Hence Physical Sciences is once again in the ‘envisioned curriculum’ phase – the first triangle of Figure 1. The more stable ‘enacted curriculum’ phase only lasted for three years – no longer than the duration of the envisioned curriculum phase of a three year curriculum. These changes have been made without any acknowledgement of the changes in the CAPS – it is left to teachers to work out what has changed. Thus rather than addressing the confusion, the CAPS adds to it by shifting the goalposts yet again, without signposting the shift. In addition, the move into another envisioned curriculum phase destabilises an already fraught situation.

Conclusion

In summary, the retreat from the original NCS vision of weighting skills and relevance equally with content occurred in two ways: through lowering the assessment weightings of LO1 and LO3, and through a transmutation in the meaning of LO1 into LO2. Evidence of this retreat is seen in the similarities between the examinations based on the NCS and those on the previous NATED 550 curriculum. The retreat detracted from congruency between the elements of the curriculum, and hence from alignment between the ideal curriculum and the attained curriculum. The retreat undermined the principle of transformation upon which the NCS curriculum was supposed to be based. The lack of transformation of the examined curriculum has implications for the implemented curriculum, since in our model the examined curriculum is the main driver for the enacted curriculum phase.

We analysed the NCS Physical Sciences curriculum documents and examinations using terms of reference provided by the NCS document. Our analysis is not exhaustive, for example we have not looked at the way in which the examinations cover the content. We have not commented on the language and diagrams or the textual and contextual literacies required in order to make sense of the paper, and which kinds of learners might be advantaged or disadvantaged by the choices which have been made in this regard. In our discussion, we did not consider issues of power and whose interests are served by the examined curriculum. These are issues for further research.

Although the Physical Sciences CAPS cements the retreat from the original vision of counting relevance and skills equally with content, we commend it for internal consistency and for honesty – it does not masquerade content-oriented science as inquiry-oriented science. We recognise that there will never be a perfect Physical Sciences curriculum. Hence we recommend that the recontextualisers allow the CAPS to indeed cap the curriculum for a time, thus allowing teachers reeling under continual curriculum change to consolidate.

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