EXPLORING CONCEPTIONS OF CURRICULUM AND STANDARDS IN HIGH SCHOOL CHEMISTRY AND ADVANCED PLACEMENT PROGRAMS IN GEORGIA

by

EVANS WAFULA MAHAYA

(Under the Direction of Norman F. Thomson)

ABSTRACT

Standards-based instruction is an important ingredient for reforms in science teaching. The *curriculum* prescribes *how* and *what* content areas to teach while *standards* provide a guide for instruction. This study explores conceptions of curriculum and standards-based practices, the structure and organization of the Advanced Placement (AP), the International Baccalaureate (IB) programs and College Preparatory (CP) Chemistry curriculum. The research questions addressed are: (1) What are the conceptions of curriculum and standards-based practices espoused in policy documents and curriculum reform initiatives? (2) What content and process overlaps are evident in the Chemistry curriculum and the science education standards? 3) How are advanced placement initiatives situated in standards-based school reforms and the Chemistry curriculum? Using qualitative documentary analysis research methodology, data were collected using refined data collection protocols. Findings from the study indicate varied conceptions of curriculum and standards-based practices and significant overlaps in content and purposes of the courses. The study recommends an all-inclusive learner centered standards-based Chemistry curriculum.

INDEX WORDS: Advanced Placement, Chemistry, Conceptions of Curriculum, Classroom Practices, College Preparatory, Document Analysis, Georgia Standards, International Baccalaureate, Pre-college Chemistry, Science Curriculum, Standards-based Practices.

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DEDICATION

In loving memory of my beloved mum and dad; the late Lydia Mahaya (1947–1982) and the late Mathew Mahaya (1936–2007). I know both of you loved us very much and wished only the very best for each one of us. Even though you are departed, I cherish the wonderful moments that we shared in the days of your lives. May your souls rest in eternal peace.

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INTRODUCTION

Background

Over the last two decades, national organizations in the United States have been working together in an effort to reform the schools, particularly in teaching (Delandshere & Arens, 2001). It has also been reported that the corresponding reform proposals resulted in over 400 science education reform documents being published since the 1970's (Krueger, & Sutton, 2001). The movement toward the development of standards and the science curriculum is evident in the school reform agenda in many states across the country, with reform initiatives being aimed not only at strengthening the teaching profession, but also enhancing the quality of student learning. As a matter of fact, achieving a more coherent and rigorous science curriculum is an important policy concern facing the scientific community in the United States (Schmidt, 2003). The most recent policy initiatives for more reforms in science education include the current congressional reauthorization of the federal No Child Left Behind (NCLB) educational laws, national reports calling for immediate improvement of precollegiate science education, and the on-going debate on whether the national educational standards should replace the existing academic standards decided upon by different states (Lawton, Berns & Sandler, 2009). This has been, and remains a critical issue in curriculum development and the standards-based approach to science teaching.

In the state of Georgia, one of the most significant initiatives to support the standards-based approach to instruction is the engagement of teachers in regular professional development workshops to strengthen their knowledge of standards-based instruction, to sharpen their content knowledge and pedagogical skills and support their transition to new standards. According to Kent, (2004), professional development is the catalyst to transforming theory into current teaching best practices (p. 427), because teachers are deeply involved in education and policy, both as stakeholders and agents of change in the curriculum implementation process.

Curriculum reforms require the provision of a support system for teachers during the implementation process (Bennett, Grasel, Parchmann, & Waddington, 2005) and comprehensive assessment methods because teachers' conceptions about their practices may be manifested in classroom practices based on what they envisage as strategies for best practice. To achieve their objectives, teachers may sometimes resort to using traditional and non-traditional approaches to teaching with some degree of success; but these may not readily align with what is envisaged in the standards and a standards-based curriculum. In current school reforms, policy makers tend to define success as students' attainment of pre-determined academic standards; which are typically assessed using high-stakes testing programs (Kugelmass & Rainforth, 2003). However, success transcends such simplistic definitions because learning requires more than application of the validated standards and the instructional strategies used especially in science teaching.

Standards-based reforms are similar to other reform initiatives that were developed on the premise that by clearly defining the curriculum in terms of both content and teaching standards; and developing *performance standards* that are monitored through external assessments, there would be transformation of teachers' instructional practices which consequently produce the desired levels of student performance (Delandshere & Arens, 2001). However, this is not the case because teachers' conceptions about teaching encompass a wide range of perspectives; from those in which teaching is envisaged as a way of transmitting knowledge to an alternative view of teaching as way of supporting students in their own knowledge construction (Eley, 2006).

Given that scientific knowledge consists of facts, theories, concepts, principles, models and laws which allow learners to assign meaning to their learning (NRC, 1996, p. 23), this may be construed as the ultimate learning goal. However, placing greater emphasis on scientific meaning - a possible outcome of the National Science Teachers' Association (NSTA) initiative - to identify science 'core content' potentially reinforces the view that other aspects of science are not significant (Munby & Roberts, 1998). In essence, prioritizing science content in curriculum development is synonymous with having the school boards and science teachers set up specific objectives with respect to science meaning, with the hope that they will add something else.

An equitable science program provides high quality science education to all students (Krueger, & Sutton, 2001). Therefore, the science curriculum is fundamentally significant, if it allows all learners to experience a reasoned nature of science by giving priority to evidence and considering alternative views to propose, justify or refute claims and build reasonable scientific explanations. Curriculum developers must recognize the importance of sound teaching and assessment procedures and consciously make the decisions to include them in planning; in order for the curriculum to be more effective (Bybee, 1998).

Lawton, et al., (2009) argue that in spite of the existence of national education laws and policy mandates, most educational decisions in the Unites States are made at the state and local level. Reform efforts must focus on the science curriculum at classroom levels in consideration of the researchers' argument that the science curriculum must be standards-based, scientifically accurate and pedagogically sound (p. 4).

The idea of a standards-based curriculum and standards-based instruction is often very confusing. According to Kugelmass & Rainforth, (2003), *Curriculum* is used to describe *what* is being taught, whereas *Instruction* is used to describe *how* it is taught (p. 8). On the basis of this, one would hope that the confusion is reconciled given the apparently clear distinction between instruction and the curriculum. However, this does not dispel general conceptions and arguments that tend to qualify instructional approaches as being part and parcel of the curriculum process.

Standards-based instruction has gained tremendous support from policy makers partly because of the popular argument that standards should be used as a guide that drives instruction (Georgia Performance Standards, 2006). Both the *Quality Core Curriculum* (AAAS, 1993) and the *National Science Education Standards* (National Research Council, 1996) provide a clear framework for teaching on the basis of which the new *Georgia Performance Standards* were adapted. Although most research and policy initiatives in science teaching are often aimed at improving the classroom instruction and transforming the learning environment, developers of the science curriculum sometimes have different interpretations of what they envisage as the focal point of curriculum. According to Bybee, (1998), some see it as “the process of science” while others see it as the “big ideas”. On the other hand, descriptions of curriculum may focus on the instructional strategies used, such as “hands on” or “use of co-operative groups” (p. 150).

Nearly three decades of research in science education shows that students lose motivation in learning science after the first few years of schooling (Schmidt, 2003), because the traditional curriculum has not addressed the issue of engaging students and making the science curriculum relevant to them. For curriculum to be coherent, the content standards must be articulated as a sequence of topics and performances that reflect a logical, sequential or hierarchical nature of the (science) content from which the subject matter derives (Schmidt, 2003).

The *National Science Education Standards* (NRC, 1996) were developed with the intent to assist the science education community to develop a more systematic framework of domains for which the standards apply; with the hope that states and school districts would then develop a variety of science curricula to meet their needs (Bybee, 1998; pp. 150–151). However, the same developers of those standards did not provide a framework for translating them into curriculum materials. This implies that the development of standards does not result in the improvement of classroom practices, student achievement and the science curriculum; because standards are only a preliminary step in a process that is often followed by translation of standards into curriculum materials and the actual practice. In fact, before the science content standards were developed to guide standards-based reforms in science teaching, the *National Science Foundation* (NSF) took the initiative to fund the development of science curricular materials in four curriculum material centers; based on some frameworks to be used for implementation of standards-based instruction in the classrooms (Schmidt, 2003). It is no surprise therefore, for many science educators to have envisaged the content standards as the basis for curriculum frameworks or the curriculum *per se*.

There has always been a big question with regard to providing a more rigorous science curriculum in high school, and hence the renewed movement towards implementation of the International Baccalaureate (IB) and more Advanced Placement (AP) programs in the United States. Many schools seeking to prepare their students for post-secondary institutions believe that the rigor of the courses is effective in propelling students to be successful in tertiary institutions (Long & Kirchhoff, n. d.). Advanced Placement and the International Baccalaureate programs have gained popularity amongst a significant number of high school students. In a recent survey interview of 200 students in 23 high schools in the United States, Hertberg-Davis & Callahan, (2008), reported that students believe the Advanced Placement and International Baccalaureate courses provide a greater level of academic challenge and more favorable learning environments than other high school science courses.

Since its inception in the United States in 1955, the Advanced Placement program has registered significant growth. In 2004, the participation rate in Advanced Placement courses was 1,081,102 students. The International Baccalaureate program has also grown since it was first introduced in 1965; and currently has about 31,000 students who participate in the program (Hertberg-Davis & Callahan, 2008). There has been great emphasis on the need to give high school students an opportunity to experience Chemistry as it is typically encountered in the scientific world; by adopting scientific approaches such as inquiry and open-ended problem-solving methods that make use of problems which have a variety of possible solutions.

As a matter of fact, the Advanced Placement courses and the International Baccalaureate program are the closest to providing a standardized national (and/or international) Chemistry curriculum in the United States (Long & Kirchhoff, n. d.). These advanced programs are widely recognized outside of the United States for potentially enhancing and optimizing students' possibilities of attending colleges or universities abroad. However, there is insufficient evidence to suggest that they are either inquiry-based or standards-based in terms of their mode of delivery.

The very first college Chemistry course that a student takes when he/she enrolls plays a crucial role in the academic of life of the college student. High school Chemistry teachers are often compelled to make deliberate, conscious and sometimes very tough decisions with regard to content and the topics to be included in their unit plans (Tai, Ward & Sadler, 2006). In essence, the big decision about which topics need more time commitment and careful planning is a very important one for high school teachers preparing students for college.

The following sections outlines the fundamental problem in the current study and sets the stage for a critical look at issues pertaining to advanced placement, standards-based practices, different aspects of the high school Chemistry curriculum.

Statement of the Problem

As a Kenyan science teacher and prospective science teacher-educator, I have often refrained from being skeptical about the strengths of the argument that "*performance standards should drive instruction.*" On the contrary, they ought to serve that very purpose, if indeed, they provide a clear guide for instruction (Chemistry Performance Standards, Appendix A). Thinking about the science curriculum and classroom practices in Kenya and the United States has over the last few years transformed my own view of standards-based practices and how I perceived science teaching. A few years ago, I took leave from my job in Kenya where I taught Chemistry within a school system for which the Chemistry curriculum is designed and developed centrally by the Ministry of Education, (MOE) through an affiliate institution called the Kenya Institute of Education, KIE.

The curriculum development process in Kenya is usually a collaborative effort between a panel of subject specialists, curriculum developers and experienced Chemistry teachers in close consultation with officials from the Ministry of Education. It involves the usual steps: Identifying objectives (derived from the national goals of education), selection of content, determination of relevant learning activities and instructional approaches; and formulation of procedures for the evaluation of the set objectives. Piloting, refinement and revisions often precede the nationwide dissemination of the Chemistry curriculum to all secondary schools across the country in the form of syllabi of each subject for respective grade levels. Syllabi are often clustered in terms of Sciences, Languages, Fine Arts, Humanities, Religious Studies, and Technical subjects. In fact, general objectives for high school science cut across various science subjects. The *Inspectorate* is responsible for the supervision of curriculum implementation and evaluation through the office of the Provincial Directorate of Education (PDE) and District Education Boards (DEBs); with the Districts serving as smaller administrative units in each of the eight Provinces across the country. Therefore, the high school Chemistry curriculum in Kenya is essentially a *national curriculum* covered in all schools across the country irrespective of their classification. However, a few private schools offer the British *General Certificate of Education* (G.C.E.) - an advanced or “A-level” curriculum that guarantees six years of high school education.

When I arrived in the United States, I was struck by the big difference in approach to the curriculum development process, and the idea of the state-mandated curriculum and the local school district curricula as opposed to a unified national curriculum as was the case in Kenya. In particular, I was intrigued by the existence of different high school Chemistry curricula, or rather different courses within the broad high school Chemistry curriculum, including the Advanced Placement, the International Baccalaureate and the Honors programs in the Chemistry courses. On the basis of this, I actually wondered how all three courses were reconciled within the context of the same school system that offered such courses. Given the fact that the *National Science Education Standards* were formulated to guide instructional planning, I reckoned that it would be a daunting task to accomplish this in a school system that offered all three sections of the courses.

Having taught Chemistry in Kenya – in a system with a unified national curriculum, there was a general ‘consensus’ that the curriculum drives instruction within Kenya’s school system. However, the situation on the ground was contrary to the idealized position owing to the fact that the school system was highly examination-oriented. Although the curriculum provided an outline of the national goals of education and the expected long-term learning objectives for students and also identified relevant content areas to be covered as key points for the establishment of sound instructional experiences, teachers often embraced instructional practices which promoted recall and rote-learning for high-stakes examinations. This instructional scenario does not represent a very significant departure from instructional practices used in the United States that make use of high-stakes standardized testing. Although teaching standards in the United State are mandated in respective states, they do not include an outline of the national goals of education which may only be inferred from the state's refined educational goals as defined in the curriculum.

During the second year of my graduate studies at the University of Georgia in the United States, I was privileged to be involved in observing teachers' science lessons in select suburban middle and high schools in Georgia as part of a research project that focused on the professional development of mathematics and science teachers. Such observations were often coupled with informal or semi-structured interviews in which teachers highlighted important aspects of their classroom practices such as inquiry-based lesson planning, task-oriented student assessment and standards-based instruction.

In one of the many encounters with mathematics and science teachers, I met a high school science teacher who, out of curiosity, wanted to know more about my experience as a Chemistry teacher in Kenya. Our discussion revolved around the curriculum and instructional practices and assessment. By virtue of my background in the subject, albeit in different school settings, my interest in the gist of the discussion was unwavering. However, one of the things that caught my attention during our discussion was the curriculum for grades K-12 called the Academic Knowledge and Skills (AKS) used in one of the Georgia school districts. He observed that for each grade level, the AKS outlined the essential components that students were expected to know at any particular grade level or subject. They served as templates upon which teachers could build their instructional units, lesson plans and curricular experiences, using curriculum guides, textbooks, technology and many other materials to teach, with the hope that each student would maximize his/her potential. He pointed out that the AKS provided a guide of *exactly* what each student was expected to learn; and teachers could therefore organize their own instructional experiences to meet every child's individual needs. This was an intriguing perspective because I had not come across a curriculum that was this explicit!

At the time, I was doubtful that even with new revisions in the *Georgia Performance Standards*, they would reach the same levels of precision with regard to addressing individual learners' needs. Later, when I embarked on conceptualizing my research idea, I saw the need for a more critical look at the high school science curriculum in the United States in general; and Chemistry in particular. To narrow down my scope, I focused on the Chemistry curriculum in the state of Georgia. My immediate attention was drawn to the Advanced Placement (AP) program, and the International Baccalaureate (IB) curriculum in Chemistry in addition to the College Preparatory course. For simplicity, I have used abbreviated forms of AP, IB and CP courses respectively; for some chapter sections in subsequent reference to each of the courses.

One of my greatest concerns about the advanced courses was the fact that curriculum development and/or assessment of the courses is carried out by external agencies. The research problem that prompted this research study was based on the current emphasis of standards-based instruction in science teaching, in addition to curriculum organization and instructional planning. My concern was that, if these organizations coordinated all the assessment and administration of the *advanced* high school Chemistry courses, would the courses be subject to standards-based instruction? A simplistic view of 'standards-based' instruction implies mere alignment with the standards. In this regard, the AP programs may be *standards-based* with respect the laid down AP standards. However, the focus of the current study makes specific reference to the *state* and *national* science standards. This is critical in view of the fact that the International Baccalaureate (IB) is an internationally acclaimed academic program, just like the AP program is nationally.

Although my ‘informant’ teacher taught the AP Chemistry at his school, the national AP curriculum is usually developed by both high school and college teachers under the auspices of the College Board while the AP Chemistry examinations are administered by the Educational Testing Services (ETS). The International Baccalaureate (IB) examinations are administered through the International Baccalaureate Organization (Mayer, 2008). However, as intriguing as it all sounded, I did not envisage the high school Chemistry in Georgia as dichotomous curriculum in school systems given that many school districts were already phasing in new standards.

Purpose of the Study

The purpose of this qualitative study is to explore conceptions of curriculum and standards-based practices by first looking at how they are articulated in policy documents and curriculum reform initiatives. The second goal was to examine the elements of standards-based practices and the purpose, structure and organization of the high school Chemistry curriculum in advanced programs from a broader perspective in terms of the curriculum goals, instructional planning, assessment and the curriculum development process.

In science education, the vision of ‘science for all’ guides reform efforts in defining and specifying the science process and content standards for scientific communities. A spot check of most science education reform documents reveals that the material is presented as an aggregated view of the science curriculum in terms of science content and process. Therefore exploring conceptions of curriculum and standards must look at them in terms of the content, the process, organization, product and praxis. Although conceptions need to be explored in the contexts in which they occur, policy documents became the contexts of this study that would ultimately bring to life the conceptions of curriculum and standards-based practices.

There is a need to develop a summative view of the conceptions of both the curriculum and standards-based practices derived from a synthesis of policy documents. On the other hand, there is need to situate Advanced Placement (AP) and International Baccalaureate (IB) courses within the context of standards-based practices and high school science because they are, in fact, very essential science courses. I therefore rationalized that they must indeed ascribe to at least the *National Science Education Standards*, if not the local standards and frameworks for science teaching and other policy documents for reforms in science teaching.

In this regard, the study takes a critical look at the curriculum for advanced placement programs in AP Chemistry and the IB Chemistry in the light of standards-based practices. The College Prep Chemistry is considered to provide relevant instances for comparison because of it's apparently less rigorous approach compared to advanced Chemistry courses. One of the main foci of the current study is the content areas, the organizing structure in the curriculum, and the content and process *standards* in both the *Georgia Performance Standards* and the *National Science Education Standards*. I endeavor to analyze the sections of the Chemistry curriculum, using appropriate organizing structures from a descriptive and interpretive point of view.

The study explores important aspects of instruction and learning that may transform the way teachers envisage the Chemistry curriculum and the teaching strategies they adopt in their classroom practices. This study comes at a time when science standards in the state of Georgia have undergone major revisions. The need to develop a deeper understanding of standards-based practice and to shed some light on the varied high school Chemistry curriculum prompted the endeavor to conduct this study; not only to describe the aspects outlined above, but also to bring on board an interpretive aspect. The goal of analyzing the broad Chemistry curriculum within the education system is to examine and establish possible ties with performance standards in general and standards-based practice in particular. Using both descriptive and interpretive approaches, this qualitative documentary analysis study is guided by the following research questions.

- What are the conceptions of curriculum and standards-based practices espoused in policy documents and curriculum reform initiatives?
- What content and process overlaps are evident in the Chemistry curriculum and the science education standards?
- How are advanced placement initiatives situated in standards-based school reforms and the Chemistry curriculum?

The *National Science Education Standards* (NRC, 1996) do not prescribe any specific approach to teaching science in the classroom. Therefore, the rationale for exploring conceptions and categorizing the Chemistry curriculum sections is because the main components described in the science content can be organized to portray a variety of emphases and perspectives which can inform practice. Individual teachers, local educational institutions and agencies are forced to determine how the science content should be organized and delivered. It has been argued that in as much as content standards are presented in organized schemes, they are not intended for use as a curriculum (NRC, 1996, p. 22); which implies that the task of determining the scope of the concepts and organization is relinquished by curriculum designers to the science teachers and implementers of the curriculum in respective institutions. However, standards-based instruction is envisaged as theory and practice of teaching approaches that make significant use of standards to stimulate students' scientific and intellectual development towards scientific literacy.

The next sections highlight some of the operational definitions as they are used in the current study; and a detailed review of broad fields of research and other relevant literature in which this study is situated.

Operational Definitions

Curriculum: A set of courses each of which has content areas and course objectives defined in terms of learning outcomes and assessment strategies and integration of topics from different subject matter, delivery mode, organization, balance and presentation (NRC, 1996 p. 22).

Conceptions of curriculum: Abstract generalizations of ideas inferred and derived from specific instances of science unit planning with details about content, scientific objectives and guides for instruction, evaluation and assessment.

Content: Refers to the curriculum to be learned (as opposed to teaching methods) or specific capacities, understandings, and abilities (NRC, 1996, p. 22).

Standards: A guide that defines the knowledge and skills for teaching with a clear outline about the content, objectives, suggested tasks, samples of student work and a guide for assessment that students should possess. A standard defines the broad expectations for an area of knowledge in a given domain and may include an expectation of the degree to which students express their individual understandings of that knowledge (GPS, 2007).

Content Standards: Broad statements that describe what students are expected to learn and be able to do in a specific content area. They state the purpose and direction the content is to take and are generally followed by elements (GPS, 2007).

Standards-based Practice: Instructional practices that allows teachers and students to be on the same page by specifying how teachers and students will meet their education goals, including specific concepts, order, or instructional materials (Krueger & Sutton, 2001).

Performance Standards: Provide clear expectations for assessment, instruction and student work and define the level of work that demonstrates achievement of standards. They incorporate the content standards, sample tasks, sample student work and teacher commentary (GPS, 2007).

CHAPTER 2

REVIEW OF THE LITERATURE

This chapter provides a detailed review of the literature to situate the current study. It is organized into four sections. The first section provides a theoretical perspective of curriculum and standards by looking at definitions, standards and standards-based practices, curriculum development models and considerations for curriculum development. The second section looks at aspects of education policy and practice, including assessment. The third section provides more detailed accounts of advanced placement programs, with brief historical accounts of their development, curriculum assessment and problems. The last section sums up the chapter with conclusions and suggestions for the way forward leading to research methodology.

Theoretical Perspective of Curriculum and Standards

Standards

In the last five years, the Georgia Department of Education (GADOE) made significant changes to the *Georgia Performance Standards*. Of particular interest to the current study are the Chemistry content and process *standards* that were modified from earlier versions to include some illustrations of sample tasks, examples of student work and the teacher's commentaries on student work; to help nurture and support teacher-transition to the newly developed standards (Georgia Performance Standards, 2006). However, a quick look at the standards may not reveal the apparent lack of explicitness in content. In fact, the older standards that were crafted on the basis of the *National Science Education Standards* (NRC, 1996) and the *Benchmarks for Science Literacy* (AAAS, 1993), highlighted the Quality Core Curriculum (QCC's) - what students were expected to know, and corresponding levels of mastery of the content areas for science teachers but only left out the sample tasks, student work and the teacher commentaries.

Unlike other forms of instruction, standards-based instruction has gained more emphasis in contemporary science classrooms. However, for many science teachers, the curriculum is like a prescribed set of academic standards to be implemented; whereas instructional planning is a race against the clock to cover the standards (Tomlinson, 2000). It has been argued that there is a big dichotomy between standards-based instruction and differentiation, the former being referred to as a recipe for teaching while the latter as a way of thinking about learning (Tomlinson, 2000). Science teachers' limited comprehension of the curriculum content and standards-based practices may raise a significant number of pedagogical questions regarding standards and the curriculum. In fact, Tomlinson, (2000), posed a very fundamental question: Are content standards being used as the curriculum per-se or are they reflected in the curriculum?

The *National Science Education Standards* describes both the curriculum content and ways of reforming sections of the education system to effectively support improved teaching and student achievement (NRC, 1996). It has also been argued that using data to drive instructional decisions improves the efficiency of reform efforts by focusing change in the desired direction towards improved student achievement (Krueger, & Sutton 2001). If this is the case, the field of science education should be 'home and dry' after decades of systematic reforms, given the fact that equitable science programs should provide high quality science education for all students.

The concept of "national" in the *National Science Education Standards* has often been misconstrued to mean federally mandated standards. On the contrary, Bybee (1998) clarifies that "national" standards are those that have a nationwide agreement with regard to what constitutes successful science learning and the school practices that optimize the learning of science (p. 157).

He reiterates that the national science standards neither define the *national* curriculum nor do they form a national standardization measure for different states to adopt. The *National Science Education Standards* were developed through extensive consensus building. Although they do not prescribe a single teaching approach, local school systems decide they way the content should be organized, emphasized and presented. By the year 2000, about 49 states in the United States were already adopting state standards and frameworks, and aligning them with state-wide student assessments (Krueger & Sutton, 2001).

In essence, what this means is that the intention of the national science standards is to guide the science education system towards achieving the theoretical goals of scientific literacy. New revisions in the *Georgia Performance Standards*(2006) over the last few years have not compromised their alignment with the National Research Council's *National Science Education Standards* and the Project 2061's *Benchmarks for Science Literacy*, which served as the core of the curriculum on the basis of which appropriate content and process skills were determined.

In the process of reforming the curriculum, professional development is a very vital component in the build-up to the implementation of the science standards and the curriculum, because it often requires teachers to undergo some form of specialized in-service training. For new content and process standards in science education to be implemented, science teachers are often subjected to intensive, long-term professional development sessions (Hofstein, Carmeli, & Shore, 2000). It is therefore, difficult to disentangle professional development from curriculum reforms and instructional planning because professional development initiatives are evidently essential aspects of science reforms practices. However, this raises a number of important questions: Why should professional development take center-stage if the science curriculum is well structured? Does professional development signify the presence of flaws in the curriculum process that need to be addressed during such workshops?

The field of teacher education recognizes not only the importance of pre-service teacher training but also the role of teacher induction in supporting the career aspirations of teachers (Olebe, 2005). This encompasses all manner of support for mentoring beginning teachers and providing them with professional development experiences and in-service training. Professional development has been defined as any educational activity that attempts to help teachers improve their instruction (Melber, & Cox-Peterson, 2005). The *National Science Education Standards* (NRC, 1996) provides some guidelines for the professional development of teachers not only in terms of technical training for specific skills but also as a way of providing teachers with the opportunities for intellectual professional growth (NRC, 1996, p. 58).

A case in point with regard to reforms in science teaching is the *Georgia Performance Standards* training workshop, a structured two-cycle process in which the first year of training takes place one year prior to implementation of subjects at specific grade levels. The second year of training runs concurrently with the first year of phase-in when implementation of the subjects in actual classrooms gets underway. The trainees become trainers at their respective schools (*train-the-trainer model*) upon successful completion of the training modules (GADOE, 2007). Success rates of this approach have not been documented but I think there is a potential problem in the modalities for transfer of knowledge and skills. I surmised that the original idea was a little too ambitious with respect to the modes of transmission. In essence, it can only be hoped that training one teacher from a school district would enable him/her to transfer the knowledge and skills to his/her colleagues at school after completing the session in the workshops modules and retreating to the respective school districts.

Students' performance in Chemistry during the first year of post-secondary education is determined by a combination of factors, but the foundation is laid at high school level where they undertake introductory courses on which college-level courses are established. Results from a research study by Tai, Sadler and Mintzes, (2006), exploring demographic/educational and high school experiential factors as predictors of college success, report that demographic/educational factors have greater significance in explaining the variations in final course grades scored by students than experiential factors. Success in introductory college Chemistry also requires a solid foundation in applied mathematics. Therefore, students who do not have sufficient mathematical skills are disadvantaged, because college Chemistry professors may assume that all the students enrolled in their section of the courses have a demonstrated proficiency in using mathematical symbolization and equations before entering the program (Tai, Ward & Sadler, 2006).

Another important issue that has been highlighted in other studies is the instructional time needed to teach standards (Florian, 1999). Understanding the structure of curriculum planning is therefore an important step in organizing content for delivery in a timely manner and in planning for remediation. A well articulated curriculum challenges students to learn more sophisticated scientific ideas during the course of their studies (Krueger, & Sutton, 2001). However, teachers may often struggle with new content and teaching standards as they set out to conceptualize and structure their teaching based on the best instructional approaches. This may arise because they have not grasped the required strategies as intended in the curriculum. In the standards-based curriculum, teachers structure the learning experiences that enable all their students to reach the levels of understanding described by the standards (Krueger, & Sutton, 2001). Studying the *standards* for student achievement is a very important aspect of science teacher education. This enables the teacher to integrate a solid understanding of science content with experiences in an array of instructional strategies that specific to science education (Krueger, & Sutton, 2001).

Science educators face numerous challenges in the current standards-based teaching and learning environment for high stakes accountability (Kelley, 2005). Kelley points out that educators have a daunting task applying local, state or national standards in their curricular, instructional and assessment contexts. Effective teaching reflects an understanding of not only the content itself, but also its structure – how ideas interconnect/build together (Kelley, 2005). Standards and research are therefore said to provide a sound theoretical foundation and vision for student and teachers; learning within the context of the classroom (Kelley, 2005).

There is need to examine the distinction between a standards-based school program and a conventional program in order to identify salient features of standards-based practices. According to Taylor (2009) the comparison of the science standards pinpoints key differences between the conventional K-12 science program and a more innovative standards-based science program. Some of these aspects are highlighted in the standards (Table 1).

Table 1.

Differences Between Conventional K-12 and Standards-based Science Programs

	Conventional	*Standards-based*
Role of student	Passive listener/Note taker	Active observer, analyst, discussant
Role of teacher	Deliverer of content	Guides for student learning
Types of materials	Text books, work sheets, and formal labs.	In-depth modules, featuring science notebooks, reading materials, etc.
Content of materials	Broad coverage ; emphasis on facts and information	Deeper treatment of fewer topics; emphasis on understanding concepts, nature of science, and abilities of inquiry
Types of assessments	Multiple-choice or fill-in-the-blank at the end of unit	Various formats (written, performance, observational, graphic etc.) given continually

Standards-based instruction places great emphasis on having students engaged in hands-on activities (and minds-on activities), conducting routine hands-on/minds-on science activities does not guarantee inquiry (NRC, 1996, p. 23). In addition, the standards go on to propose that inquiry into authentic questions generated from student's experiences is the most central strategy for teaching science (p. 31).

Although inquiry has been fronted as an important feature in standards-based practices, teachers sometimes face tensions while teaching inquiry which occur due to two competing beliefs, one stemming from the school culture which constrains inquiry, and the other stemming from teachers' own beliefs about achieving some level of inquiry-based activities in their teaching (Wallace & Kang, 2004). Although beliefs about teaching are developed from years spent in the classroom both as students and as teachers, they are not always consistent with the 'prescribed' methods about best practices in teaching (Lumpe, Haney & Czerniak, 2000).

Curriculum

Traditional approaches for curriculum planning efforts often follow an almost defined pattern; starting off with generation of a topic, then clarification of the science content and the corresponding learning activities and some definition of the criteria for assessment. According to Bybee & Scotter (2007), such an approach tends to over-emphasize the learning activities as opposed to mastery of science concepts and scientific inquiry as defined in the *National Science Education Standards* (NRC, 2000). However, in the last decade a popular model for curriculum planning called the "*Backward Design*" has emerged where the desired results are identified prior to the determination of acceptable evidence and planning of learning experiences and instruction (Wiggins & McTighe, 1998).

The *Backward Design* (Figure 1) defies convention by proposing the movement away from "*covering the curriculum*" towards "*creating the curriculum*". With respect to standards-based approach in *Backward Design*, Wiggins & McTighe (1998) advocate starting off with selection of the relevant standard(s) and then determination of the acceptable evidence that will demonstrate students' achievement. Last is the development of a lesson plan that will provide students the opportunity to attain desired objectives. The model is advocated for because teachers tend to begin their lesson plans with textbooks, favored lessons, or time-honored activities; instead of deriving the learning tools from the targeted standards (Wiggins & McTighe, 1998).

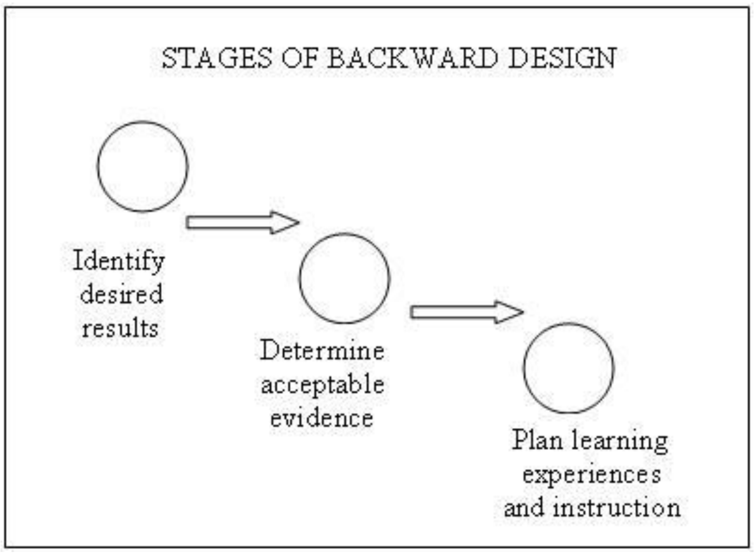

Figure 1. "Backward design" for curriculum planning

According to Kelly (2004), many teachers tend to equate a *curriculum* with a *syllabus*. This limits their planning and consideration of both content and body of knowledge in subjects that they wish to transmit. He argues that focusing only on the content or subject matter to define curriculum is less effective and counter-productive because it does not justify the purpose and effect of transmission of such knowledge or content (p. 4). The socially acquired roles, attitudes and values that constitute the "hidden curriculum" –things that students learn depending on how the school is planned and organized– is often ignored. This is significant especially when the same curriculum is planned and imposed by the government (Kelly, 2004). As a matter of fact, the definition of *curriculum* is often a daunting task for many science educators because different elements are considered. However, defining the *educational curriculum* should by all means include all of the essential elements. Tanner (1990) defines curriculum as “the planned and guided learning experiences and intended learning outcomes, formulated through the systematic reconstruction of knowledge and experiences, under the auspices of the school, for the learners’ continuous and willful growth in personal social competence.”

A significant consideration in curriculum development is the distinction between the *planned curriculum*, the *translated* (enacted) *curriculum*, the *received* (experienced) *curriculum* and the *assessed curriculum*. Kelly (2004) defines the planned curriculum as the laid down *syllabi* and prospectuses embodied in the state or school district curriculum guidelines, and the received curriculum as the realities of actual students’ classroom experience. The rationale for taking this stance is, in my opinion, a result of the apparent disconnect between theory and practice; or a mismatch of intentions in curriculum developers’ ‘package’ and the process of unpacking for dissemination; a daunting responsibility for many teachers. On the other hand, the translated (enacted) curriculum involves the learning activities and experiences that the teacher organizes for his/her students, while the assessed curriculum is a set of learning(s) tested through teacher-made tests or standardized tests developed by school districts and other testing agencies.

Therefore, defining *curriculum* without including activities that teachers carefully plan and execute and how they justify those activities may inevitably portray a narrow view of the curriculum. Tanner’s definition of the curriculum, in fact, encompasses what was envisioned in the elements of curriculum planning (*Dimensions of Curriculum Planning*), that were proposed by Ralph Tyler over half-a-century ago. He identified four elements namely; objectives, content or subject matter, methods (procedures/educational experiences) and evaluation (Tyler, 1949).

The identification of dimensions of curriculum planning ultimately led to fundamental questions that needed to be answered on the basis of Tyler's curriculum model. These are not any more different than the questions that curriculum planners and developers encounter today:

- What educational purposes or objectives does the school seek to attain?
- What educational experiences are likely to result in attainment of the purposes?
- How can the educational experiences be effectively organized?
- How can one determine that the purposes or objectives are being attained?

Taking a closer look at the reform initiatives in science teaching and curriculum development on the basis of these questions, it is apparent that after 50 years of science reforms, Tyler's approach (Figure 3) seems to have been replicated in salient features of the curriculum, with only subtle adjustments. I adopted the elements from Tyler's dimensions of curriculum planning to create a more refined model titled the 'Dimensions of Chemistry Curriculum Planning' (Figure 2).

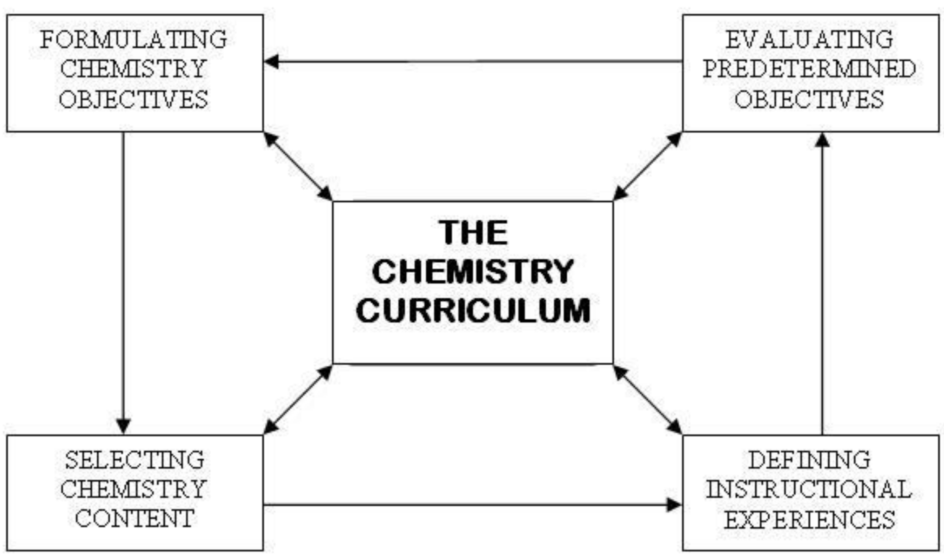

Figure 2. Dimensions of Chemistry curriculum planning.
(Adapted and modified from: '*Dimensions of Curriculum*' By Ralph Tyler, 1949).

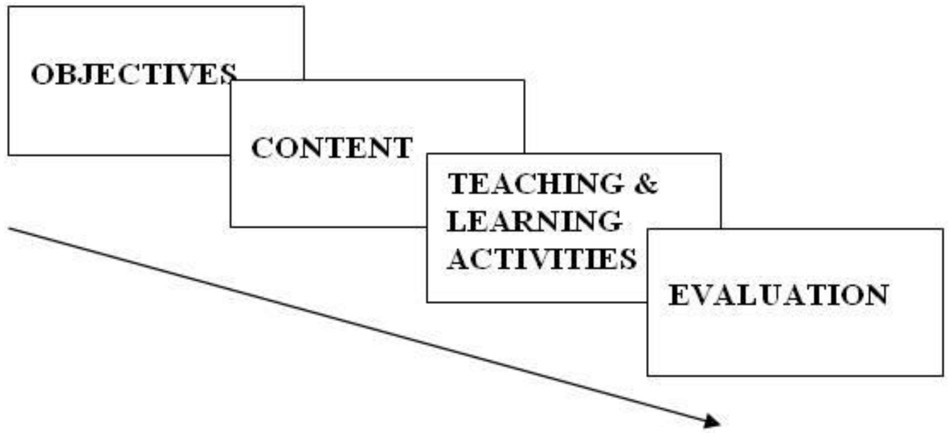

Figure 3. Tyler's Model – Dimensions of curriculum planning (Tyler, R., 1949).

Although Tyler's model of the dimensions of curriculum planning (Figure 3) gave the impression of a simplistic view of a linear model that merely required specification of objectives, identifying relevant content, the methods to achieve the objectives and a measure for the extent of success, I believe it fell short of taking into consideration personal and institutional factors such as teachers competencies and the changing trends in the use of instructional technology currently emphasized in contemporary classrooms.

The complex interaction between the various elements is, in fact, not necessarily a linear progression. For instance curriculum *objectives* must be discernible from the *content*, while the *evaluation* of objectives may dictate change in *instructional experiences* or the very *content* being covered. In fact, Tyler's model has been and still remains a reliable template and basis for which current and future curriculum planning and development can be established and improved.

Achieving appreciable levels of success in curriculum and educational reform requires science teachers to implement the innovations by considering intentions that were premeditated by curriculum developers during the development process. However, imposing new curriculum materials upon teachers can be potentially counter-productive and is likely to evoke implicit, intuitive, or outright resistance from the teachers to implement the materials (van Driel, 2005); unless they consistently meet the learning goals that individual teachers set out to achieve.

Educational Policy and Practice

The creation of aligned content *standards* and reliable assessment systems under the No Child Left Behind (NCLB) legislation that became effective on January 8, 2002), require that the *standards* should be assessable in a variety of ways, have the capacity to be illustrated by examples of student work, and be instrumental in defining and supporting meaningful instruction (Rabinowitz, et al., 2006). This was done with the hope that the NCLB legislation would provide support for effective teaching of science. This has not always been the case due to a shift in priority by the teachers to mathematics and reading, whose assessment and scores are used in determining Adequate Yearly Progress (AYP) for schools (Johnson, 2007) as opposed to science. However, the mandatory assessment and testing in science began in 2007 but was not included in AYP calculations. In spite of that position however, it does not pre-empt the fact that students are still required to undergo state assessments in science and meet all the requirements to earn a high school diploma (Johnson, 2007).

Students' success is critical to a school's rating because all schools that fail to meet AYP for 2 years are assigned an 'NI' – '*Needs Improvement*' status. The NCLB legislation provided a framework for guiding these reforms in public schools. On the other hand, the Georgia *standards* and the Georgia High School Graduation Test (GHSGT) in particular have traditionally been used to determine the schools AYP.

The formal assessment programs for Chemistry in Georgia high schools include the customized criterion-referenced tests, the National Assessment of Educational Progress (NAEP) (12th grade), and an optional norm-referenced test. The mandatory state assessments include the

Criterion-Referenced Competency Tests (CRCT), the End-of-Course Tests (EOCT) and Georgia High School Graduation Tests (GHSGT) (GADOE, 2008).

The NAEP is a national survey of knowledge and skills in major learning areas taught in schools. This assessment is guided by frameworks developed by teachers, curriculum experts and policymakers to provide theoretical the basis for assessment and direction for the kinds of skills and knowledge to be assessed (GADOE, 2008). In addition to providing useful trends in student achievement, NAEP also informs the education policy by documenting descriptive information from students and the school administration. According to the Georgia law (O.C.G.A., Section 20-2-281) mandate, each school can choose to administer a national norm-referenced instrument in sciences (and other subjects) with the help of the State Board of Education. This initiative is funded by the state to determine the performance of Georgia's students in comparison other students using the national sample as an external reference group (GADOE, 2008).

Under the No Child Left Behind Act (NCLB), the Georgia Alternate Assessment (GAA) was mandated to address the needs of individuals with significant cognitive disabilities through alternate assessments based on *alternate achievement standards* which sets the expectation of performance that differs in complexity from a grade-level achievement standard to accommodate the needs of such students. However, alternate achievement standards must be aligned to state academic content standards even if they reflect prerequisite entry-level skills (GADOE, 2008). An alternative assessment tool is a portfolio of student work samples used to capture student learning and progress in the content area. Rubrics for evaluating the student work samples are developed by educators to score portfolio entries in four dimensions: fidelity to standard, context, progress, and generalization. However the focus of such endeavors is always on the academic content and skills (GADOE, 2008).

On the other hand, the *National Assessment of Educational Progress* (NAEP) is usually norm-referenced across states and has for a long time been used to rank states. A recent report published by the *National Assessment of Educational Progress* (NAEP) reported a decline in high school students' mastery of science (Moore, 2006). There has been great concern about the development of courses and teaching practices with a goal of having students pass examinations rather than ensuring that they receive more comprehensive science education. In view of the need to effect changes in the science curriculum and draft more appropriate goals for high school Chemistry, Moore (2006) argues that teachers who demonstrate strong content knowledge and sound pedagogical backgrounds in developing their own courses should be fully supported.

By the time middle school students reach high school, they have already been exposed to basic chemical knowledge from their physical science in grades 6 to 8. At the high school level, Chemistry-type content areas that are tested in the Physical Science End-of-Course Test (EOCT) examination include: *Atomic and Nuclear Theory*, the *Periodic Table*, *Chemical Reactions and Properties of Matter* (GADOE, 2005). These may seem like broad categorizations and one may think that some aspects of Chemistry are not tested. However, sub-topics that come under these major topics show evidence that students delve deeper into the principles of Chemistry that they are expected to learn and understand.

The new *Georgia Performance Standards* are being implemented in nearly all classrooms across the state. To keep pace with these reforms, the EOCT has constantly undergone changes to reflect the new curriculum (GADOE, 2005). High school students who are enrolled to receive credit for EOCT courses are required to take the test, usually administered in two formats: the paper-and-pencil test or the online format. For most academic courses, EOCT is the culminating examination for the course. The final grade is calculated using the course grade at 85% and the

EOCT accounts for 15%. To pass the course and to earn credit toward graduation a student must have a final course grade of 70% or above (GADOE, 2005).

The score reports are developed to provide reliable and valid test results to enable every student to identify strengths and weaknesses of their content knowledge and skills; and for the teachers to determine if their students have mastered the required content knowledge and skills in order to pinpoint the strengths or flaws in instructional planning and implementation. State-wide test score reports enable stakeholders to determine if schools are actually providing students with the right opportunities to learn the state-mandated curriculum, to analyze student-progress and to provide recommendations for reforms, to ensure a more rigorous curriculum (GADOE, 2005).

Advanced Placement Programs

Advanced Placement (AP) Chemistry Program

Since its establishment in 1958, the Advanced Placement (AP) program has provided both coursework and testing with more than 15,000 high schools spread across the United States offering a form of AP coursework. More than 1.2 million high school students across the country took at least one AP examination during the 2004-2005 school year (College Board, 2005 as cited in McMillen, & Dulaney, 2005). However, there has been a marked increase in enrollment tallies each year which translates into a marked increase in the number of students who eventually take the Advanced Placement (AP) examinations.

In the 2007–2008 academic years, over one-third of students in Georgia public high schools were enrolled in AP courses (GADOE, 2008b). In fact, the state of Georgia pays for one AP examination annually; for each public high school student who is enrolled in an AP course; and also pays for *all* AP examinations for students enrolled in AP courses in public high schools which qualify for free and reduced price lunch (GADOE, 2008a). There are specialized schools that offer AP courses which allow students to receive college credit for the first year courses; or be exempted from taking the freshman college Chemistry course. Although advanced placement programs claim to challenge the academically gifted students, there is insufficient empirical evidence to support these claims (Poelzer & Feldhusen, 2006).

One of the most important approaches used to prepare high school students for college is through participation in the AP courses and examinations (Dougherty, Mellor, & Jian, 2006). However, for science teachers to have their courses labeled as “AP” and start teaching, they are required to be ‘College Board certified’ and must participate in the AP course audit (College Board, 2008). The AP Chemistry teacher certification process follows intense training sessions usually attended by teacher trainees, experienced teachers and some College Board personnel. Schools that intend to offer the AP courses must also develop their own curricula which are then subjected to the AP course audit which specifies certain expectations that are established by college and university faculty for college-level courses (College Board, 2008).

The College Board cautions that such courses can only be authorized to use the "AP" designation if they meet or exceed those expectations. In accordance with this requirement the AP course audit was created at the request of the secondary school and college members of the College Board to serve two main purposes; (1) to provide teachers and administrators with clear guidelines on curricular and resource requirements for Advanced Placement courses, and (2) to help colleges and universities better interpret secondary school courses marked "AP" on students' transcripts (College Board, 2008).

Each AP teacher is required to submit an AP course audit form, and a syllabus to receive the "AP" designation; a process that takes about 60 days following initial submission of the AP course audit materials and their course syllabus. In the event that AP course auditors are not satisfied with the syllabus, additional information is requested from the teacher prior to course authorization (College Board, 2007). The AP course audit identifies key elements that are considered to be essential to college-level courses and therefore assures consistence in *standards* for unequal AP classes in different schools across the country without setting any mandated AP curriculum (College Board, 2007). It has been argued that the responsibility for effectiveness of the AP programs should not be bestowed exclusively on schools that offer them due to the absence of a national curriculum.

Although the College Board presents the AP Chemistry curriculum as a summary of curricula and approaches used in college courses that correspond to their AP courses, Chemistry teachers enjoy the flexibility of developing their own syllabi and lesson plans, and to exercise creativity in restructuring their instructional approaches to suit their respective AP classrooms (College Board, 2007). In fact, the AP Chemistry examinations are designed around the same flexibility to allow equal opportunities for all students whose courses may vary significantly, to demonstrate college-level achievement. The College Board requires schools to ensure that the AP courses listed on their students' transcripts, the course catalogs, and the school's web site are authorized and renewed each fall by the course administrator (College Board, 2008).

One of the most intriguing aspects of the teacher certification in AP program is the College Board’s position about who can teach the AP courses:

> “There are no educational or professional background requirements to serve as an AP teacher. The College Board recognizes that there are many paths toward becoming an effective AP teacher, and the audit does not review anything about teachers beyond how they are demonstrating on their syllabi the inclusion of the course requirements or a viable alternative” (College Board, 2008).

This in essence supports the alternative certification programs for science teachers, some of which are approved by the Georgia Professional Standards Commission. Given the fact that the Advanced Placement program undeniably supports the principle of having individual schools develop their own curriculum for Advanced Placement courses, there are no national or state mandates for any one curriculum. According to the College Board (2008), the course audit provides each AP teacher with a set of expectations that have been established by college and secondary school faculty nationwide for college-level courses. AP courses are supposed to provide high school students with learning experiences that are equivalent to those obtained in a one-year general Chemistry course in college. This requires familiarity with the topics covered in general Chemistry college courses and different text books used at that level.

Grading for Advanced Placement courses is defined by the College Board as a 5-point scale for scoring: [1] *no recommendation*, [2] *possibly qualified*, [3] *qualified*, [4] *well qualified*, [5] *extremely well qualified*. Some colleges and universities provide course credit to high school students scoring a ‘3’ or higher on some AP examinations. Although AP courses tend to compete favorably with some Honors courses for the award of college credits; in addition to the End-of-Course grade, Honors courses are developed by local district teachers to meet the needs of talented students. In fact, the Honors class parallels the curriculum offered in the corresponding regular class but often covers additional topics or some topics in greater depth. It is common for Honors courses to be constituted as separate classes, extra projects or seminars, supplementing a regular course. Given the fact that Advanced Placement and Honors courses are more rigorous than the regular courses offered in schools, the school districts award weighted grade points as (A=5; B=4; C=3) for these classes. The added grade points are factored in to boost a student’s grade point average (GPA) and class ranking.

It is important to note that only a fraction of high school students take the AP courses; and out of these, only a few of them actually end up taking the corresponding AP examinations. The AP Chemistry course requires the application of concepts and skills that are learned in pre-requisite courses; and builds upon what students have already mastered to consolidate their knowledge. The AP Chemistry examinations feature five content areas namely; *Structure of Matter*, *States of Matter*, *Descriptive Chemistry*, *Reactions* and *Laboratory* (Crippen & Brooks, 2001). These are broad categories that cover a wide range of topics within the AP Chemistry curriculum. According to Crippen, et al., (2001) the descriptive part of AP Chemistry is usually the most challenging for students taking the examinations.

Identifying students' problems when taking tests has the potential of informing practice and planning for instruction. A research study was conducted to investigate students' errors in AP Chemistry using web-based interface software (Crippen, Brooks & Abuloum, 2005). The four-year project named "design theory experiment" that provided the software for high school students preparing for the descriptive questions on the Advanced Placement (AP) Chemistry examinations was used to identify common problems in test-taking. Using descriptive analyses of students' responses, the study identified common test-taking errors such as failure to write appropriate chemical formulae, failure to recognize reactive species in net ionic reactions, and problems with recognizing weak electrolytes (Crippen & Brooks, 2005). Students taking computer-based AP Chemistry examinations may make errors (provide incorrect responses) for the multiple choice questions that are commonly used for the test items. These are not isolated cases in Chemistry content areas; they are specific pointers to the much needed change of tact with respect to the use of appropriate teaching methods and content organization, and the use of strategies that can lead to improved student performance on the AP Chemistry examination.

Findings from similar studies can reveal patterns in student errors that may unearth possible misconceptions held by students, pertaining specific chemical concepts. Many sets of responses could reveal important information regarding the level of mastery of the content. There is need to integrate the AP descriptive Chemistry across the curriculum and implement the use of repetitive testing to further improve student performance (Crippen & Brooks, 2001).

Success in AP examinations is a clear demonstration of students' ability to perform or undertake college-level before to graduating from high school. Traditionally, the courses were only available for a small group of high achieving and selected top students. Frequent criticism has been directed at the Advanced Placement curriculum for being too broad in content coverage but too shallow in emphasizing the understanding of important principles of science; thereby giving students a relatively shaky foundation for post-secondary science. A published report from the Chemistry panel of the National Research Council (NRC) committee recommendations for advanced high school courses in Chemistry indicates that AP examinations that are provided by nearly 62% of high schools in the United States are rather formulaic and predictable in their approach and have question-structures which promote rote-learning (Moore, 2002). It has been argued that these examinations do not reflect recent developments in Chemistry teaching; and that the courses fall short of including key concepts and disciplines relevant to modern Chemistry (Moore, 2002).

The National Research Council (NRC) panel also highlighted the need for teachers of the Advanced Placement Chemistry to have relevant qualifications and take part in professional development (Moore, 2002).This complements the College Board's position with regard to AP teachers' qualifications; to demonstrate excellent organizational skills and teaching prowess.

There has been a tendency to evaluate teachers on the basis of the number of students that pass specific standardized tests, rather than the number of students who demonstrate thorough understanding of the subject matter. Therefore, there is need to consider alternative parameters and evaluation tools than mere test results to evaluate the quality of education and the science curriculum. For instance, teachers may be evaluated on the basis of defined assessment rubrics developed externally to assess student achievement as evidence of the teacher's performance. If the NRC report about the decline in high school students' science mastery between 2000 and 2005 (as measured by the NAEP) is anything to go by, then there is need address the underlying issues in curriculum implementation.

The benefits to taking AP courses have been highlighted in many research studies. These include: savings on college tuition for a particular course if a student receives college credits, exposing high school students to college–level curriculum with standard requirements, avoidance of remedial classes at college and meeting high school requirements while fulfilling first year college requirements at the same time (Matthews, 2004 as cited in McMillen & Dulaney, 2005). Although accelerated programs have gained popularity over the years, the National Research Council's study of Advanced Placement courses (Moore, 2002) came up with a resounding conclusion regarding the AP curriculum and advanced placement:

> "…acceleration alone does not define a quality program. Indeed, the inclusion of too much accelerated content can prevent students from achieving the primary goal of advanced study: a deep understanding of the content and unifying concepts of a discipline…" (p. 903).

Apart from the AP and IB courses, the College Preparatory Chemistry course that is taught in some schools to college-bound high school students who intend to pursue Chemistry at higher level in post-secondary settings. Although the course does not guarantee college credits, it also involves a variety of laboratory activities structured in a way to stimulate students' conceptual understanding to acquire useful skills. It is usually taught at grades 11-12 as an introductory course designed to provide a solid background on basic Chemistry themes; as a foundation for success in science at college level. It provides the students with some kind of 'sneak peek' about what college Chemistry looks like. However, unlike the Advanced Placement course, College Prep is not administered through the College Board and is often considered to be lacking in rigor.

Some topics taught in College Prep include *Classification of matter*, *Chemical bonding*, *Nomenclature, Modern atomic theory, Solutions, Equilibrium systems* and *Acid-base theories*. These topics often require rigorous mathematical and conceptual knowledge and skills with mandatory laboratory experimentation and a routine summary of laboratory experimental reports. Students who have no intention of advancing to 4-year post-secondary institutions have the option of selecting an enrichment courses that require less rigorous mathematical and conceptual applications. A limited mathematical background and the intent to get into a technical college to pursue non-science majors are the main considerations for placement in the enrichment courses.

Although such enrichment courses lack the rigors of the Advanced Placement, College Preparatory, Honors Chemistry, and the International Baccalaureate (IB), the curriculum design ensures that all the themes covered in the high school Chemistry curriculum are included in the enrichment course but a relatively more student-centered approach is used.

International Baccalaureate (IB) Program in Chemistry

The International Baccalaureate Organization (IBO) was founded in Geneva, Switzerland in 1968 as a non-profit educational foundation (Sacko, 2008). There are over 1,454 International Baccalaureate programs in 1,286 schools throughout Canada, the Caribbean and the United

States (IBO, 2005-2009). However, only 2% American public high schools offer International Baccalaureate Programs, compared to 67% of all American public high schools who offer the Advanced Placement (AP) program (Bunnell, 2009). The original purpose of the IB program was to facilitate the international mobility of students preparing for college or university by providing schools with a curriculum and diploma qualification recognized by universities around the world. Since then its mission has expanded, and it now seeks to make an IB education available to students of all ages. The IB Diploma Program aims to provide students with a truly international education that encourages an understanding and appreciation of other cultures and languages.

The International Baccalaureate (IB) program is a two-year comprehensive curriculum that offers examinations to grades 11 and 12 students in six subject areas and a core in three others. The International Baccalaureate Diploma (IBD) is therefore awarded by the International Baccalaureate Organization (IBO) to students aged 16-19 who complete a prescribed two year course of study. Each student is expected to take the *core curriculum* of an extended Essay, the Theory of Knowledge (TOK); and Creativity, Action and Service (CAS) (Williams (2007, p. 50). The *Theory of knowledge* (TOK) course explores and compares knowledge claims across major discipline areas and across cultures using critical thinking skills, while the *Creativity, Action and Service* (CAS) course is organized as a regular activity that involves having *creative*, *action* and service *elements* occur simultaneously. Therefore it contributes to the development of the whole person through experiential learning, empathy, respect, and critical self-reflection (Hill, 2006).

The overarching goal of the International Baccalaureate curriculum is to enable students to gain a deeper and broader understanding of knowledge to develop critical thinking a reflective mind. To earn a diploma a student must pass examinations in all six subjects and complete three additional core activities (Mayer, 2008). The curriculum is modeled by a hexagon of academic areas in groups 1–6 (*English, Mathematics, Experimental Sciences, The Arts, Individuals and Societies*, and *Foreign Languages*) surrounding the three core requirements (Figure 4).

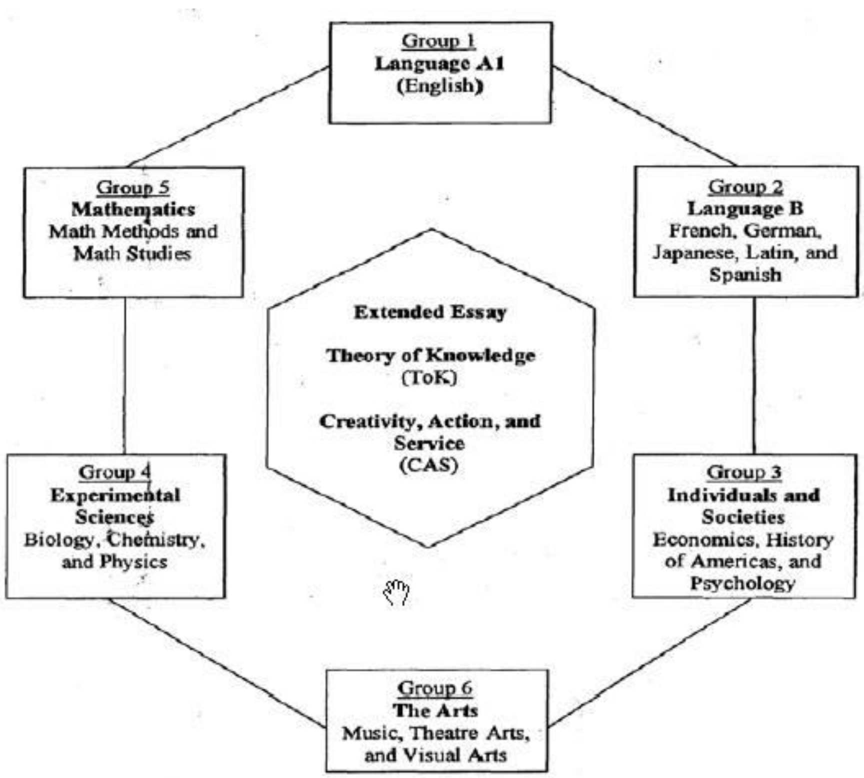

Figure 4: Structure of the IB diploma curriculum (IBO, 2009).

According to Williams, (2007), students study six subjects selected from a hexagon group of courses; three of which are studied at *higher level* (240 teaching hours each) and the other three at *standard level* (150 teaching hours each).

The International Baccalaureate is a pre-university curriculum where students must take at least one subject from group 4 called the 'Experimental Sciences' on the hexagon group of courses in Figure 4 (James, 2007). The IB Chemistry course has both the standard level and the higher level. The topics covered in the standard level include: *Stoichiometry, Atomic Theory, Periodicity, Boding, States of Matter, Energetics, Kinetics, Equilibrium, Acids and Bases, Oxidation and Reduction* and *Organic Chemistry*. Students also have the option to choose two topics from: *Higher Physical and Organic Chemistry, Chemical Industries, Fuel and Energy*.

There are many reasons why schools adopt IB programs. The main one is to provide an internationally accepted, reputable and transferable pre-university certification (Williams, 2007). The recent surge in numbers of IB diploma candidates in the United States may be attributed to the absence of a national curriculum (and even state curriculum), the general concern for falling education standards and the and the much publicized 'No Child Left Behind' government policy (Williams, 2007). One of the most fundamental goals of the International Baccalaureate of North America (IBNA) is increasing access for underrepresented students in the International Baccalaureate program (Mayer, 2008).

The IBO implements a rigorous curriculum and assessment process to ensure the high standards are maintained. The IB uses standardized testing as the assessment criteria and to determine if the aims and objectives are being achieved (Williams, 2007). Examinations are scored on a scale of 1 to 7; where a score of 4 or higher assures a recommendation for college credit or an advanced placement in a college course. Exceptional students who pass the IB courses and examinations may earn an International Baccalaureate Diploma (IBD) or a widely recognized certificate if they complete additional program requirements (IBO, 2004, as cited in Wimberly, & Powell, 2006).

Independent research on the efficacy of AP courses and the impact of the IB program has been very limited. It has been argued that research on both the AP courses and the IB programs is characterized by a lack of control for aptitude and motivational variables (Hertberg-Davis & Callahan, 2008). These researchers further argue that the National Research Council (2002) panel raised questions about the impact of AP and IB courses on student achievement (p. 200) thereby giving rise to the debate about the appropriateness of the AP and IB curricula in science with respect to depth of coverage, the quality of the examinations and the type of learning and reinforcements used when students prepare for examinations (Hertberg-Davis, Callahan, 2008).

Most students who take AP and IB classes are satisfied with the nature of the curriculum and instruction within the courses that are traditionally perceived as relatively more challenging (Hertberg-Davis & Callahan, 2008). Students believe that most advanced level courses, including the AP and IB, are taught by the most experienced teachers. Therefore, successful development of teaching strategies would be characterized by increased competence and raise the challenge level of the curriculum and instruction (Hertberg-Davis & Callahan, 2008), in addition to understanding the unique needs of individual students in the program. It has been argued that the advanced level classrooms are not homogenous in terms of student populations and that AP and IB courses do not constitute a comprehensive program that sufficiently address the needs of different students (Hertberg-Davis, Callahan, 2008). There is need for a differentiated curriculum to address the needs of students in advanced level programs.

Conclusions

Having looked at the theoretical perspectives of *curriculum* and *standards*, curriculum development models and considerations for the policy practices, and more specifically at the advanced placement programs, it is apparent that conceptions of curriculum and standards-based practices are based on a wide frame of curriculum development but have not been explored in the context of standards-based practices in Chemistry; especially in the AP and IB programs. Indeed there are many theoretical perspectives in which to situate this research study. However, on the basis of current literature, it is possible to curve out a niche to cradle the current study. There is no evidence in literature to conclude whether Advanced Placement courses are standards-based or not; except the fact that the state of Georgia pays for one AP course annually for a student enrolled in the course in public schools. With this in mind, the main focus for exploring the conceptions of curriculum and standards is the content, the process of curriculum, the underlying education policy in the school curriculum, and advanced placement courses with relevant conceptual aspects that may have great significance to practice and the implementation of the science curriculum.

A highlight of the theoretical conceptions on various components of content areas and goals in both the Advanced Placement courses, the International Baccalaureate program and the College Preparatory Chemistry is an important step in establishing harmony between curriculum domains to create possible avenues that allow the process of dissemination in ways that assure mastery and a sustained content development of the science curriculum content. It is therefore important to consider various ways of looking at these aspects from a suitable methodological perspective. The next chapter therefore highlights some of the most important considerations in the research methodology and provides the rationale for the choice of the research procedure, the data collection, analysis and presentation. The research methodology is discussed in view of the overarching problem in the study and the guiding research questions that this research addresses.

CHAPTER 3

RESEARCH METHODOLOGY

Methodological Perspective

There are very few approaches in qualitative research that merit both as research methods and theoretical perspectives. Given the fact that the choice of research methodology is dependent upon one's research questions and the choice of a strategic plan in a given research study for data collection, I decided to the use qualitative document analysis method (Altheide, Coyle, DeVriese & Schneider, 2008) for my data collection and data analysis. A document has been defined as any symbolic representation that can be recorded and retrieved for description and analysis (Altheide, et al., 2008, p. 127). Document analysis therefore entails the collection, review, interrogation, and analysis of various forms of texts as primary sources of qualitative data.

Using specific protocol (See Protocol, p. 49), I tapped into the relevant documents on the subject matter from the information bases, both electronic and print I theoretically sampled them using both the systematic and constant comparison analysis procedure. I rationalized that this approach would allow me to quickly review almost all available the documents in order to refine my data collection protocol. According to Altheide, et al. (2008), theoretical sampling enables one to use his or her findings as a resource basis for illustrating the emergent process (p. 127). Therefore, I searched for the relevant contexts and identified some patterns, meanings and the underlying curriculum processes for the purpose of description and interpretation.

Qualitative document analysis views research as an emergent process and therefore offers an opportunity for one to explore an initial body of documents simultaneously for broad concepts followed by the eventual immersion explicitly and in subtle ways (Altheide, et al., 2008). This eliminates the need for a series of fixed steps in the research and empowers one to explore some additional sources of documents. The criteria for selection of reform document and policy papers was based on the premise that: (a) they provide guidelines for standards-based and systemic reform in high school science education (b) they cover science content for grade levels 9-12; and (c) they are representative of the content standards, the *performance standards*, and assessment frameworks used in high school Chemistry or the high school Physical Science. These criteria were also used in another research study to look at conceptions of science achievement in reform documents (Lee, & Paik, 2000).

It has been argued that the credibility of qualitative document analysis approach lies in the strength of its ethnographic orientation that often results in eventual saturation of the data collected (Altheide, et al., 2008). The bulk of the data sources that were used in this study are documentary sources. These included reform documents on policies and practices, research-based journal articles, library resources, reports and Internet resources that were duly described and analyzed to constitute the evidential basis for this qualitative study.

In recognition that qualitative document analysis is a recursive process encompassing concept development, theoretical sampling, data collection, coding, analysis and interpretation (Altheide, et al., 2008), I built flexibility into my methodology because of the numerous sources of documents but kept the data collected within the context of the three research questions. I also familiarized myself with the context of the information, identified examples of relevant documents and used specific categories to draft a protocol as a guide for my data collection. This was then used for initial data collection from various documents and was later revised further to accommodate additional data that were accessible and were deemed relevant.

Although part of the approach used in this qualitative study is more descriptive in nature (Wallace & Kang, 2004), I sought to examine and critique some conceptions of the Chemistry curriculum and standards-based practices using an interpretive frame of mind; a decision that was partly dictated by the nature of the research problem and questions that this study aimed to address; and partly by the need to provide an insightful and detailed account of the conceptions of the Chemistry curriculum in the context of the standards-based practices.

Altheide, et al., (2008), reiterate that the strength of the qualitative document analysis approach is nested in the use of theoretical sampling in the search for documents. They argue that it entails structured emergence that seeks out contradictions as one approaches conceptual closure (p. 148). Most of the research endeavors that make use of *quantitative* methods are often structured. However, due to the unstructured nature of qualitative document analysis approach, it has been argued that *qualitative* research is less replicable (with a few exceptions) and hence less *dependable*. However, I structured this study for descriptive and interpretive purposes to mitigate the dependability aspect and the need for replication would therefore be redundant. Although qualitative document analysis is not highly structured, it is disciplined and systematic; hence the questioning, the comparative and the analytical phases of the approach are empirically informed by the materials (documents) and the emergent questions (Altheide et al., 2008, p. 148).

I considered the Advanced Placement (AP), the International Baccalaureate IB) program; and College Preparatory course to conduct a descriptive analysis of the Chemistry curriculum as a large ‘case study’ but also highlighted their distinctive attributes. Erickson (1998) asserts that qualitative case studies enable inquirers to identify understandings held by individuals and the meanings they make of the experiences. In this context the arbitrary ‘case’ was not tangible; but rather elements of the curriculum.

In another study, Keeves (1998) reports that case studies are certified as having the capacity to recognize the dependence of the parts on the whole and the process that interrelates these parts. In consideration of the field of Chemistry as a discipline, the intent if the study is to place the enduring understanding of the broad Chemistry curriculum not only nestled snugly within the framework of large curriculum domains, but also highlight some of the key aspects that identify it as a carefully structured guide for the science discipline.

The constant comparison method allowed me the flexibility of extending across different documents and information bases in order to generate a broader view of the science curriculum; by exploring content areas and the curriculum processes. Constant comparative analysis goes hand in hand with theoretical sampling. Boeije, (2001), provides a very succinct explanation:

> "This principle [constant comparison] implies that the researcher decides what data will be gathered next and where to find them on the basis of provisionary theoretical ideas…possible to answer questions that have arisen from the analysis of and reflection on previous data…concern[ing] interpretations of phenomena as well as boundaries of categories, assigning segments or finding relations between categories" (p. 393).

The challenge however, lies in the fact that even as I engaged in the qualitative document analysis, newer documents are constantly emerging, including those that are still in press. I however excluded policy documents that were published prior to the 1993 *Benchmarks*. I also assumed the role of a quasi 'forensic' document analyst but focused on more recent information that was accessible electronically and in print. In this regard, my data sources were limited to the search terms and browser capability of the Google search engine; in addition to making use of relevant library curriculum materials. The strength in the use of documents however, lies in the fact that they are relatively more reliable than the use of simple observation devoid of crucial documentary support. The whole data collection and analysis became like a big ‘cultural’ immersion experience for me. Altheide, et al., (2009) concur when they state that:

> “…document analysis becomes ethnographic when the researcher immerses him or herself in the materials and asks key questions about the organization, production, relationships and consequences of the content…” (p. 135).

Although I encountered numerous policy documents and materials on curriculum theory; it was not significant to qualify me as a document analysis ‘ethnographer’ with regard to my choice of this methodology. However, it gave me a feel of the magnitude of work and the process entailed in its use as a research methodology. At least from my experience, I concur with the fact that documentary analysis is more in-depth in the sense that it goes beyond the simple analogies of putting together a reading list or compiling a literature review for a research proposal.

Altheide, et al, (2008), argue that the use of theoretical sampling in qualitative document analysis approach to search for documents entails a structured emergence that essentially seeks out contradictions as one approaches conceptual closure in data collection (p. 148). Theoretical sampling promotes the quest for origins that is consistent with ethnographic orientations towards immersing oneself in the subject matter. Given the fact that qualitative documentary analysis is both a perspective and a research method; unlike quantitative methods, I rationalized that it would be appropriate for the current study because it is more interactive and requires extensive familiarity with the research topic and solid grounding in the character or organization of the documents being analyzed. According to Altheide, et al., (2008), the method is versatile because it does not preclude “outlier” documents or the “deviant cases” from informing the study; but instead, directs the researcher to domains of more information rather than specific ethnographic settings (p. 136). Theoretical sampling utilizes conceptual comparisons drawn from existing data in an effort to qualify and test analytical categories. It has also been argued that the *credibility* of qualitative document analysis lies in the strength that its ethnographic orientation often results in eventual *saturation* of the data collected; an important ingredient in qualitative methods given that it is not guided by statistical representations but rather by theoretical relevance (p. 141).

Some of the initial descriptors used in abstracting data from documents include: "*advanced placement*", "*college credit*", "*rigorous curriculum*" "*external assessment*", "*course grades*" "*national/international recognition*", "*alternative curriculum*", "*standardized assessment*", "*standards-based*", and "*coherent curriculum*" among others. These were therefore incorporated in the refined protocol. I expanded the search terms and parameters to develop other categories that were not originally evident. The initial analysis of documents yielded broad categories that were used as templates to initiate subsequent searches from different data sources.

Data Collection Methods

There are many techniques used for data collection in document analysis. However, this qualitative study used two approaches to draw data from documents. The first approach was '*the interview*'. Documents were treated as a 'respondents' and I therefore, 'posed' questions to each document using relevant 'probes' formulated from my research questions (See Protocol, p. 49); and highlighted passages or marked sections in the document that provided answers. The second, approach was '*logging instances*'. Instead of quantifying occurrences of particular words, or the frequency of occurrence of phrases and/or descriptors within a given document, I focused on the quality of the raw data presented in the document through a reflective process. Although this was a matter of judgment, it was deemed more appropriate than merely lifting phrasal generalizations. The initial abstractions from the documents were mostly descriptive in nature with respect to formal accounts of the curriculum, policy and practice. However during analysis, I decided to build in more interpretive accounts of the analysis process to ‘thicken’ my descriptions. In a bid to gain a deeper understanding about conceptions of curriculum and the complex interaction between the Chemistry curriculum and standards-based practices, I used the most immense resource in research today–the Internet; and library materials. This method was influenced by factors such as the choice of search terms and relevant phrases. Therefore the amount and quality of data was subject to web-browser capability of pulling out information upon each search prompt. However, the Google-Scholar was useful with regard to accessing scholarly documents.

Internet-based data collection has the capacity to provide immense quantities of information. However, the task of sifting through and determining what was relevant to answer my research questions was both a daunting task and a matter of judgment that had to be guided by proper protocol. Some search terms that I used included: Advanced placement, International Baccalaureate, Chemistry, science curriculum, standards–based instruction, Georgia assessment programs, science objectives, college Chemistry, benchmarks, classroom practices, science teaching, teacher beliefs, performance standards, conceptions of curriculum, curriculum theories, curriculum design,, assessment in science, and the College Board. The list is not exhaustive.

To understand the conceptions of curriculum and standards-based practices in the policy documents, standards, and assessment plans and procedures, I factored in some brief descriptive summaries of aspects in the standards that would constitute the conceptions based on standards and reform documents, the *National Science Education Standards* and other publications that focused on policy and reforms in science education. I therefore worked from episodic narratives from these documents as the basis for my analysis. Below is the data collection protocol that was used in the current study to gather data from documents and facilitate the initial data analysis. The probes are abbreviated question forms that were used to ‘interview’ various documents.

DOCUMENTARY ANAYLSYIS DATA COLLECTION PROTOCOL

Q1) ANALYZING CONCEPTIONS OF CURRICULUM AND STANDARDS

Conceptions of Curriculum…

GUIDING PROBES

What is-
Process of-
Product of-
Types of-
Objectives of-
Elements of-
Limitations of-

Conceptions of Standards…

GUIDING PROBES

What are-
Origin of-
Emphases in-
Types of-
(content-/process-/assess
Process of-
R/ship with-

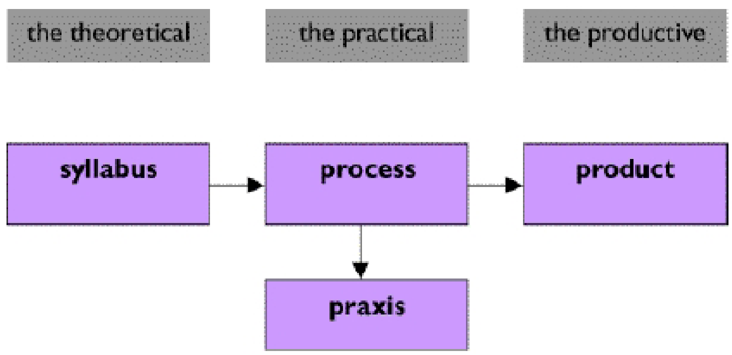

Chart: Representing 3-Level Conceptions of Curriculum and Standards

Q2 CONTENT AND PROCESS OVERLAPS IN STANDARDS AND DOCUMENTS

GUIDING PROBES

Analyze the…
Topics- ……………. (*common emphases*) … "terms"
Content Areas- ………... (*alignment*)… "subject matter"
Objectives- ……………. (*end goals*)… "what to achieve"
Purpose- …………………. (*what for*)…"curricular emphases"
Process-………………….. (*the how*)…"instructional empases"

Q3) NEGOTIATING ADVANCED PLACEMENT IN STANDARDS AND CURRICULUM

GIUDING PROBES

~ Emphases of AP/IB/CP/Honors, ~ Rationale for Varied Curriculum,
~ Features of Standard-based Curriculum, ~Universality of Science

Q1 – Q3 GUIDING DESCRIPTORS: "advanced placement", "college credit", "rigorous curriculum" "external assessment", "course grades" /international recognition", "alternative curriculum", "standardized assessment", "standards-based", and "coherent curriculum"

Patton (1989), states that having multiple sources of data is one of the most intrinsic characteristics of qualitative research (as cited in Seidman, 2005, p. 5). This study made use of various sources of data including the high school Chemistry ‘curriculum’ (GPS) from the Georgia department of education (Appendix A), Chemistry curriculum (sample syllabus) for Advanced Placement Chemistry from the College Board web site (Appendix B), and the International Baccalaureate Chemistry curriculum (Appendix C). I used various research articles that highlight key aspects of the high school Chemistry curriculum.

Others sources of data include curriculum from institutions (e.g. The College Board), textbook outlines of topics, and online resources for Chemistry content. In addition, there are common sources of reform and policy documents such as *Science for All Americans, Science Matters: Achieving Scientific Literacy*, *Benchmarks for Science Literacy*, the *National Science Education Standards, Making Sense of Secondary Science: Research into Children’s Ideas, Atlas of Science Literacy*, *Georgia Science Standards* (GPS) from Georgia Department of Education web site and the local *District Curriculum Guidelines* (e.g. AKS) among others.

The national *standards* were more relevant because they got published later than the *Benchmarks* and other policy documents and therefore incorporated most of the ideas from previous documents. During data collection, I identified tens of documents and compiled some preliminary categories for data comparison and summary. After conducting the initial theoretical sampling analysis, I drafted a summary of category findings to refine my protocol. In document analysis, a *protocol* is way of asking questions of a document and consists of a list of questions, items, or categories that guide data collection from documents. Table 2 summarizes the data sources and the corresponding research questions to match. The three research questions are listed below for a more descriptive match with the data sources. It is important to point out that not all of my data sources were mutually exclusive. This is because each of the data sources had at least some salient elements that addressed each of the research questions to some extent.

RQ_1 : What are the conceptions of curriculum and standards-based practices espoused in policy documents and curriculum reform initiatives?

RQ_2 : What content and process overlaps are evident in the Chemistry curriculum and the science education standards?

RQ_3 : How are advanced placement initiatives situated in standards-based school reforms and the Chemistry curriculum?

Table 2.

Matrix of Data Sources and Research Questions

DATA SOURCES	RESEARCH QUESTIONS		
	RQ_1	RQ_2	RQ_3
General Internet Resources	X	X	X
Electronic (and print) Policy documents (*Standards*, *NSES*, *Benchmarks e.t.c*)	X	X	X
Journal articles, Reports, Newspapers	X		X
ChemistyCurricula/Syllabi/Course outlines	X	X	X
ChemistryTextbooks Library/Curriculum materials	X	X	

Data Analysis and Interpretation

The process of qualitative document analysis that I used has several elements that are not necessarily organized as to suggest a linear progression but involved a series of six steps. These include: thorough planning, broad resource gathering, comprehensive review, deliberate interrogation, reflections and refinement, and appropriate analysis (See figure 5). The most critical stage in my data collection and data analysis was the ‘deliberate interrogation’ stage because this is where the materials were evaluated on the basis of my protocol as opposed to the 'broad resource gathering' stage where any document that focused on AP, IB and high school Chemistry, curriculum and/or standards was obtained.

In the 'comprehensive review' stage, I perused each document and isolated pieces that I thought were more focused on the subject matter. I rationalized that if they addressed some elements in the research questions, they would merit being considered. The 'reflection and refinement' stages allowed me to separate different pieces for organization. Document analysis procedures that were used to guide the data collection/analysis is shown in figure 5.

My raw data were captured in form of abstractions from documents and materials identified using the data collection/analysis protocol that I had developed earlier. The data analysis was conducted in stages which also highlight preliminary activities that were used in data collection. The first steps involved organizing documents and materials for relevance.

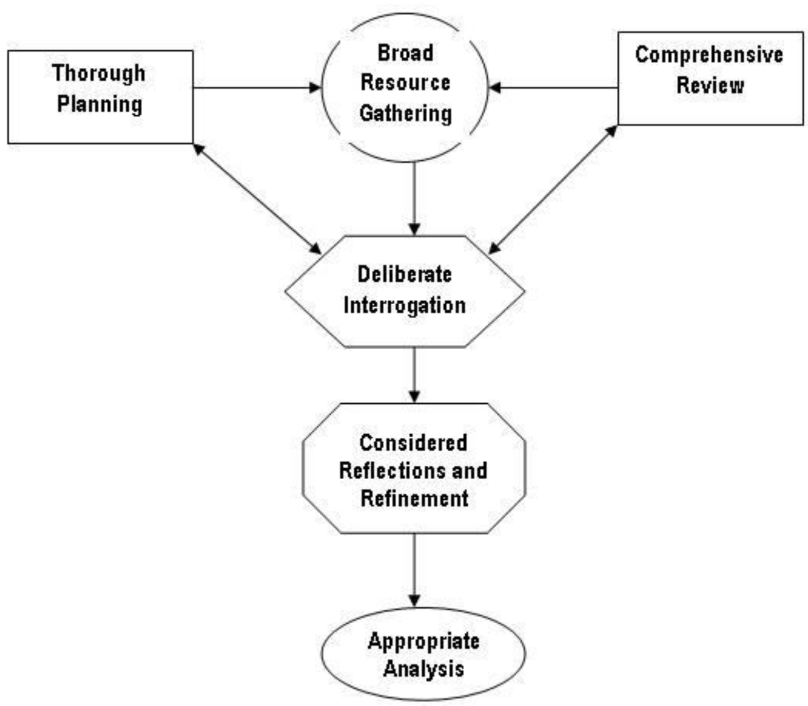

Figure 5: Qualitative document analysis data collection process.

Data were categorized in terms of elements in each research question with broad themes being the areas under consideration namely: advanced placement, Chemistry curriculum, conceptions of curriculum and standard–based practices. Owing to the qualitative nature of the research data, descriptive attributes were extracted and organized thematically before more interpretive terms were considered appropriately. Other categories included the individual topics within each curriculum level that were assessed for similarity. These were classified together for the purpose of describing the conceptions of curriculum and standards. A closer look at content areas outlined in the *NSES* and *GPS* standards was necessary to establish a match with themes.

Instead of using the inductive approach of the constant comparative analysis to identify emergent categories from the data, I opted for deductive categorizations by locating passages in the data that represented a priori themes that I had already identified. This is because the aim of the study was not to generate an emergent theory but rather to provide categorized descriptive attributes of the curriculum and standards. Although data were not substantive to be analyzed using a qualitative analysis software, I found relevant qualitative data analysis procedures such as coding the information by identifying categories and descriptors (Sánchez & Valcárcel, 1999) and the use of constant comparative methods for analyzing data from the various sources very useful in order to identify the patterns within the Chemistry curriculum through triangulation of various data sources. Given that the data obtained and my research questions required descriptive interpretation, the themes used in each case were in fact predetermined by specific content areas.

Researcher Subjectivity

It is especially difficult for a researcher to be perfectly objective in collecting, analyzing and presenting data because one's worldview becomes a part of how you understand and make sense of the data. Another difficulty in unbiased reflection is the researcher's own expectations because as he/she goes about research they are more likely to see the things they expect to see rather than what is actually evident in the bigger picture. This was the case with the current study by virtue of my science background and experience as a high school Chemistry teacher. Prior experiences with Chemistry presented subtle biases on how I envisaged my role as the researcher because it was easy to find myself almost critiquing the various aspects of the curriculum that are similar in some contexts but also different from the curriculum under which I last taught science.

I made a conscious decision not to describe conceptions of my experiences in spite of Chemistry being a universal discipline, because some approaches that teachers employ in their instructional design got me thinking about what I would use given similar circumstances. Data collection and analysis of relevant content area Chemistry was relatively manageable without having to struggle with technical terms and technical jargon of concepts and topics, especially in Chemistry. However, curriculum is a broad field that cannot be summed up in descriptions and interpretations of conceptions. Knowledge of Chemistry content was an advantage in terms of formulating descriptions and interpreting curricular concepts.

Because of the possibility that the descriptions, interpretations and document analysis procedures could be tainted with issues of bias, I endeavored to include credibility checks in my methodology to ensure a thorough examination of conceptions and objectivity in interpretation and confirmation. I was aware of the possibility that my data collection and analysis methods could be 'contaminated' by unrecognizable biases emanating from some policy documents and opinions. These were beyond my control as a researcher because policy decisions go beyond those who are the recipients and implementers of educational policy. I also kept some opinions and ideas that I heard from practicing teachers about the science curriculum, the education policy, and the NCLB education Act within wraps because these were potential sources of bias.

CHAPTER 4

SUMMARY OF FINDINGS

To address each of the three research questions, I have organized the findings of the study into three sections on the basis of each of the research questions and provided relevant examples from the data. Each section may have sub-headings to address specific aspects of the broader thematic categorizations. In some sections, I have used data organizers such as tables and brief summaries and quotations for specific pieces of text citations.

Conceptions of Curriculum and Standards

My first research question focused on exploring conceptions of curriculum and standards-based practices that are evident in educational policy documents and reform-based documents. After a comprehensive data analysis, I came up with some statements of evidential data to explore the conceptions of standards-based practices and the curriculum.

Conceptions of standards-based practices

According to Kelley, (2005), *Benchmarks for Science Literacy* represent the very first coherent set of "standards"; and since their initial publication, many schools have used them to develop their own curricula and course syllabi. Kelley reiterates that many science teachers find *Benchmarks* to be one of the most invaluable resources because of their specificity and clarity of goals. However, given that the *National Science Education Standards* borrowed a great deal from the *Benchmarks for Science Literacy* content-wise, this study focused more on the *NSES.*

Although standards-based pedagogy in science teaching is sometimes seen as a very confounding term, it is essentially a combination of knowledge of standards and skills that one requires to be an effective science teacher. In an apparent shift from the traditional chemical knowledge taught in lectures, the teaching of Chemistry has undergone changes by taking up board laboratory experimentations intended to provide students with opportunities to experience Chemistry as inquiry (Erduran, 2001). However, traditionally standards-based instruction has been envisaged in terms of the theory and practice of teaching that makes a significant use of *standards* to stimulate scientific and intellectual development of students. According to the *National Science Education Standards*, the science education standards provide criteria to judge progress toward a national vision of learning and teaching science in a system that promotes excellence (NRC, 1996 p. 12). This is evident in the excerpt from the standards:

> "Standards provide criteria that people at the local, state, and national levels can use to judge whether particular actions serve the vision of a scientifically literate society. Standards bring coordination, consistency, and coherence to improve science education."

This is also echoed in the *Georgia Performance Standards*' academic content *standards* (GPS, 2006) with the argument that *standards* must have unique characteristics that define them. First, they should be explicit enough to provide a vision of expected outcomes that align well with the science curriculum, the corresponding performance (teaching) standards and the principles of learning, instruction and assessment. Secondly, they should be easily understandable to students and the science teachers. It has been argued that they should also be explicit to all stake-holders involved in the curriculum process. Finally, they should serve a utilitarian role in defining the instruction and providing room for assessment using multiple ways that can be illustrated by examples of student work. The Chemistry content standards in the newly revised *Georgia Performance Standards* actually underscore these principles (GPS, 2006; Appendix A).

As stated earlier, there has been great emphasis on the need to give high school students an opportunity to experience Chemistry as it is typically encountered in the scientific world; through the adoption of scientific approaches such as the use of open-ended problems, or those that have a variety of possible solutions. In fact the science education reforms as proposed in the *National Science Education Standards* (NRC, 1996) puts great emphasis on scientific inquiry and students' ability to understand and engage in inquiry. This involves having students engage in scientifically oriented questions; giving priority to evidence and using the evidence not only to develop scientific explanations, but also to evaluate, revise and communicate or justify their explanations (NRC, 2000). A standards-based curriculum therefore provides opportunities for learners to engage in activities that promote the understanding of the nature of science and the ability work to as scientists (Carlone, 2004, p. 395).

Inquiry ranges from a teacher-directed structure: where learners are engaged in questions provided by the teacher with some data to analyze or steps to follow, to a more learner-directed structure: where learners pose their own questions and determine what counts as evidence and formulate logical arguments to communicate their explanations (Carlone, 2004). These ideals in fact represent the principle and vision of the learner-centered curriculum that is advocated in the "science as inquiry" standards (See Appendix A).

School science reflects both the intellectual and cultural traditions that characterize the practice of contemporary science, and hence improving science education is part of systemic education reform (NRC, 1996). However, all new ideas tend to experience initial resistance thus creating tensions that accompany the incorporation of these principles into standards. The standards assume the inclusion of all students in challenging science learning opportunities, and therefore define the levels of understanding and abilities that all students should develop.

Standards-based practices should therefore endeavor to emphatically reject any situation in science education where students are discouraged from pursuing science or are denied opportunities to learn and experience science (NRC, 1996, p.20).

In science teaching students establish connections between prior knowledge of science and the scientific knowledge found in many inquiry-oriented investigations in which they interact with their teachers and peers (NRC, 1996, p.20).Therefore standards-based practices essentially cultivate collegial collaboration when students interact and engage in problem solving, planning, group discussions decision making; and also experience assessments that are consistent with an active collaborative approach to learning.

Conceptions of curriculum

A coherent curriculum is that in which ideas build on each other over time (Krueger, & Sutton, 2001). Most concepts in Chemistry are relatively abstract and learners may not visualize and comprehend some of the chemical processes. To address this problem, the 'science as inquiry' standards put more emphasis on the importance of students' understanding of how they 'know what they know' in science (Erduran, 2001). Chemistry teachers often make use of teaching aids that mimic actual chemical processes in order to make the learning process more vivid although these may not have been necessarily suggested in the curriculum.

It has been argued that knowledge of the pedagogy of science teaching must include methods that vary the instruction, such as inquiry, cooperative learning, evaluating and guiding students' projects and different questioning techniques (Hofstein, Carmeli, & Shore, 2004). The lack of success of many educational reform projects is often attributed failure by teachers to implement the change as per intentions of the curriculum developers (van Driel, 2005). In fact, curriculum developers assume they (themselves) know how the curriculum may be changed and expect teachers to adapt their classroom practices accordingly (p. 303).

Exploring conceptions of curriculum reveals diverse perspectives gleaned from policy documents and curriculum reform initiatives. According to the *Benchmarks for Science Literacy* “no matter how the curriculum is organized, it should provide students with opportunities to become aware of the range of science disciplines that exist” (AAAS, 1993). The argument in *Benchmarks* is that when students gain lots of experiences doing science, they become more and more sophisticated in explaining their findings and accumulate sets of concrete experiences on which they can draw to reflect on the process of science (AAAS, 1993). Hence, the curriculum is a means of stirring up awareness in students; to reflect on the process of science and the need to communicate scientifically as opposed to making arbitrary statements without scientific evidence. However, the *Benchmarks* also caution that the very notion of “scientific knowledge is always subject to modification” can be very difficult for many students to grasp; and hence students need appropriate learning materials to construct knowledge and gain a deeper understanding of how science works.

It has been argued that the *National Science Education Standards* present a vision of a scientifically literate population (NRC, 1996, p. 2). Hence standards provide an outline of what students are expected to know and understand in order to merit as being scientifically literate. The curriculum therefore nurtures that vision to maturity. For students to demonstrate high levels of performance, teachers must be empowered to make the sound decisions essential for effective learning. Accordingly, teachers ought to use different strategies to nurture the understandings and abilities in their students as described in the standards (NRC, 1996).

The curriculum is aimed for the good of the student; in view of the principle of “Science standards for all students”. According to the *National Science Education Standards* this phrase embodies both excellence and equity (NRC, 1996). They argue that standards must apply to all students, regardless of their individual differences, physical attributes, their cultural or ethnic inclinations or interest and motivation in science. From the standards, it is apparent that every student deserves an opportunity to learn. Therefore the curriculum is an avenue for assuring equity in education. This is embodied in the goals for school science as outlined in the *National Science Education Standards* (NRC, 1996, p. 13). These argue that all students should be able to:

- experience the richness and excitement of knowing and understanding the natural world
- use appropriate scientific processes and principles in making personal decisions.
- engage intelligently in public discourse and debate scientific and technological concern
- increase their economic productivity through the use of the knowledge, understanding, and skills of scientific literacy in their careers.

Due to the diversity of students' needs, experiences, and backgrounds, teachers and schools are required to support a variety of high-quality opportunities for all students to learn science.

Curriculum is a process of science because science is an active endeavor. The principle articulated in the standards is that learning science is something that students do; not something that is done to them (NRC, 1996, p. 20). The standards clarify the fact that "Hands-on" activities are essential but are not enough; and emphasize that students must therefore be engaged in more "minds-on" experiences as well (p. 20); to stimulate their cognitive and intellectual development.

Standards call for more than "science as process" in which students learn such skills as observation, inference, and experimentation. This is the same reason why inquiry is central to science learning. However, these engagements must be meaningful and carefully planned in order for them to be effective. In fact, according to the *Benchmarks for Science Literacy*:

> "acquiring knowledge about the world does not lead to one to understand how science works; and neither does knowledge of philosophy of science alone lead to a scientific understanding of the world" (AAAS, 1993).

When students engage in inquiry they describe activities, ask scientific questions and construct explanations. However, they must also state their assumptions, and think critically and logically when formulating their explanations; and ground them in current scientific knowledge; when they communicate their ideas to others (Bybee, 2002; NRC, 2000). In hindsight, the principle articulated in the *Benchmarks* is similar to Kuhn's *paradigm shift theory* which argues that a theory may be replaced by another theory if the current one becomes inconsistent with new knowledge. The *Benchmarks for Science Literacy* argues that:

> "As students continue to investigate the world, the consistency premise can be strengthened by putting more emphasis on explaining inconsistency" (AAAS, 1993).

Benchmarks go further and reiterate that no matter how well one theory fits observations, a new theory might fit them just as well, or might fit a wider range of observations. It is therefore very important to encourage students to explore a variety of alternatives when explaining scientific phenomena in order to offer more reliable explanations and make more accurate predictions.

This is also relatively consistent with the *constructivist learning theory* where learners construct knowledge (Mayer, 1999). Constructivist learning occurs when learners actively create their own knowledge by making sense of the learning activities and materials presented in the classroom. There are three views of constructivist learning. According to Mayer (1999), learning may be envisaged as response strengthening, knowledge acquisition and knowledge construction.

In view of learning as response strengthening, a popular approach in the first half of the 20th Century, emphasis is placed on drill and practice oriented tasks in which learners are either rewarded or ‘punished’ during the learning process. On the other hand, the view of learning as knowledge acquisition, developed in the 1950s–1970s, is based on the notion that learners are passive recipients of knowledge and can be able to commit the knowledge to their long term memory (Mayer, 1999). The role of the teacher is to present information to learners. Finally, in the view of learning as knowledge construction, learners actively construct knowledge in their working memory. This view portrays the learner as a sense-seeker and the teacher as a cognitive guide who provides guidance and models instruction based on authentic instructional tasks and academic assessment. The instructional designer’s role is to foster meaningful interaction of learners with the materials through the creation of appropriate learning environments that s. The principle behind this instructional planning is selection, organization and integration of scientific knowledge and skills to promote meaningful learning (Mayer, 1999).

In the constructivist learning theory, there are three kinds of learning outcomes. These include: *no learning* - where learners exhibit relatively poor retention of scientific knowledge, *rote-learning* - where learners exhibit relatively poor application and transfer of knowledge in problem solving tasks, and *constructivist learning* - where learners are actively involved in the learning process through the retention and transfer of knowledge. Learners actively make sense of the information presented using coherent representations that depend on their cognitive activities rather than their behavioral tendencies (Mayer, 1999).

With regard to inquiry in science teaching, the *Benchmarks* are very categorical. They argue that science inquiry is more complex than “making a great many careful observations and organizing them” and good science often requires imagination and inventiveness (AAAS, 1993).

In this regard, they propose that inquiry labs can be re-designed to enable students to learn the principles of scientific inquiry. Due to the apparent “confusion” between the curriculum, the standards and standards-based practices, the national science standards provide a distinction:

> “Standards should not be seen as requiring a specific curriculum. A curriculum is the way content is organized and presented in the classroom. The content embodied in standards can be organized and presented with many different emphases and perspectives in many different curricula” (NRC, 1996, p. 22).

This aspect is important because there are many curricula that may exhibit different aspects of a standards-based curriculum but are not qualified as such. With renewed emphasis on standards-based practices it is only a matter of time before science teaching embraces standards at all levels.

Curriculum represents flexible means of fulfilling individual educational needs. In this regard, the *National Science Education Standards* argue that continuing dialogue between those who set and the implementers of *standards* at all levels (national, state, and local) ensures that the *standards* evolve to meet the needs of students, educators, and society at large (NRC, 1996). Hence the *National Science Education Standards* should be seen as a dynamic understanding that is always open to review and revision. This effectively dispels the notion of the ‘national’ science standards as a nationally mandated curriculum for science education, because standards are open to interpretations to align them with specific local situations. In fact, the argument in the standards is that schools and district must translate the *National Science Education Standards* into a program that reflects local contexts and policies (NRC, 1996, p. 8).

Curriculum is a process of change where the teacher is the agent of change. Effective teaching is at the heart of science education and hence science teaching standards important. According to *National Science Education Standards*, teachers’ assessments of students and their own teaching enables them to build strong, sustained relationships with their students; grounded in the knowledge of students' individual differences (NRC, 1996). Teachers are in fact members of science-learning communities and need support from the rest of the educational community to achieve the objectives embodied in the standards. Reforms in science teaching require concerted efforts. For instance, in the development of standards-based curriculum materials, there were concerted efforts to ensure that the materials were effective in supporting classroom instruction. Standards-based instructional materials encourage more hands-on inquiry-based student work (Lawton, Berns & Sandler, 2009). The development of improved materials was informed by research through rigorous pilot-testing and field testing (p. 21). The exemplary materials were developed on the premise that they would transform the thinking, theory and practice of science teaching, and hence support the standards for teaching and learning to challenge all students to learn science successfully.

The *National Science Education Standards* represent landmark efforts to define essentials of science. Beyond the basic content, the standards spell out expectations for student teaching (Taylor, 2009). Therefore the science teaching standards describe what science teachers should know and be able to do in terms of the actions taken to guide and facilitate student learning, assessment and the development of enabling environments that enable students to learn science in communities of science learners.

Curriculum also presents an opportunity for mentorship and induction. All beginning teachers must have opportunities to work with more experienced educators and reflect on their teaching practices. The *National Science Education Standards* support this endeavor because teachers get to learn how students with diverse interests, abilities, and experiences make sense of scientific ideas; and what a teacher do to support and guide students (NRC, 1996). Professional development and induction, allows teachers to engage in research on science teaching and learning; by regularly sharing their learning experiences with colleagues. Both prospective and practicing teachers need collective opportunities to enhance personal and professional growth.

Curriculum is a vehicle for reforms and policy. Reforming science education requires substantive changes in how science is taught, which calls for substantive change in professional development practices. Teachers need to be provided with opportunities to develop theoretical and practical understanding and ability; not just technical proficiencies (NRC, 1996). Such opportunities need to be clearly and appropriately connected to teachers' work in the context of the classroom so that in this way, teachers gain the knowledge, understanding, and ability to implement the standards.

Reforms in teaching are also embedded in assessment techniques used by teachers. The assessment standards provide criteria against which to judge the quality of student assessment practices (NRC, 1996). They must be consistent with the decisions they inform and opportunities to learn science. Authentic assessment in science must communicate its consequences based on specified criteria and exhibit the fairness of assessment practices. In so doing, one can make sound inferences from the assessments about student achievement and the opportunity to learn.

The vision of assessment described in the standards is that they are primary feedback mechanisms in the science education system for students, teachers, school districts and policy makers. This feedback in turn stimulates changes in policy, guides the professional development of teachers, and encourages students to improve their understanding of science (NRC, 1996, p. 5). Assessment has also evolved to keep pace with the changing approaches in science teaching. It has been argued that assessment and learning are two sides of the same coin. This is echoed in the *National Science Education Standards*:

> "Assessments provide an operational definition of standards…they define in measurable terms; what teachers should teach and students should learn…when students are engaged in assessment they should learn from them" (NRC, 1996, p. 6).

In fact, from the literature review, it was pointed out that Advanced Placement examinations (assessments) did not reflect recent developments in Chemistry teaching; and that the courses fell short of including key concepts and disciplines relevant to modern Chemistry (Moore, 2002). The argument in the standards is that assessments have become more sophisticated and varied and focus on higher-order skills. They argue that instead of simply checking whether students have memorized certain concepts, refined assessments probe for deeper understanding, reasoning, and the use of knowledge and skills developed through inquiry (p. 6).

Standards, Content and the Chemistry Curriculum

My second research question focused on determining the areas in the content standards and process standards that exhibited significant overlaps with curriculum materials. I explored these in terms of the goals, content areas and the corresponding topics, paying attention to those that received specific emphasis in some course and accounting to their absence in other courses.

Different kinds of assessment tools, instructional approaches and procedures used in Chemistry are aimed at achieving these objectives in addition to more specific learning goals. The following are useful tools that teachers use to instruct, assess and evaluate their students.

- Tests and quizzes
- Essays
- Labs and activities
- Assignments
- Lab reports
- Homework
- Class work assignments
- Graphing data
- Constructing charts or tables
- Notebook journals
- Demos/guided observations
- Group discussions
- Video presentations with guided questions
- Project presentations
- Midterm, final examinations

The Chemistry courses offered in high school are advanced level courses that are aimed at preparing students not only to emerge as young scientists; but also gain the most fundamental knowledge and skills to be successful in post-secondary institutions of higher learning; and to be productive members of the society who can make informed decisions. Communicating the advantages of new assessment methods to parents and policy makers is one of the greatest challenges for teachers (NRC, 1996). Besides the conventional paper and pencil assessments and tests, there is a variety of other ways for assessing students. These may include performances, portfolios, interviews, investigative laboratory reports, or written essays. It has been argued that assessments ought to be developmentally appropriate and set in contexts that are very familiar to all students and are free from possible bias.

The activities and assessment tools listed above are crafted on the basis of fundamental goals of Chemistry as a discipline and the endeavor to achieve additional instructional objectives for each topic that is taught in the classroom. The list above is not exhaustive and is also not an endorsement for the use of these tools and procedures, but if carefully organized they have the potential of helping students to succeed in science. The quality of the science curriculum materials should be presented in terms of their content, student work, teachers' engagements, and assessment of learning in the implementation of changes in standards-based curriculum materials.

What *exactly* are the main goals of high school Chemistry school science? Table 3 below provides a summarized outline of the goals of high school Chemistry and the general goals of school science (as in the *National Science Education Standards*). Teachers often concentrate on one or two teaching goals; which may even skew their teaching. For example, some high school teachers do not allocate much time for laboratory work in the AP Chemistry course because of the general argument that laboratory work is not necessary for students to pass the AP Chemistry examinations. In fact, a sample of the AP syllabus (Appendix B) shows that the laboratory work constitutes a very small proportion of the bulk of the AP Chemistry content that is tested in the AP examinations. In spite of all the problems, AP courses have been expanded as more students consider the merits of taking the AP Chemistry examinations as a way of preparing for college.

Table 3.

Goals of High school Chemistry and School Science

Goals of High School Chemistry	*Goals for School Science (Outlined in NSES)*
Introduce students to a science and the scientific method	Get students to experience the richness and excitement of knowing about and understanding the natural world
Provide students with a foundational knowledge for college level Chemistry	Allow students to use appropriate scientific processes and principles in making personal decisions
Provide a fair amount of college education at the high school level	
Increase students' chance of doing better on standardized assessments	
Enable students to develop problem-solving skills applicable in Chemistry and other science subjects	
Help students develop adequate laboratory skills (observation, measurement, report writing and safe handling of apparatus and equipment	Increase students' their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers
Help students appreciate the role of Chemistry in day to day life and support them in making informed decisions	Enable students to engage intelligently in public discourse about scientific and technological matters.

According to the *National Science Education Standards*, the goals of school science define a scientifically literate society (NRC, 1996, p. 13; Table 3). Therefore content standards define what the scientifically literate person should know, understand, and be able to do after 13 years of formal education in school science. On the other hand, the goals of Chemistry are more structured in terms of acquiring skills and fundamental principles of Chemistry knowledge; and the ability to apply the knowledge and skills to solve problems requiring similar techniques; and excel in the formal tests or other assessment items (Table 3). If students are unable to achieve the standards in most schools today, the implementation of the standards will require a relatively more sustained, long-term and focused commitment to change (NRC, 1996, p. 13).

In addition to looking at the general aims of Chemistry as a subject, I explored specific instances of the goals that are found within various sections of the courses. General Chemistry courses tend to put more emphasis on theoretical aspects of Chemistry. In fact, there has been a growing need to present topics such as the *Structure of Matter*, *Chemical Equilibrium*, *Chemical Kinetics*, *Chemical Thermodynamics*, and the *Kinetic Theory of Gases* and in more considerable depth. In both cases, I considered and harmonized categories of their purposes in the curriculum for which I provided as a summary in Table 4.

Table 4.

Purposes of the Advanced Chemistry Courses

Purpose of the Course (Focus)	*AP Chemistry*	*CP Chemistry*	*IB Chemistry*
Meet high school requirements for science	☑	☑	☑
Provide a foundation for post-secondary chemical science	☑	☑	☑
Provide grade for possible college credits	☑	☒	☑
Match/align content with equivalent content in introductory post-secondary curriculum	☑ Except practical	☑	☑
Assess/evaluate students using equivalent Post-secondary assessment rubrics.	☑	☒	☑
Impart and develop scientific knowledge and applied skills	☑	☑	☑
Promote environmental awareness	☑	☑	☑

Key:

AP = Advanced Placement
CP = College Preparatory
IB = International Baccalaureate

☑ = Serves outlined purpose
☒ = Does not serve outlined purpose

The International Baccalaureate and Advanced Placement Chemistry are more tailored to prepare students for advanced placement in college than the College Preparatory course; because they cover a wider variety of topics. The increasing levels of enrolment witnessed in AP courses in the last few years may serve to reinforce this aspect of college placement. Students who are engaged successfully in the Advanced Placement (AP) and the International Baccalaureate (IB) Chemistry courses can get college credits in addition to meeting the course requirements and getting a course grade, where as students who enroll into the other courses such as the College Preparatory Chemistry will only meet requirements for a course credit and course grade.

Although students taking College Preparatory Chemistry do not earn some college credits, recently there have been concern about the College Preparatory Chemistry curriculum; which is relatively broader in terms of topics and content areas covered (Table 5). This often puts teachers under a lot of pressure to cover all of the content areas within the stipulated time. The result has often been a sacrificing of the understanding of chemical principles for content coverage. There is growing concern about depth of the subject matter as opposed to the breadth of content. The general tendency is to assume that a broader curriculum is considerably better. However, it also carries the potential of diminishing the focus, which may be perceived as a disadvantage for the students who study Chemistry to gain a strong foundation for college (Bennett & Holman, 2002).

Content standards are stated in terms of the content to be understood or certain abilities are to be developed as a result of activities provided for all students in respective grade levels (NRC, 1996, p. 6). These standards refer to broad areas of content or the nature of scientific knowledge. The need to ensure students' safety in the laboratory at all times is critical in science teaching. In the *Georgia Performance Standards*, the content standard #7: (**SC7. Students will characterize the properties that describe solutions and the nature of acids and bases)**, they

caution that teachers may use *Gas Laws* to achieve the *standard* but it is not mandated. This is because strong acids and strong alkalis (bases) are very corrosive and are potentially harmful. However, the standard is still stated to reflect the content area or topic (*Acids and Bases*) and the abilities that students should develop (*characterize properties, describe nature of the solutions*). All the topics covered under each course in the curriculum (Table 5) and their organization for classroom presentation is very crucial because it determines the ease with which the content standards can be located and aligned with the corresponding topics and instructional objectives.

The need to provide a more objective critique of the curriculum in the context of standards-based practices is a result of sustained interest in the instructional approach especially in the field of science inquiry. The Chemistry standards in the *Georgia Performance Standards* provide an outline of key content areas, concepts and skills that need to have greater emphasis by Chemistry teachers (Table 5, Appendix A).

After carefully examining the content areas, I also identified matching topics within the curriculum outlined in the Advanced Placement Chemistry, College Preparatory Chemistry the International Baccalaureate Chemistry; and also considered the as key areas that received greater emphasis in the *Georgia performance standards*; aimed at giving high school students a solid foundation in Chemistry. These are topics that feature most prominently in the general Chemistry curriculum for high school. However, other areas that are relatively more structured to include some of the college-level content were evident in Advanced Placement Chemistry with the exception of laboratory work that receives less emphasis in the AP Chemistry (Appendix C).

Although the topics presented in each course usually differ in depth and breadth, some specific topics are unique to each course because of nature of goals and objectives for respective courses is uniquely may be complementary but are also uniquely different from the other courses.

Table 5.

Topics in Advanced Chemistry Courses and the Chemistry GPS

AP Chemistry	*CP Chemistry*	*IB Chemistry*	*Topics in the Chemistry GPS*
Matter & Measurement	Scientific Method, States of Matter: Properties & Changes	States of Matter	Classifications of Matter
Atoms, Ions and Molecules	Atomic Theory (Structure of the atom)	Atomic Theory	Atomic Theory and Configuration
Electronic Configuration	Electrons in Atoms		
Stoichiometry	Stoichiometry	Stoichiometry	Stoichiometry
Qualitative and Quantitative Chemistry	The Mole		Empirical/Molecular Formulas
Gases	Gas Laws	Energetics	Gas Laws
Periodicity	The Periodic Table Periodic Law	Periodicity	Periodicity
Chemical Bonding Covalent/Ionic	Covalent/Ionic Bonding	Boding	Bonding and Nomenclature
Thermochemistry	Chemical Reactions		Chemical Reactions
Transition Metals	Metals and Ionic Compounds		
Ionic Equations	Solutions	Chemical Industries	Solutions and Concentrations
Equilibrium	Chemical Equilibrium	Equilibrium	
Acids and Bases	Acids and Bases	Acids and Bases	
Kinetics (Rates of Reaction)	Rates of Reactions	Kinetics	Kinetic Molecular Theory/Phase Change
Electrochemistry	Electrochemistry Energy/Chemical Change)	Fuel and Energy.	
	Reduction-Oxidation (Redox) Reactions	Reduction and Oxidation	
Organic Chemistry		Organic Chemistry	
	Nuclear Chemistry	Higher Physical/Organic Chemistry	

Key: AP = Advanced Placement; IB = International Baccalaureate; CP = College Preparatory; GPS = Georgia Performance Standards

The topics in Advanced Placement Chemistry courses tend to mimic topics and content areas that students can expect to encounter in their introductory college level courses unlike the topics in College Preparatory Chemistry course (Table 5, Appendix C). As much as the topics are not organized in the order in which instructors present them in class, it is worth noting that certain concepts covered in a particular topic may be required in subsequent topics in order to provide a more coherent understanding. For instance, *Mole Concept* (defined simply as the unit of measure for the amount of substance present in a given quantity of an atom, molecule ion or compound) is usually presented before a topic such as *Stoichiometry* (defined in simple terms as the mathematics behind Chemistry). In other words, students need the requisite knowledge for computing the *number of moles* and *mole ratios* before they can be able to write balanced chemical equations for reactions, by making use of the mole ratios of reacting species.

It may appear as if some topics are not listed in respective courses (left blank in table 5). However, some broad topics such as the *Periodic Table* and *Periodicity* usually cover sub-topics such as *Metals*, and *Electrons in Atoms*; listed as separate topics in the other courses. There are specific topics in Chemistry that pose a big challenge to students. These include the ideas of *ionic bonding*, *inter-molecular forces* and open system *chemical reactions* (in which matter can enter or leave the reacting system from the surrounding). According to Bennett & Holman, (2002), students who experience gradual introduction and a review of ideas such as *Chemical Bonding* (formation of bonds between atoms) and *Thermodynamics* (conversion of chemical energy to do work) at different contexts during a particular course often to develop a better understanding of the concepts than those who follow conventional approaches (p. 175).

Another key component in the organization of the high school Chemistry curriculum is the importance of measurement and the scientific method; usually presented as the introductory topic. It provides the learners with adequate foundation to explore science at higher levels within the course; using important knowledge and skills that they acquire to conduct scientific inquiry.

In order to be exhaustive in my analysis of topics and content areas, I considered a list of topics (Table 6) from a typical recommended textbook for high school Chemistry (Dingrando, Braden, Tallman, Hainen & Wistrom, 2005). Most of the topics covered within the different high school Chemistry courses also appear in the table of contents of the Chemistry textbook.

Table 6.

Topics from a Common Chemistry Textbook (CHEMISTRY: *Matter and Change*)

Table of Contents - CHEMISTRY: Matter And Change	
Introduction to Chemistry	Gases
Data Analysis	Solutions
Matter: Properties and Changes	Energy and Chemical Change
Structure of the Atom	Reaction Rates
Electrons in Atoms	Chemical Equilibrium
The Periodic Table and Periodic Law	Acids & Bases
The Elements	Redox Reactions
Ionic Compounds	Electrochemistry
Covalent Compounds	Hydrocarbons
Chemical Reactions	Substituted Hydrocarbons and their Reactions
The Mole	The Chemistry of Life
Stoichiometry	Nuclear Chemistry
States of Matter	Chemistry in the Environment

Source: Dingrando, L., Braden, G., Tallman, K., Hainen, N., & Wistrom, C. (2005). Chemistry: Matter and change [Teacher Wraparound Edition]. Columbus, OH: Glencoe/McGraw-Hill.

One of the most remarkable things about Chemistry text-books is the manner in which the topics are organized. They tend to present topics in such a way that they sequentially follow each other in terms of the pre-requisite concepts for subsequent topics. This is very important because it makes the task of organizing content presentation relatively easier especially when teachers begin to construct instructional units because they only need to match the content with relevant instructional objectives and organize appropriate teaching and learning experiences. However, teachers may take actually advantage of this aspect when planning for instruction and ultimately ignore the content standards altogether.

Due to an increasing concern about environmental degradation, global warming and depletion of the ozone layer, it was notable that most of the courses emphasized environmental awareness as a key component in their curriculum. However, the mere presence of important topics in the curriculum and syllabus does not imply that they will be effectively presented in classroom instruction as proposed in the standards. Therefore different aspects of instructional planning and content delivery are important for consideration. In fact, it has been argued that knowledge of only the subject matter, even at an advanced level, is not enough to fully equip teachers with the tools to fulfill their teaching roles; and neither does getting acquainted with the ready-made curriculum materials and teaching aid (Hofstein, Carmeli & Shore, 2000).

In addition to curriculum and content knowledge, teachers must also be familiar with the pedagogy of science teaching. In recognition of the fact that Chemistry is a practical-oriented subject, I devised a model that depicts how Chemistry students can venture in inquiry tasks and make the best of them. I did not intend this as a linear progression but a relatively structured and continuous process aimed at consolidating the understanding of key principles in Chemistry.

Given that there are various levels of inquiry as outlined in the standards, when students are provided with experimental procedures to engage in inquiry or investigate a concept, they often might decide to revise their own strategy if the procedure does not yield expected results.

Another alternative would be to modify certain parameters in order to make a second or even third try. Students should be encouraged to justify why they modified or revised their strategy and make a connection with relevant scientific knowledge and articulate sound scientific principles to back their approach and justify their explanations (Figure 6).

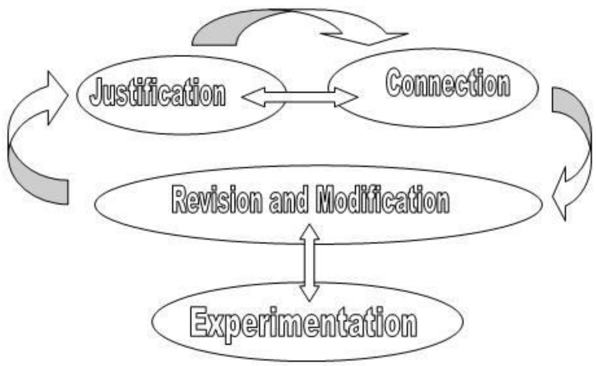

Figure 6. Schematic model for experimentation in Chemistry.

At the end of an experiment, students may be encouraged to review their strategy and how it helped them solve the problem. This again would involve justification of what they did on the basis of a coherent connection; consistent with sound scientific evidence and explanation to back their results and arguments. This is clearly emphasized in the standards with regard to inquiry.

The discussion of these courses is not exhaustive without considering all the domain areas for standards as provided in the Chemistry Georgia Performance Standards (Appendix A). These are the *Co-requisite* characteristics of science and *Co-requisite content*. They include: *Habits of Mind* (How students should think about learning science and their response in different situations); the *Nature of Science* (History of science and distinction between science and non-science) and the science *Content Co-requisite* (What students are expected to know and the corresponding benchmarks that indicate specific learning goals). It is apparent that the standards not only outline what students are expected to know and what they need to be engaged in; but also the expected specific learning outcomes (Appendix A). These are closely tied with the goals of Chemistry outlined in the previous section (Table 3). For example the Co-Requisite Content Standard # 3 below from the Georgia Performance Standards (Appendix A) identifies the content areas and the corresponding benchmarks detailing content areas that students need to know.

SC3 Students will use the modern atomic theory to explain the characteristics of atoms.

a) Discriminate between the relative size, charge, and position of protons, neutrons, and electrons in the atom.
b) Use the orbital configuration of neutral atoms to explain its effect on the atom's chemical properties.
c) Explain the relationship of the proton number to the element's identity.
d) Explain the relationship of isotopes to the relative abundance of atoms of a particular element.
e) Compare and contrast types of chemical bonds (i.e. ionic, covalent).
f) Relate light emission and the movement of electrons to element identification.

However, the main topic for the content area is listed as *Atomic Theory/Configuration*. This means therefore, that standards effectively break down the content areas to facilitate ease of unit development in terms of the learning objectives that are closely tied with the content areas.

By the same token the content standards in the *National Science Education Standards* describe learning outcomes or what students should understand and be able to do; not the manner in which students will achieve those outcomes (NRC, 1996, p. 20). This means that it is the responsibility of science teachers to organize appropriate teaching and learning activities and experiences; and make use of meaningful instructional materials to achieve these objectives.

Another example from the *National Science Education Standard* presents the 'science as inquiry' *standards*; described in terms of student understanding of inquiry and in terms of the activities that result in student development of certain abilities (NRC, 1996, p. 176) such as:

Physical Science
Content Standard B
As a result of their activities in grades 9-12, all students should develop an understanding of

- Structure of atoms
- Structure and properties of matter
- Chemical reactions
- Motions and forces
- Conservation of energy and increase in disorder
- Interactions of energy and matter

Some of the content area topics listed above come from grade 9-12 *physical science*. Although these are not specifically stated as content area topics in high school Chemistry, the topics and objectives are straight on target with respect to the high school Chemistry curriculum. Most of the topics are stated in broad terms. For instance, the *Interaction of Energy and Matter* may involve Chemistry topics such as *Acids and Bases,* and *Rates of Reaction.* Under each topic, the *standard* provides descriptive fundamental concepts and principles that underlie the specified standard and content area. For instance, in *Structure of the atom*, the description is given below:

> STRUCTURE OF ATOMS
>
> - Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and electrons holds the atom together.
> - The atom's nucleus is composed of protons and neutrons, which are much more massive than electrons. When an element has atoms that differ in the number of neutrons, these atoms are called different isotopes of the element.
> - The nuclear forces that hold the nucleus of an atom together, at nuclear distances, are usually stronger than the electric forces that would make it fly apart. Nuclear reactions convert a fraction of the mass of interacting particles into energy, and they can release much greater amounts of energy than atomic interactions. Fission is the splitting of a large nucleus into smaller pieces. Fusion is the joining of two nuclei at extremely high temperature and pressure, and is the process responsible for the energy of the sun and other stars.
> - Radioactive isotopes are unstable and undergo spontaneous nuclear reactions, emitting particles and/or wavelike radiation. The decay of any one nucleus cannot be predicted, but a large group of identical nuclei decay at a predictable rate. This predictability can be used to estimate the age of materials that contain radioactive isotopes.
>
> (NRC, 1996, p. 178).

The same topic and content areas are presented differently in AP Chemistry syllabus (Appendix C). It is apparent from the content in AP Chemistry that some of what is featured covers college-level Chemistry. However most high school Chemistry topics delve deep into content areas exploring electron energy levels; including quantum numbers, molecular orbital theories and descriptions of higher order structure and properties of atoms covered in college.

> **Atomic theory and atomic structure**
>
> 1. Evidence for the atomic theory
> 2. Atomic masses; determination by chemical and physical means
> 3. Atomic number and mass number; isotopes
> 4. Electron energy levels: atomic spectra, quantum numbers, atomic orbitals
> 5. Periodic relationships including, for example, atomic radii, ionization energies, electron affinities, oxidation states (Excerpt from Appendix C).

Excellence in science education embodies the ideals that all students can achieve a relatively solid understanding of science if they are given the opportunity (NRC, 2006, p. 20). On the other hand, implementing the *National Science Education Standards* implies that students must be enabled to acquire scientific knowledge and develop an understanding of how science works.

Advanced Placement in Curriculum and Standards

My third question focused on how advanced placement initiatives are situated within the context of standards-based practices and the Chemistry curriculum. I looked at the major content skills and emphases in the standards and the Chemistry curriculum in advanced courses to determine possible connections with the general attributes of standards-based practices.

The decision to embrace standards-based practices in school is often a challenging and requires a lot of discipline and commitment. According to the *National Science Education Standards*, some outstanding things still happen in the science classroom today, even without [the use of] national *standards* (NRC, 1996, p. 12). However, these things happen because some extraordinary teachers engage appropriate practices despite conventional practices, by ignoring the vocabulary-dense textbooks and encouraging student inquiry using activities that are relevant to students' lives (p. 12). Such approaches may not necessarily be standards-based but learners actively engage in a meaningful ways and maximize their learning opportunities.

The *Georgia Performance Standards* emphasize the following aspects with regard to knowledge, skills and attitudes. These are: characteristics of science, recording investigations clearly and accurately, using scientific tools, interpreting graphs, tables, and charts; writing reports clearly, using proper units, organizing data into graphs, tables, and charts, using models, posing scientific and quality questions, using appropriate technology, using proper safety techniques, analyzing scientific data via calculations and inferences; and recognizing the importance of explaining data with precision and accuracy (GPS, 2006; Appendix A). From the literature review it is argued that most students who take AP and IB classes are satisfied with the nature of the curriculum and instruction in these courses which are traditionally perceived as relatively more challenging (Hertberg-Davis, Callahan, 2008). However, they can only be successful if they embrace their role like the ones defined in the science standards and the standards-based school program described in table 1.

In order to situate the advanced placement programs (AP and IB Chemistry) I considered the aspects of curriculum and instruction that are emphases in the *National Science Education Standards*. These include: understanding and responding to individual students' needs, adapting the curriculum to address individual differences , focusing on student understanding and use of scientific knowledge, guiding students in active and extended inquiry, providing opportunities for scientific discourse among students, taking ownership for learning with all students, supporting a collaborative classroom community with shared responsibility; and team-teaching (collegial co-operation) with other teachers to enhance science programs (NRC, 1996).

Most of the advanced courses in Chemistry ascribe to these ideals that are emphasized in the standards. I therefore looked at main emphases in the International Baccalaureate Diploma program (also covered in literature review) to provide more grounds for situating these programs in standards-based practices and the Chemistry curriculum.

From the literature, it is argued that "Standards should not be seen as requiring a specific curriculum. A curriculum is the way content is organized and presented in the classroom. The content embodied in standards can be organized and presented with many different emphases and perspectives in many different curricula" (NRC, 1996, p. 22). This implies that the standards may be used to guide instruction in a science course especially if the relevant content standards and process standards are coupled with the appropriate content and learning experiences.

The International Baccalaureate (IB) curriculum guide contains evidence of the aims, objectives, content and teaching approaches that point towards the need for students to develop critical thinking skills, deep understanding of different cultural identities, an appreciation of the interdependence of global issues, and an awareness of the human condition (Hill, 2006). The first aim for group 4 subjects in experimental sciences (in which IB Chemistry belongs) is to "provide opportunities for scientific study and creativity within global contexts which can stimulate and challenge students" (Chemistry IBO, 2001, p.6 cited in Hill, 2006).

The International Baccalaureate Diploma (IBD) assesses student work as direct evidence of their achievement against the stated goals of the Diploma program because the IBD is an internationally recognized university entrance qualification. Although the IBD program is academically demanding and challenging, it provides students with an extensive but balanced education; whose main goals are to help students develop skills in critical-thinking, reflective research, independent learning and intercultural understanding (IBD, 2009).

The program assessment procedures are a measure of the extent to which students have mastered advanced academic skills in analyzing and presenting information, evaluating and constructing arguments and solving problems creatively. Special emphasis is given to basic skills that are also assessed; such as retaining knowledge, understanding key concepts and applying standard methods. In addition to the academic skills, the IBD program assessment tasks also encourage students to develop an international outlook and intercultural skills (IBD, 2009).

Students' performance weighed against set standards and not by their respective position or rank in class. The program aims at developing important skills in students' to enable them to think critically and act compassionately in complex situations. In the literature review it is argued that successful development of teaching strategies is characterized by increased competence, raising the challenge level of the curriculum and instruction, and understanding the unique needs of individual students in the program (Hertberg-Davis, Callahan, 2008). The IB programs target groups of student with diverse academic, cultural, linguistic and economic backgrounds. Overall goal of the program is to measure teaching and learning against an international standard (IBD, 2009).

The IB Chemistry program contains a body of knowledge, scientific principles and techniques which students are required to learn and apply. When applying scientific methods, students develop an ability to analyze, evaluate and synthesize scientific information, and communicate these to their peers. These aspects are also emphasized in the *National Science Education Standards*. In the IBD program, students are involved in a compulsory project work to enable them to appreciate science and its implications in the environment and the society; in addition to other and ethical implications. The project is conducted as a *collaborative* and interdisciplinary effort. For instance students maybe opt to analyze a topic or problem which can then be investigated in any science discipline (IBD, 2009).

Hence the program is also an opportunity for students to extend their knowledge and skills to explore scientific solutions to global questions. These aspects of the International Baccalaureate program are also in resonance with the goals of school science outlined earlier (Table 2). Indeed the advanced placement programs can be accommodated in standards-based curriculum for the reasons that national science standards are used as templates in formulating curriculum and instructional units that fit local situations. From literature, it is argued that the overarching goal of the International Baccalaureate curriculum is to enable students to gain a deeper understanding of knowledge to develop critical thinking a reflective mind (Mayer, 2008).

In fact, all science teachers have implicit and explicit beliefs about science learning and teaching. Teachers can be effective in guiding students learning science only if they have the opportunity to examine their own beliefs, as well as to develop an understanding of the tenets on which the standards are based (NRC, 1996, p. 28). Standards help in channeling these beliefs so that the science learning is not shrouded in teacher beliefs but rather grounded in authentic scientific principles. These can apply to any subject or discipline and the advanced Chemistry programs are therefore not exempt.

On the other hand, the AP Chemistry examination is broken down into five content areas: structure of matter, states of matter, reactions, descriptive Chemistry, and laboratory. It has been claimed that the descriptive section of the AP Chemistry examinations is traditionally difficult for students (Crippen & Brooks, 2001). The argument is based on the notion that the section is difficult to teach because it requires a large amount of memorization or experience. Another perspective points to the apparent disconnect within the traditional Advanced Placement curriculum (Crippen & Brooks, 2001). There is need to harmonize the high school Chemistry curriculum because the key ingredients are already evident in the various Chemistry courses.

Although Tanner (1990) defines curriculum as the planned and guided learning experiences and intended learning outcomes formulated through a systematic reconstruction of knowledge and experiences, the science curriculum as portrayed in the *National Science Education Standards* place emphasize the acquisition of specific capacities, understandings and abilities, and the process involved, including the structure, organization and presentation of the content. One interesting factor is that the state standards (GPS) are often used as the curriculum and hence the need to harmonize standards and the science curriculum to address the discrepancy.

CHAPTER 5

DISCUSSION, IMPLICATIONS AND CONCLUSIONS

This Chapter provides a general discussion of results from the findings of this qualitative research to distil the main arguments. In addition to examining what counts for conceptions of curriculum and standards-based practices, some sections of this chapter also highlight important implications for science teaching, classroom practice, curriculum development and important considerations for advanced placement initiatives. Conclusive remarks provide a summarized perspective of the current study.

Conceptions of Curriculum and Standards

Curriculum has been defined in terms of sum total of goal-oriented learning experiences which are deliberately planned, designed and formulated for implementation through educational programs for a specific group of learners. A planned curriculum must therefore be able to accept responsibility at three levels; to justify its rationale, the rules of engagement for implementation and effects of the curriculum implementation process. In fact the *National Science Education Standards* belabor to strike the distinction between the curriculum and content standards that:

> "The content standards are not a science curriculum. The content of school science is broadly defined to include specific capacities, understandings, and abilities in science. Curriculum is the way content is delivered and includes the structure, organization, balance, and presentation of the content in the classroom." (NRC, 1996, p. 22).

This should therefore allay the worries of science teachers who have always asked pertinent questions such as: "What does standards-based instruction entail?" or "Why do we need an understanding of the science curriculum if we already have the content standards?" When actual teaching eventually gets underway, teachers will be too engrossed in their experiences of what is involved in standards-based practice to notice any difference because it will become a culture.

Chemistry is a practical subject that has its foundations in inquiry-based activities that involve experimental procedures. Students' understanding of the nature of science is considered to be a very important educational objective the whole world over. Such an understanding is often considered to be a very significant aspect of scientific literacy (Lederman, 1999). One of the most discernible trends in the high school Chemistry curricula has been to use contexts and applications of Chemistry as a means of developing chemical principles (Bennett & Holman, 2002). It is argued that learners' motivation has been the strongest driving force in the recent development of 'relevant' curriculum materials (p. 166). In fact, teachers' understanding of the content and the nature of science is fundamental for inculcating and nurturing in the learners the same conceptual framework through classroom transactions. In a study about teachers understanding of the nature of science and classroom practices, however, teachers held the view that scientific knowledge is tentative and their conceptions of the nature of science did not influence their classroom practices (Lederman, 1999, p. 925).

The *National Science Education Standards* (NRC, 1996), describe standards as: "criteria to judge progress toward a national vision of learning and teaching science in a system that promotes excellence". Extending this view of science standards requires a differentiated kind of instruction in the science classrooms to treat learning as an active process. In that respect, many researchers recommend an appraisal of materials in local situations to create more avenues for dialogue based on the *National Science Education Standards* (NRC, 1996) and *Benchmarks for Science Literacy* (AAAS, 1993); because the conceptions of learners, science teachers and the society which are envisaged in the standards and benchmarks are often theoretical and general (Bybee, 1998). Science teachers have to respond to unique events in the classroom; so they often have to adapt the curriculum materials to emerging situations and adapt to the learners' cognitive constructions and prior knowledge. Standards-based instruction is therefore a means to fuel this vision and propel it to greater heights by stimulating students' intellectual development to make the vision come to reality.

Professional development has been touted as an important aspect in supporting standards-based initiatives. Such forums can enable teachers to learn how a well articulated curriculum can challenge students to learn sophisticated ideas. In the literature review, the 'backward design' of curriculum planning is indeed an eye-opener because it puts the teacher in the driving seat as a curriculum planner and allows him/her to pay attention to desired results or learning outcomes prior to planning the instruction. Professional development is also the right forum for resolving conflicts that teachers feel within them with regard to inquiry teaching; because they have the support of their colleagues. Professional development presents the opportunity for mentorship and induction of new teachers an aspect of curriculum planning and implementation. In this regard the curriculum is a vehicle for pushing reforms, and hence teachers may facilitate the process as they brainstorm ideas during workshops.

Due to the increasing emphasis on engaging students in inquiry activities that allow them to experience Chemistry as portrayed in the scientific world, the choice of appropriate content and learning activities is crucial. Standards-based curricula provide numerous opportunities for learners to engage in a variety of activities that promote an understanding of the nature of science and ability work to as scientists; using nearly the same procedures used by the scientists; but scaled down to classroom conditions.

Given that research studies reported that advanced placement courses are formulaic and predictable, there is need to have students grounded in the subject matter and not merely 'regurgitate' what they have memorized for the sake of the examinations. Teachers ought to be evaluated on the basis of their ability to enable students to demonstrate mastery of concepts as opposed to passing standardized examinations. It is amazing that student seem to be contented with the status quo as far as the curriculum for advanced placement programs is concerned.

However, research studies report that the courses are not homogenous with regard to addressing students' needs. For instance, they don't provide opportunities to challenge gifted students because they assume that all students enrolled in the courses are high-ability students. The selection criteria for enrolment into advanced placement courses is often based on the students' demonstrated academic ability and having the pre-requisite course requirements such as advanced algebra and an introductory Chemistry/Physical Science.

One of the most prominent challenges for teachers in the United States is the integration of standards-based instruction into their classroom practice in accordance the state-mandated or school district-mandated curriculum. Considering the process and purpose of developing reliable professional teaching standards provides new perspectives on their meaning and situation within a different paradigm (Delandshere, & Arens, 2001). In fact, both the content and curriculum standards were originally conceived of as frameworks for teaching; whereas the professional teaching standards were defined to provide a framework for the assessment of various teaching performances (Delandshere, & Arens, 2001). In this regard, *performance standards* are qualified as having the capacity to stand as the learning outcomes for the science curriculum. In essence they can merit as guides to the pedagogy of standards-based practices to enable teachers to embrace the standards-based instructional ‘culture’. In this way, standards can be seen as criteria to judge progress towards scientific literacy.

Teacher education, school reforms and the focus of science literacy has for a long time been directed towards the integration of inquiry-based instructional ideology into the teaching of science. Therefore, standards reflect the current thinking about how students learn; emphasizing the instructional practices that allow them to construct their own knowledge and take an active role in the learning process (Stepanek, 1997). Teacher’s understanding of the Chemistry content and standards goes a long way in facilitating this process within their classrooms and making the interpretation of what is contained in the curriculum more meaningful. With regard to strategic planning for teaching, Stepanek (1997) points out the fact that teaching strategies which go hand in hand with standards are closely tied with those of other authentic teaching methods which endorse instructional activities that involve active learning. When organized meaningfully these assessments have the capacity to stimulate intellectual development and enhance students’ grasp and comprehension of the subject matter. Standards therefore provide for opportunities to engage learners in inquiry-based experiences.

However, there is evidence to suggest that students’ performance is still dismal in terms of the National Assessment of Educational Progress (NAEP) and international assessments such as the Third International Mathematics and Science Study, TIMSS (Schmidt, 2003). According to Schmidt, (2003), there is certainly *no need* to reinvent the broad-based science standards. He argues that what is actually needed is an organizing principle to limit the number of essential topics, by subordinating some topics in the science standards to others that play more significant roles (P. 570). The idea behind this endeavor is to have a logical sequence of topics that make science intrinsically interesting to students and one that provide the basis for understanding science devoid of memorization (Schmidt, 2003).

In addition to the principle of organization, Schmidt, (2007) argues that the coherence of this vision goes beyond a thematic bundling of science topics and related learning opportunities and proposes an approach that is aimed at conceptual links among topics when sequencing and prioritizing them. None of these endeavors can be accomplished without the co-operation of individual teachers. It has been argued that teachers cannot modify their instructional practices to reflect more effective approaches to science teaching unless they can see the benefit; or else they would keep teaching science as isolated concepts and ignoring the dynamic field of science (Johnson, 2007).

The responsibility of individuals and institutions to achieve the new vision of science education portrayed in the standards is central in institutions that offer public education, with the responsibility for improving science literacy (NRC, 1996, p. 12). Although most policy decisions are generally made at the state (but sometimes at the local) level with regard to the content of the school science curriculum, the characteristics of the science program, the nature of science teaching, and assessment practices; these policies must be consistent with the vision of science education described in the standards (p. 12). The most crucial undertaking however, is being able to give learners the opportunity to learn and experience science in ways that are challenging; both intellectually and in terms of developing important scientific skills and understandings to be economically productive and make informed decisions. Standards-based practices have the capacity to cultivate more responsibility and collegial collaboration in these endeavors; to promote a community of practice and science learning.

The *National Science Education Standards* are designed to guide science education towards achieving a scientifically literate society. Standards are founded in exemplary practice and research; and therefore describe that vision and present criteria for science education that will allow that vision to become reality (NRC, 1996, p. 11). A standards-based curriculum offers the promise of nurturing that vision to maturity. Science education standards provide criteria to judge progress toward a national vision of learning and teaching science especially in a system that promotes excellence, providing a banner around which reformers can rally (p. 12)

National standards present criteria by which judgments can be made by state and local school personnel and communities, helping them to decide which curriculum, staff development activity, or assessment program is appropriate. However, a coherent curriculum must ensure that ideas presented therein build on each other. National standards encourage policies that will bring coordination, consistency, and coherence to the improvement of science education and help to chart the course into the future. By building on the best of current practice, they aim to take us beyond the constraints of present structures of schooling toward a shared vision of excellence (NRC, 1996, p. 12). The curriculum should essentially cultivate this awareness in the learners.

Assessment of students must convey a clear message about what are the most valuable scientific meanings in the science curriculum and tell more about both the students' achievement of instructional objectives and teachers' classroom performance. One of the most fundamental principles of the Project 2061 was that schools should *not* be compelled to teach more *content*, but rather be allowed to focus on aspects of the curriculum that are essential for science literacy and devise strategies to organize their instruction more effectively (AAAS, 1993). These aspects point to the planning aspect of the curriculum. In fact, AP Chemistry needs to actively promote greater emphasis on inquiry, hands-on practical work and experimentation. Indeed, the utilitarian role of education and the process of curriculum development must take into consideration not only the needs of the learner but also the nature of knowledge and the needs of the society.

Although teachers and science educators are allowed to participate in reform efforts, their participation is often mediated by prescribed guidelines rather than one of open participation and principled deliberations (Delandshere & Arens, 2001, p. 556). However, the standards-based curriculum developmental model is very different from the most prevalent traditional 'centre-periphery' model of curriculum innovation (Bennett & Holman, 2002); which in the crudest form, requires decisions to be taken by a group of centrally-based policy makers and implemented by teachers (p. 179). Standards-based practices therefore contrast the 'center-periphery' approach by involving teachers in almost all stages of curriculum innovation, ranging from continued decision-making over content and the structure of science courses and eventual implementation.

Other factors that must be considered particularly in instructional planning include nature of learners, their prior knowledge, the available institutional resource and time allocation. It is now apparent that curriculum is not an end in itself. Given that many research studies have tried to justify high school *Grade Point Average* (GPA) and *SAT Reasoning Test scores* (standardized tests for college admissions in the United States) as indicators of students' success in four-year post-secondary institutions, is easy to conclude that student achievement is the product of the curriculum. Learning science in an integrated fashion lends itself to deeper understanding and hence the fundamental theme in the *National Science Education Standards* is discipline-specific inquiry. The science content remains an important companion of inquiry in the *National Science Education Standards*; and hence the greatest emphasis in policy is the need to have a curriculum that supports standards and includes a variety of instructional experiences activities that promote inquiry and collegial responsibility.

There is need for science teachers and curriculum developers to make science teaching and scientific investigations more meaningful to learners. Teaching science as portrayed in the standards requires teachers to have theoretical and practical knowledge and skills about science teaching and learning (NRC, 1996, p. 28). Even though the content standards in the *NSES* do not prescribe a curriculum, they are a complete set of outcomes for students (NRC, 1996, p. 103).

Like many other approaches to classroom instruction, standards-based instruction has had some criticism with regard to the mode of organization and delivery. According to Delandshere & Arens, (2001) teaching competencies are assumed to have great impact on student learning as defined and assessed through enacted performances. They argue that standards reflect a view of teaching that is not justified by logic; and if they are state-mandated to assess current forms of scientific understanding about teaching, they would reinforce teaching in a defined approach and effectively prevent teachers, schools and science educators from serving as a catalyst for reforms (Delandshere & Arens, 2001p. 556). Given that Chemistry is a practical subject some of the most prominent culprit practices include: over-using of teacher demonstrations, allocation of too much time on pre-class preparation for laboratories, and class project assignments that are of little or no significance.

The main goal of standards-based and systemic reform is high academic achievement for all students (Lee, & Paik, 2000). However, one of the greatest challenges in science teaching is the development of a curriculum for chemical and scientific literacy that meets the needs of all students (Bennett & Holman, 2002). It is argued that a curriculum for scientific literacy represent the logical system for science teaching requires rigorous and fundamentally newer approaches that exclude anything that does not meet the selection criteria (p. 182).

The impact of reforms in science teaching always appear to be most obvious when individual teacher educators engage in talks about the way they evaluated their students and the criteria that they use or don't use (Delandshere & Arens, 2001). However, when reforms are envisaged through the lens of standards that focus on competence, the strength of standards-based practices begins to become more apparent. However, teachers will always have divergent opinions with regard to the approaches used in structuring and organizing classroom instruction.

Meshing Content Standards and Curriculum

The current reform emphasized that a small number of key ideas should be presented in greater depth in view of the principle of "less is more" (Lee, & Paik, 2000). Given that there are 855 benchmarks in the Project 2061 (AAAS, 1993) and 77 sections of learning goals in the *National Science Education Standards* (NRC, 1996) spread across 13 grades, the decision about the scope and priorities of science teaching poses a daunting challenge for most science teachers (Lee, & Paik, 2000). Standards-based practice is conceived in the context of science content and process, and the components that transcend the components of the science content itself.

In the previous section Schmidt, (2007), belabored the principle of organization in the content areas and argued that the coherence of this vision goes beyond a thematic bundling of science topics and related learning opportunities. He advocates and proposes an approach that is aimed at conceptual links among topics when sequencing and prioritizing them. In fact, it was argued that a coherent curriculum is that in which ideas build on each other. However, there has is concern about an overloaded curriculum especially in AP courses; where depth of coverage is often sacrificed for breadth of content. This means that students are not well grounded in the material that they learn, and end up having a very shaky foundation in scientific knowledge and may not get another opportunity to engage deeper once they get college credits in these courses.

According to Bybee, (1998) the elements in the content standards provide meaning to the science curriculum. On the other hand, the teaching and assessment standards facilitate the actual realization of scientific meaning in the science classroom. More often than not, *content* is seen exclusively as discipline-based subject matter while other potential ‘content’ that may also be relevant in building a strong understanding of basic principles and scientific concepts in learning is often dismissed as “fluff” implying that it is content-free.

The aims of high school Chemistry in all the three courses are almost complementary. From data, each of the courses serves main purposes for a general Chemistry course at the high school level. These include: Meeting the high school requirements for science, providing a foundation for post-secondary science, provide grade for course credit (or possible college credits), aligning content with equivalent content in introductory post-secondary curriculum, assessing students using equivalent post-secondary rubrics and imparting scientific knowledge and skills in addition to promoting environmental awareness.

There is great emphasis on inquiry methods in Chemistry. In fact, the IB diploma and AP programs advocate activities that enable students to engage in critical thinking, analyze, evaluate, synthesize and communicate ideas. The IB diploma specifically prepares students to have a sense of cultural identity and possess intercultural skills to confront, investigate and attempt to resolve global issues. Some of the ideas emphasized in the IB and AP programs align well with the main emphases in inquiry; a key ingredient in standards-based practices.

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their investigations. The activities that students engage in mimic the ways of scientists and enable then to develop knowledge and an understanding of scientific ideas, and understanding how scientists study the natural world.

The main activities in scientific inquiry is a multifaceted activity making observations; posing questions; examining books and materials for known facts; planning the investigations; reviewing facts in light of experimental evidence; using tools to collect, analyze, and interpret data; report the findings, provide explanations and predictions; and communicating the results. Students are expected to identify the assumptions, and use critical and logical thinking to propose alternative explanations. These same principles are articulated in the *National Science Education Standards*, the *Georgia Performance Standards*; and implicitly in the content areas in the Chemistry courses which require scientific procedures.

However, even though the *standards* emphasize inquiry, this does not imply that they recommend a single approach to science teaching. Teachers should use different strategies to enable students develop knowledge, understandings, and abilities as described in the content s*tandards*. In fact inquiry should essentially emanate from students' activities that foster discourse, investigative collaboration and shared responsibility.

Findings from the study show that the content standards are stated in terms of the content to be understood or certain abilities are to be developed as a result of activities provided for all students in respective grade levels (NRC, 1996, p. 6); in reference to broad areas of content or the nature of scientific knowledge. In the analysis of the content standards and the corresponding content areas in the Chemistry courses, it was apparent that there is a significant overlap in terms of emphases and objectives. Although the topics in the AP Chemistry course tend to mimic the content areas that students expect to encounter in introductory college level Chemistry courses, they did not represent a significant departure from those listed in College Preparatory Chemistry course and the IB Chemistry (Table 5, Appendix C). Some content areas may not be apparent in the listing of the topics, but some of them are covered as sub-topics under a broad theme.

Situating Advanced Placement Initiatives

The main science courses for high schools in the United States have traditionally been structured and organized to follow the order: Biology–Chemistry–Physics; for the 9th, the 10th and the 11th grades respectively. It means that most students do not get to learn Chemistry until their second year of high school. Hence this potentially puts a heavier cognitive load on students who must recall key concepts learned in their middle school science courses. AP Chemistry courses are usually designed to be taken by students after completion of the first course in high school Chemistry and the Advanced Algebra mathematics course (College Board, 2008). One may in fact, challenge the assumption that Advanced Placement courses are too far above the other high school courses in the sense that they are essentially college-level courses and advocate or justify the need for Honors courses as an alternative in the event that some of the students cannot ‘leap’ that high to take an Advanced Placement course.

Advanced Placement (AP) courses and the International Baccalaureate (IB) courses have gained emphasis as important factors in college admissions. Although student performance on AP examinations is strongly related to college performance, simply taking the AP courses is not a valid indicator of the likelihood that students will excel college (Geiser, & Santelices, 2004).

One of the challenges in using AP course grades for college admission decisions is that students do not take AP courses until their junior year or senior year of high school. Therefore, their scores on the end-of-course AP examinations in some cases are not availed until after the admissions process is completed (Geiser, & Santelices, 2004). Often time teachers and parents encourage students to take the advanced courses (for high achieving students who need to be challenged more) by engaging them in stimulating, exciting and thought-provoking activities to avoid boredom. In fact, it would therefore be counter-productive to have them stuck in courses that are less challenging. The Advanced Placement Chemistry course offered at grade 11-12 establishes its foundation of major chemical concepts and themes that were presented during students' first encounter with introductory high school Chemistry or *Physical Science*.

The main goal of Advanced Placement Chemistry and the International Baccalaureate program is to enable students to develop a conceptual framework for modern Chemistry and appreciate of science as a process. The International Baccalaureate Chemistry curriculum provides a brief description of Chemistry that could capture anyone's imagination:

> Chemistry is an experimental science that combines academic study with acquisition of practical and investigational skills. It is often called the central science because chemical principles underpin both physical environments and biological systems (Appendix C).

In the context of standards-based instruction, not only does this inform about practical the aspects of chemical concepts but also provides new perspectives for both students and teachers and a leeway for investigative research that looks at their practices through the framework of self–reflection. The understanding of the curriculum ultimately transforms teachers' conceptions about curriculum and instruction in Chemistry and has the potential of transforming their understanding of standards-based instructional approaches.

Due to the rapid expansion of the AP program in recent years, schools are continually under intense pressure from state education agencies and parents to increase the number of AP courses offered. This effectively constrains the school budget because school administrators are compelled to act within existing budgetary allocation. Rural schools with low income are especially vulnerable as compared to larger suburban high schools. In fact teachers in large suburban schools often specialize in a particular subject area as compared to those in rural schools; who specialize in teaching multiple subjects at all academic levels. Although the

College Board recommends that AP teachers should have at least an advanced degree in the subject area and considerable teaching experience, local school administrators are completely autonomous when making decisions about who gets to teach AP courses.

According to Hofstein, et al., (2000), substantial knowledge of the pedagogy of science teaching is required because Chemistry should be viewed as an inquiry-based discipline, giving rise to new knowledge and insights. In fact, they argue that for teachers to make Chemistry more relevant to students' lives and to the society in which they live and operate, it should be taught as an applied science that has major economic and technological importance. This is underscored by the fundamental goals for high school Chemistry courses outlined earlier. The cartoon below (Figure 7) actually captures very important aspects of the secondary school curriculum that are often ignored in when talking about the rigors of different courses in the Chemistry curriculum.

Figure 7. AP Cartoon from the Washington Post, June 14, 2007, p. T08.
(By Julie Zhu -- Montgomery Blair High School)

In the cartoon, Advanced Placement courses are portrayed as relatively manageable to some students while the regular (College Prep?) courses is portrayed as being relatively less challenging and potentially more boring to gifted students. However, the Honors course's apparent ‘lack of rigor’ in terms of content, the learning activities and assessment may only be apparent in comparison with the Advanced Placement course and the International Baccalaureate program. With more students taking keen interest in the Advanced Placement courses at the 10th grade and 11th grade, and the continued student enrollment in AP programs coupled with good grades one can justifiably say “AP” is not just for seniors any more. This implies that in the long run the AP Chemistry curriculum might be able to accommodate students at all grade levels.

The high school Chemistry curriculum for advanced placement programs and other Chemistry courses may have significant curriculum domains as pre-requisites that are not limited to Advanced Algebra and the introductory high school Chemistry course. The major concern however, is the fact that students in the 9th and 10th grades may not be quite ready for Advanced Placement courses if they have insufficient knowledge lack a solid foundation and in the pre-requisite courses. However, it does not preclude the fact that many students have successfully attempted Advanced Placement courses at lower grades in high school, and yet they were not necessarily gifted or geniuses.

In the last two grades of high school when students are more likely to consider taking advanced level courses, the decision to Advanced Placement or regular courses is often a difficult one. This puts students in the position of choosing an AP course with the hope that they would excel and attain good grades to receive college credits, unlike students who take regular Chemistry courses. The AP and IB Chemistry courses offered at grade 11-12 establish their foundation upon the major chemical concepts and themes that are usually presented during the first year of Chemistry. The main goal of AP Chemistry is to help students develop a conceptual framework for modern Chemistry and appreciate of science as a process. Within the context of standards-based instruction, not only does the framework inform about practical aspects of the chemical concepts, but also provides new perspectives for students and teachers and a leeway for investigative research that takes a closer look at their practices in the context of self–reflection. An understanding of the Chemistry curriculum may ultimately transform teachers' beliefs about instruction in Chemistry and in turn transform their understanding of inquiry and the standards-based instructional approaches.

The International Baccalaureate program; like any other international education program subscribes to international statutes governing the education program. For instance, the UNESCO declaration of 1996 reaffirmed the aims of *international education* (UNESCO, 1996, p. 9, as cited in Hill, 2006). The aims of international education are to develop: (1)a sense of universal values for a culture of peace, (2) the ability to value freedom and the civic responsibility that goes with it, (3) intercultural understanding which encourages the convergence of ideas and solutions to strengthen peace, (4) skills of non-violent conflict resolution, (5) skills for making informed choices, (6) respect for cultural heritage and protection of the environment, and (7) feelings of solidarity and equity at the national and international levels.

These are clearly different from the academic goals that the course sets out for students enrolled in the IB program. The *goals* of international education appear to be complementary to the *elements* of international education. Hill, (2006) enlisted the elements: (a) understanding cultural identities across national borders, (b) knowledge about global issues and the interdependence of nations, (c) critical thinking skills applied to trans-national issues and world cultures, and (4) appreciation of the human condition around the world. With regard to the element of sound judgment and critical thought, Hill, (2006), points out that critical analysis engages students in reflection on the interpretative nature of knowledge (p. 100) and makes them aware of the validity and limitations of their own points of view.

The Chemistry Curriculum

The science curriculum, in general, and that of high school Chemistry in particular is designed with the students in mind; a justification of the fact that students have wide-ranging interests and capabilities that need to be nurtured. It provides students with an understanding of the utilitarian role that science plays in their lives. In order for curriculum to drive instruction, it must have the capacity to support and assess both teachers and students with the aim of improving student achievement. Although *performance standards* provide clear guidelines on how to assess students, how to organize instruction, and goes a step further to provide samples of appropriate student work, a clear framework for defining the content organization proficiency level for achievement of the standards is needed to enable teachers to rate their output critical consideration in the curriculum implementation process.

Some topics have greater impact on students' success in college Chemistry than others. For instance, the Mole and Stoichiometry are the foundation of Chemistry. Results from a study that explored the connection between success in introductory college Chemistry and high school Chemistry content revealed that students who placed more emphasis on Stoichiometry at high school level scored significantly higher points than their peers who dedicated less time to the topic (Tai, Ward, & Sadler, 2006).There is need therefore to put more emphasis on topics that give students a leap in introductory college Chemistry and assure their success. High school Chemistry teachers should familiarize with the requirements for college Chemistry in order to determine which content areas will get more priority and emphasis.

Studies have shown that teachers' understanding and conceptions about curriculum and the nature of science do not directly influence their classroom practices (Lederman, 1999). Their intentions and perceptions of students on the other hand often determine their teaching strategies.

However, with standards-based instruction such a conclusion is not obvious. Even though the knowledge of what the curriculum prescribes and mastery of content are critical to science instruction, research studies have also found that that the experience in teaching, often intercede the relationship between what teachers believe and what they actually do in their classroom practices (Lederman, 1999).

Content knowledge of the subject matter and familiarity with the curriculum alone are not sufficient to equip teachers with what they need fulfill their role (Hofstein, et al, 2000). Teachers also need to come to the realization that learners come from diverse social backgrounds and have different intellectual abilities therefore they should adopt the correct use of appropriate teaching strategies suited for science teaching and learning. Effective professional development for teachers should focus on the improvement of teachers' pedagogical knowledge and leadership skills that should enable them to make changes in the curriculum, instructional approaches, and the way they assess their high school chemistry students (Hofstein, Carmeli & Shore, 2000).

Science reforms emphasize achievement of excellence through systematic school reforms. According to Wiggins & McTighe, (1998), the "Backward Design" is a strategy that turns most unit-planning on its head; by emphasizing fundamental ideas that affect the way students view their world. They reported that this design has several advantages which include:

- Students are less likely to be deeply immersed in factual details of a unit plan until they miss the gist of the topic.
- Instruction focuses on global understandings and not on daily events. Lessons are constructed with a clear vision of what the overall "gain" from the unit is to be

Assessment is designed before lesson planning, so that instruction drives students toward the essence of what they need to know. This model brings to the fore the fact that science educators have tended to follow the prescribed curriculum without putting themselves in a position where they set out their achievement targets by starting off with the desirable level of achievement and then strategizing to achieve it.

For instance, the *National Science Education Standards* provides the criteria for selecting science content areas. First is obligation to the domain of science. The basis for the argument is that the subject matter in the standards is central to science education and must therefore be accurate and be able to accommodate the needs of learners and those who will implement the standards. Second is the appropriate representation of students' developmental and learning abilities. An organizing principle is selected to express meaningful links that direct students' classroom observations especially those involving abstract and conceptual understandings. Lastly is the obligation to provide enough depth of content to direct the design of science curricula.

Schmidt, (2003) suggests that one of the most important ingredients missing in the science curriculum reforms effort is an organizing principle that would limit the number of essential topics and only prioritize those that play larger role in accordance with the organizing principle. Specific learning opportunities should therefore be aligned with specific content outlined in the *standards*. To ensure coherence in the curriculum content standards must convey a sequence of topics and performances which reflect a logical, sequential and hierarchical order of the curriculum content (Schmidt, 2003). He does not, however, suggest an arbitrary succession of topics across grades but rather logical organization of topics rather than an outline of what is contained in the text books.

On a broader scale, the incorporation of content standards into curriculum materials may require one to pay attention to the teaching (process) standards, assessment standards and their implications to professional development and school reform. Bybee (1998) argues that exemplars in standards-based practices are needed in order to bring standards to life, to demonstrate their use and provide a basis for understanding and discourse (p. 153). There is need to understand the curriculum developers' intentions as conveyed by the elements in the materials related to science teaching and assessment procedures; which are critical considerations for the interpretation of standards and creation of science curriculum materials.

The vision of science education that is expressed by the standards accommodates one of the main purposes of science education: to promote scientific literacy. Research seems to concur that the concept of scientific literacy plays a key role in recent science education reform efforts (AAAS, 1989; NRC, 1996). In this regard, the contemporary science curriculum is essentially supposed to fuel that same vision of scientific literacy and bring it into reality because educators have a general consensus that scientific literacy should be an important culminating outcome of schooling (Bybee, 1998).

The quality of the instructional material is directly related to student achievement. Hence the selection criteria should be based on materials that will result in student understanding of concepts emphasized in the standards (Krueger, & Sutton, 2001). Given that many teachers base their lesson plans on the instructional materials, the science content in the materials should match the curriculum standards. The materials should allow students to learn science as inquiry and provide suggestions for scientific investigations. Materials should emphasize the connection between and among curriculum ideas. Teachers must therefore integrate student assessment into the instructional programs using relevant learning activities.

An important approach can be adopted is to link the content with appropriate learning opportunities that align well within each topic and source the curriculum materials that would be instrumental in supporting their implementation. This would therefore serve as a template for future organization of content and curriculum development. The learning and instructional tasks to be considered for inclusion would be those that are not only challenging to students, but also stimulate intellectual growth and development of appropriate scientific skills. However this should not sacrifice the emphasis on sound scientific principles by reducing them into mere chronological topical themes as opposed to an organized scientific progression that builds on science content and appropriate skills from the preceding topics.

It is difficult to separate the structure and meaning of standards from the content because language of the standards tends to be committed to the instructional learning process. However, the type of learning and instructional strategies that seem to be emphasized are assumed to occur as a result of teachers being immersed in a particular representation of teaching that is advocated in the standards-based movement. However this is not always the case because teachers often use their best judgment to manipulate the conditions in their classrooms depending on circumstances of the moment. Similarly the conception of inquiry reflected in the standards is relatively narrow and seems to be equated with aspects of self-reflection.

Educational reform therefore, needs more than an understanding of the classroom environment and the proposed learning outcomes. Carrington (1999) points out that a close understanding of the cultural, social, institutional setting and teachers' beliefs and values of teachers can help them to deal with a diverse range of students in the school community (p. 259). There is need therefore, for science educators to bridge the gap between research and practice by reaching out to practicing teachers with more focused research agenda aimed at providing substantial clues that can transform science teaching (Johnson, 2007)

According to Guskey (1986; cited in Ertmer, 2005), a change in beliefs does not precede practice. Instead it follows practice and therefore he argues that by helping teachers adopt new practices which are pedagogically successful the beliefs and conceptions associated with the experience will also change. It is difficult to distinguish teachers' philosophy and their beliefs about teaching. Researchers have argued that belief systems, unlike knowledge, do not require group consensus and may therefore be quite personal. This may explain why two teachers who know the same things about say, inquiry, might believe different things about it. Therefore personal philosophies about teaching do not have to be universal and consistent with each other.

Standards-based movements make it difficult for science teachers to embrace alternative perspectives on teaching outside of the framework provided implicitly by the standards. It is evident that teachers' conceptions of teaching and personal philosophies are dynamic and do not always align with what is implied and expected in both the teacher education programs and the standards-based reforms. Therefore reform documents and policy on classroom practice should incorporate teachers' personal beliefs and epistemologies based on actual classroom experiences in the context of a reform-oriented standards-based movement. Standards should provide for a meaningful assessment system for a student that is more responsive to the changes in the curriculum. The *content* standards must provide a vision of what is expected relative to the curriculum requirements and align with the *process* standards and assessments to articulate the principles of instruction and learning, and be clearly understandable to teachers, students and other stake-holders. Conceptions of curriculum frameworks act as the bridge between standards and the curriculum to provide direction on the basis of which schools and districts can construct a curriculum that addresses all their students' needs contains and standards that apply to all students, regardless of their experiential backgrounds, individual differences and abilities.

The limitations and drawbacks of this study may be arise because it is based solely on information gathered from reform documents, policy proposals and subject syllabi and research articles as opposed to other research methods that take into account first hand methods of gathering data from primary sources. However, since I adopted a broad stance and explored a wide variety of documents that were gathered using the theoretical sampling approach of the qualitative document analysis method, I believe that aspect increased the dependability of the study; by presenting a wide perspective of conceptions of curriculum and standards-based practices, and salient aspects of the Chemistry curriculum, and the extent of the organizational structure of the content, the general objectives of the courses and the potential learning outcomes.

Implications for Practice

The implications for science teaching, school reforms and curriculum planning gleaned from this study are variable. At the heart of reforms in curriculum development is the science teacher whose responsibility is to implement the state-mandated curriculum. Conceptions of standards-based practices and an examination of contexts in which they arise can be very useful. Teachers' beliefs about content knowledge, science teaching, and strategic planning for teaching often have a great influence on their science classroom practices. Hence, detailed guides for implementing standards-based practices needs to be made available to practicing teachers.

Future research should explore teachers' conceptions of the science curriculum and standards-based practices. Therefore, there is need for curriculum developers to recognize the importance of sound teaching and assessment procedures and consciously make the decisions to include them in planning; in order for the curriculum to be more effective. This study has addressed these concerns and provided a clear distinction between them. In spite of this, teachers may still rely on textbooks rather than attempt to interpret the content and teaching standards that they are supposed to cover. I believe a science curriculum which proposes instructional designs that outline end goals and learning contexts as the focal points of the learning process can be more accommodating This would lead students to understand the underlying chemical concepts and skills; because it would place the learner at the center of the learning process and allow him/her to take ownership of the process. The curriculum must therefore provide a guide of what to teach and provide many different views and strategies for implementation.

There is need to have a unified standards-based high school Chemistry curriculum that brings on board all the desirable attributes. In any case, all learning is for the good of students; and ensuring a scientifically literate nation. However, teachers also need some level of autonomy with regard to responsibility and decisions about teaching and learning. There is need for teachers to embrace the challenges of teaching science in a manner that is consistent with the content and performance standards; and ebb away from direct teaching (lecture); and approach science teaching through inquiry. Teachers should recognize the curriculum and standards as guiding principles for facilitating student-directed inquiry and problem-based learning.

Due to the fact that standards provide criteria that people at the local, state, and national levels can use to judge whether particular actions serve the vision of a scientifically literate society (NRC, 1996); standards-based instruction should work towards the goal of responding to individual students interests. It has been argued that standards bring coordination, consistency, and coherence to improve science education. Therefore teachers need to move away from primary emphases of focusing on student acquisition of discrete packets of information and focus on instructional methods that approach investigative science and supports inquiry.

There is need to develop thoughtful assessment practices that situate the teacher as a collaborator and colleague in knowledge-building with students rather than having students as passive recipients of knowledge. In essence, collaboration is a critical component in scientific inquiry. Finally there is need to build a community of practice by sharing experiences and brainstorming ideas for best practice in professional development workshops, instead of working in isolation. Resistance to reforms is something that cannot be overcome overnight. Standards were formulated to provide a standardizing principle for science education. Effectively integrating the science curriculum for all students has the potential of offering them opportunities to experience increased achievement. Future research should also address the foundations of curriculum implementation such as the manner in which knowledge is transmitted; whether theoretical or practical and whether the knowledge is empirical or rational; and the contexts in which such knowledge is passed, in addition to personal meaning and relevance that the learners attach to new knowledge. Future research should also focus on exploring teachers' actual classroom practices in school settings where they are currently implementing the curriculum. Comparative analyses of their practices and teaching strategies can reveal vital information regarding the curriculum implementation process in science teaching.

Conclusions

This study explored the conceptions of curriculum and standards based practices as they are articulated in policy documents and curriculum reform initiatives; and looked at important aspects of curriculum planning by taking a closer look at the content, teaching, assessment and professional development standards and the corresponding content areas advanced placement courses and the *National Science Education Standards* and the *Georgia Performance Standards*; and *Benchmarks for Science Literacy*. To situate these endeavors the study critically analyzed the structure, purpose and goals of the high school the Chemistry curriculum in Advanced Placement Chemistry, the International Baccalaureate Diploma program and College Preparatory Chemistry. The qualitative document analysis research methodology was deemed appropriate in gathering data from policy documents, Among the challenges for most states regarding curriculum implementation is a response to recent requirements is the creation of academic content standards from state mandates that serve local purposes (Rabinowitz, Roeber, Schroeder, & Sheinker, 2006). This implies that the creation of standards that provide for meaningful student assessment systems that are responsive to the changes in the curriculum need priority treatment. In order to garner teachers' support for different curriculum emphases, a new curriculum should have a relatively flexible organization (van Driel, 2005); to allow teachers to make subtle adjustments that suits their teaching styles. It has been argued that for the science curriculum to be coherent, the content standards must be articulated as a series of topics and performances that reflect a logical, hierarchical or sequential nature of content from which the subject matter derives (Schmidt, 2003). He points out that the content standards should provide a vision of what is expected in relation to the curriculum requirements, be aligned with process standards and assessment standards that articulate the principles of sound instruction and learning that can best reflect in, or direct classroom practices. An equitable science program provides high quality science education to all students (Krueger, & Sutton, 2001). The science curriculum should significantly allows all learners to experience a reasoned nature of science; giving priority to evidence and considering alternative views to propose, evaluate (justify or refute) claims and build reasonable scientific explanations.

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APPENDIX - A

CHEMISTRY GEORGIA PERFORMANCE STANDARDS

Revised July 13, 2006

Chemistry Curriculum

The Georgia Performance Standards are designed to provide students with the knowledge and skills for proficiency in science. The Project 2061's *Benchmarks for Science Literacy* is used as the core of the curriculum to determine appropriate content and process skills for students. The GPS is also aligned to the National Research Council's *National Science Education Standards*. Technology is infused into the curriculum. The relationship between science, our environment, and our everyday world is crucial to each student's success and should be emphasized.

The performance standards should drive instruction. Hands-on, student-centered, and inquiry-based approaches should be the emphases of instruction. This curriculum is intended as a required curriculum that would show proficiency in science, and instruction should extend beyond the curriculum to meet the student needs.
The hands-on nature of the science curriculum standards increases the need for teachers to use appropriate precautions in the laboratory and field. It is recommended that micro-chemistry techniques be used where appropriate. The guidelines for the safe use, storage, and disposal of chemicals must be observed. Safety of the student should always be foremost in science instruction.

Science consists of a way of thinking and investigating, and includes a growing body of knowledge about the natural world. To become literate in science, therefore, students need to acquire understandings of both the **Characteristics of Science** and its **Content**. The Georgia Performance Standards for Science require that instruction be organized so that these are treated together. Therefore, **A CONTENT STANDARD IS NOT MET UNLESS APPLICABLE CHARACTERISTICS OF SCIENCE ARE ALSO ADDRESSED AT THE SAME TIME.** For this reason they are presented as co-requisites.
This Performance Standards include four major components. They are:

The Standards for Georgia Science Courses. The Characteristics of Science co-requisite standards are listed first, followed by the Content co-requisite standards. Each Standard is followed by benchmarks that indicate the specific learning goals associated with it.

Tasks that students should be able to perform during or by the end of the course. These tasks are keyed to the relevant Standards. Some of these can serve as activities that will help students achieve the learning goals of the Standard while others can be used to assess student learning. Many of these tasks can serve both purposes.

Samples of student work. As a way of indicating what it takes to meet a Standard, examples of successful student work are provided. Many of these illustrate how student work can bridge the Content and Characteristics of Science Standards. The Georgia DOE Standards web site will continue to add samples as they are identified, and teachers are encouraged to submit examples from their own classroom experiences.

Teacher commentary. Teacher commentary is meant to open the pathways of communication between students and the classroom teacher. Showing students why they did or did not meet a standard enables them to take ownership of their own learning.

Georgia Performance Science Standards-- Explanation of Coding

Characteristics of Science Standards
SKCS1
Science **K**indergarten **C**haracteristics of **S**cience Standard #**1**
S8CS2
Science Grade **8 C**haracteristics of **S**cience Standard #**2**
SCSh8
Science **C**haracteristics of **S**cience **h**igh school Standard #**8**
Content Standards
S5P3
Science Grade **5 P**hysical Science Standard #**3**
S4E2
Science Grade **4 E**arth Science Standard #**2**
S7L4
Science Grade **7 L**ife Science Standard #**4**
SC1
Science **C**hemistry Standard #**1**
SB4
Science **B**iology Standard #**4**
SPS6
Science **P**hysical **S**cience Standard #**6**
SP3
Science **P**hysics Standard #**3**

Chemistry

The Chemistry curriculum is designed to continue student investigations of the physical sciences that began in grades K-8 and provide students the necessary skills to be proficient in chemistry. This curriculum includes more abstract concepts such as the structure of atoms, structure and properties of matter, and the conservation and interaction of energy and matter. Students investigate chemistry concepts through experience in laboratories and field work using the processes of inquiry.

Major Concepts/Skills	**Concepts/Skills to Maintain**
Classifications of Matter	Characteristics of Science
Atomic Theory/Configuration	Records investigations clearly and accurately
Periodicity	Uses scientific tools
Bonding/Nomenclature	Interprets graphs, tables, and charts
Chemical Reactions	Writes clearly
Law of Conservation of Matter	Uses proper units
Empirical/Molecular Formulas	Organizes data into graphs, tables, and charts
Stoichiometry	Uses models
Kinetic Molecular Theory/Phase Changes	Asks quality questions
Gas Laws	Uses technology
Solutions/Concentrations	Uses safety techniques
Acid/Base Chemistry	Analyzes scientific data via calculations and inferences
	Recognizes the importance of explaining data with precision and accuracy

Co-Requisite – Characteristics of Science

Habits of Mind

SCSh1. Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science.

a. Exhibit the above traits in their own scientific activities.
b. Recognize that different explanations often can be given for the same evidence.
c. Explain that further understanding of scientific problems relies on the design and execution of new experiments which may reinforce or weaken opposing explanations.

SCSh2. Students will use standard safety practices for all classroom laboratory and field investigations.

a. Follow correct procedures for use of scientific apparatus.
b. Demonstrate appropriate techniques in all laboratory situations.
c. Follow correct protocol for identifying and reporting safety problems and violations.

SCSh3. Students will identify and investigate problems scientifically.

a. Suggest reasonable hypotheses for identified problems.
b. Develop procedures for solving scientific problems.
c. Collect, organize and record appropriate data.

d. Graphically compare and analyze data points and/or summary statistics.
e. Develop reasonable conclusions based on data collected.
f. Evaluate whether conclusions are reasonable by reviewing the process and checking against other available information.

SCSh4. Students will use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.

a. Develop and use systematic procedures for recording and organizing information.
b. Use technology to produce tables and graphs.
c. Use technology to develop, test, and revise experimental or mathematical models.

SCSh5. Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations.

a. Trace the source on any large disparity between estimated and calculated answers to problems.
b. Consider possible effects of measurement errors on calculations.
c. Recognize the relationship between accuracy and precision.
d. Express appropriate numbers of significant figures for calculated data, using scientific notation where appropriate.
e. Solve scientific problems by substituting quantitative values, using dimensional analysis and/or simple algebraic formulas as appropriate.

SCSh6. Students will communicate scientific investigations and information clearly.

a. Write clear, coherent laboratory reports related to scientific investigations.
b. Write clear, coherent accounts of current scientific issues, including possible alternative interpretations of the data
c. Use data as evidence to support scientific arguments and claims in written or oral presentations.
d. Participate in group discussions of scientific investigation and current scientific issues.

The Nature of Science

SCSh7. Students will analyze how scientific knowledge is developed.

Students recognize that:

a. The universe is a vast single system in which the basic principles are the same everywhere.
b. Universal principles are discovered through observation and experimental verification.
c. From time to time, major shifts occur in the scientific view of how the world works. More often, however, the changes that take place in the body of scientific knowledge are small modifications of prior knowledge. Major shifts in scientific views typically occur after the observation of a new phenomenon or an insightful interpretation of existing data by an individual or research group.
d. Hypotheses often cause scientists to develop new experiments that produce additional data.
e. Testing, revising, and occasionally rejecting new and old theories never ends.

SCSh8. Students will understand important features of the process of scientific inquiry.

Students will apply the following to inquiry learning practices:

a. Scientific investigators control the conditions of their experiments in order to produce valuable data.

b. Scientific researchers are expected to critically assess the quality of data including possible sources of bias in their investigations' hypotheses, observations, data analyses, and interpretations.

c. Scientists use practices such as peer review and publication to reinforce the integrity of scientific activity and reporting.

d. The merit of a new theory is judged by how well scientific data are explained by the new theory.

e. The ultimate goal of science is to develop an understanding of the natural universe which is free of biases.

f. Science disciplines and traditions differ from one another in what is studied, techniques used, and outcomes sought.

Reading Standard Comment

After the elementary years, students are seriously engaged in reading for learning. This process sweeps across all disciplinary domains, extending even to the area of personal learning. Students encounter a variety of informational as well as fictional texts, and they experience text in all genres and modes of discourse. In the study of various disciplines of learning (language arts, mathematics, science, social studies), students must learn through reading the communities of discourse of each of those disciplines. Each subject has its own specific vocabulary, and for students to excel in all subjects, they must learn the specific vocabulary of those subject areas *in context.*

Beginning with the middle grades years, students begin to self-select reading materials based on personal interests established through classroom learning. Students become curious about science, mathematics, history, and literature as they form contexts for those subjects related to their personal and classroom experiences. As students explore academic areas through reading, they develop favorite subjects and become confident in their verbal discourse about those subjects.

Reading across curriculum content develops both academic and personal interests in students. As students read, they develop both content and contextual vocabulary. They also build good habits for reading, researching, and learning. The Reading Across the Curriculum standard focuses on the academic and personal skills students acquire as they read in all areas of learning.

SCSh9. Students will enhance reading in all curriculum areas by:

a. Reading in All Curriculum Areas

- Read a minimum of 25 grade-level appropriate books per year from a variety of subject disciplines and participate in discussions related to curricular learning in all areas
- Read both informational and fictional texts in a variety of genres and modes of discourse
- Read technical texts related to various subject areas

b. Discussing books

- Discuss messages and themes from books in all subject areas.
- Respond to a variety of texts in multiple modes of discourse.
- Relate messages and themes from one subject area to messages and themes in another area.
- Evaluate the merit of texts in every subject discipline.
- Examine author's purpose in writing.
- Recognize the features of disciplinary texts.

c. Building vocabulary knowledge
- Demonstrate an understanding of contextual vocabulary in various subjects.
- Use content vocabulary in writing and speaking.
- Explore understanding of new words found in subject area texts.

d. Establishing context
- Explore life experiences related to subject area content.
- Discuss in both writing and speaking how certain words are subject area related.
- Determine strategies for finding content and contextual meaning for unknown words.

Co-Requisite - Content

SC1 Students will analyze the nature of matter and its classifications.

a. Relate the role of nuclear fusion in producing essentially all elements heavier than helium.
b. Identify substances based on chemical and physical properties.
c. Predict formulas for stable ionic compounds (binary and tertiary) based on balance of charges.
d. Use IUPAC nomenclature for both chemical names and formulas:
- Ionic compounds (Binary and tertiary)
- Covalent compounds (Binary and tertiary)
- Acidic compounds (Binary and tertiary)

SC2 Students will relate how the Law of Conservation of Matter is used to determine chemical composition in compounds and chemical reactions.

a. Identify and balance the following types of chemical equations:
- Synthesis
- Decomposition
- Single Replacement
- Double Replacement
- Combustion

b. Experimentally determine indicators of a chemical reaction specifically precipitation, gas evolution, water production, and changes in energy to the system.
c. Apply concepts of the mole and Avogadro's number to conceptualize and calculate
- Empirical/molecular formulas,
- Mass, moles and molecules relationships,
- Molar volumes of gases.

d. Identify and solve different types of stoichiometry problems, specifically relating mass to moles and mass to mass.
e. Demonstrate the conceptual principle of limiting reactants.
f. Explain the role of equilibrium in chemical reactions

SC3 Students will use the modern atomic theory to explain the characteristics of atoms.

a. Discriminate between the relative size, charge, and position of protons, neutrons, and electrons in the atom.
b. Use the orbital configuration of neutral atoms to explain its effect on the atom's chemical properties.
c. Explain the relationship of the proton number to the element's identity.
d. Explain the relationship of isotopes to the relative abundance of atoms of a particular element.
e. Compare and contrast types of chemical bonds (i.e. ionic, covalent).
f. Relate light emission and the movement of electrons to element identification.

SC4. Students will use the organization of the Periodic Table to predict properties of elements.

a. Use the Periodic Table to predict periodic trends including atomic radii, ionic radii, ionization energy, and electronegativity of various elements.

b. Compare and contrast trends in the chemical and physical properties of elements and their placement on the Periodic Table.

SC5. Students will understand that the rate at which a chemical reaction occurs can be affected by changing concentration, temperature, or pressure and the addition of a catalyst.

a. Demonstrate the effects of changing concentration, temperature, and pressure on chemical reactions.

b. Investigate the effects of a catalyst on chemical reactions and apply it to everyday examples.

c. Explain the role of activation energy and degree of randomness in chemical reactions.

SC6. Students will understand the effects motion of atoms and molecules in chemical and physical processes.

a. Compare and contrast atomic/molecular motion in solids, liquids, gases, and plasmas.

b. Collect data and calculate the amount of heat given off or taken in by chemical or physical processes.

c. Analyzing (both conceptually and quantitatively) flow of energy during change of state (phase).

Teacher Note: The use of Gas Laws to achieve this standard is permissible, but not mandated.

SC7. Students will characterize the properties that describe solutions and the nature of acids and bases.

a. Explain the process of dissolving in terms of solute/solvent interactions:

- Observe factors that effect the rate at which a solute dissolves in a specific solvent,
- Express concentrations as molarities,
- Prepare and properly label solutions of specified molar concentration,
- Relate molality to colligative properties.

b. Compare, contrast, and evaluate the nature of acids and bases:

- Arrhenius, Bronsted-Lowry Acid/Bases
- Strong vs. weak acids/bases in terms of percent dissociation
- Hydronium ion concentration
- pH
- Acid-Base neutralization

APPENDIX B

AP CHEMISTRY SYLLABUS

I. Structure of Matter (20%)

A. Atomic theory and atomic structure
- 1. Evidence for the atomic theory
- 2. Atomic masses; determination by chemical and physical means
- 3. Atomic number and mass number; isotopes
- 4. Electron energy levels: atomic spectra, quantum numbers, atomic orbitals
- 5. Periodic relationships including, for example, atomic radii, ionization energies, electron affinities, oxidation states

B. Chemical bonding
- 1. Binding forces
  - a. Types: ionic, covalent, metallic, hydrogen bonding, van der waals (including London dispersion forces)
  - b. Relationships to states, structure, and properties of matter
  - c. Polarity of bonds, electronegativities
- 2. Molecular models
  - a. Lewis structures
  - b. Valence bond: hybridization of orbitals, resonance, *sigma* and *pi* bonds
  - c. VSEPR
- 3. Geometry of molecules and ions, structural isomerism of simple organic molecules and coordination complexes; dipole moments of molecules; relation of properties to structure

C. Nuclear chemistry: nuclear equations, half-lives, and radioactivity; chemical Applications

II. States of Matter (20%)

A. Gases
- 1. Laws of ideal gases
  - a. Equation of state for an ideal gas
  - b. Partial pressures
- 2. Kinetic molecular theory
  - a. Interpretation of ideal gas laws on the basis of this theory
  - b. Avogadro's hypothesis and the mole concept
  - c. Dependence of kinetic energy of molecules on temperature
  - d. Deviations from ideal gas laws

B. Liquids and solids
- 1. Liquids and solids from the kinetic-molecular viewpoint
- 2. Phase diagrams of one-component systems
- 3. Changes of state, including critical points and triple points
- 4. Structure of solids; lattice energies

C. Solutions
- 1. Types of solutions and factors affecting solubility
- 2. Methods of expressing concentration (use of normalities is not tested)
- 3. Raoult's law and colligative properties (nonvolatile solutes); osmosis
- 4. Nonideal behavior (qualitative aspects)

III. Reactions (35 – 40%)

A. Reaction types

1. Acid-base reactions; concepts of Arrhenius, Brønsted-Lowry, and Lewis; coordination complexes; amphoterism
2. Precipitation reactions
3. Oxidation-reduction reactions
    a. Oxidation number
    b. The role of the electron in oxidation-reduction
    c. Electrochemistry: electrolytic and galvanic cells; Faraday's laws; standard half-cell potentials; Nernst equation; prediction of the direction of redox reactions

B. Stoichiometry

1. Ionic and molecular species present in chemical systems: net ionic equations
2. Balancing of equations including those for redox reactions
3. Mass and volume relations with emphasis on the mole concept, including empirical formulas and limiting reactants

C. Equilibrium

1. Concept of dynamic equilibrium, physical and chemical; Le Chatelier's principle; equilibrium constants
2. Quantitative treatment
    a. Equilibrium constants for gaseous reactions: K_p, K_c
    b. Equilibrium constants for reactions in solution
        (1) Constants for acids and bases; pK; pH
        (2) Solubility product constants and their application to precipitation and the dissolution of slightly soluble compounds
        (3) Common ion effect; buffers; hydrolysis

D. Kinetics

1. Concept of rate of reaction
2. Use of experimental data and graphical analysis to determine reactant order, rate constants, and reaction rate laws
3. Effect of temperature change on rates
4. Energy of activation; the role of catalysts
5. The relationship between the rate-determining step and a mechanism

E. Thermodynamics

1. State functions
2. First law: change in enthalpy; heat of formation; heat of reaction; Hess's law; heats of vaporization and fusion; calorimetry
3. Second law: entropy; free energy of formation; free energy of reaction; dependence of change in free energy on enthalpy and entropy changes
4. Relationship of change in free energy to equilibrium constants and electrode potentials

IV. Descriptive Chemistry (10 –15%)

Knowledge of specific facts of chemistry is essential for an understanding of principles and concepts. These descriptive facts, including the chemistry involved in environmental and societal issues, should not be isolated from the principles being studied but should be taught throughout the course to illustrate and illuminate the principles. The following areas should be covered:

1. Chemical reactivity and products of chemical reactions
2. Relationships in the periodic table: horizontal, vertical, and diagonal with examples from alkali metals, alkaline earth metals, halogens, and the first series of transition elements
3. Introduction to organic chemistry: hydrocarbons and functional groups (structure, nomenclature, chemical properties)

V. Laboratory (5 –10%)

The differences between college chemistry and the usual secondary school chemistry course are especially evident in the laboratory work. The AP Chemistry exam includes some questions based on experiences and skills students acquire in the laboratory:

- making observations of chemical reactions and substances
- recording data
- calculating and interpreting results based on the quantitative data obtained
- communicating effectively the results of experimental work

For information on the requirements for an AP Chemistry laboratory program, the *Guide for the Recommended Laboratory Program* is included on pages 29–39 of this book. The guide describes the general requirements for an AP Chemistry laboratory program and contains a list of recommended experiments. Also included in the guide are resources that AP Chemistry teachers should find helpful in developing a successful laboratory program. Colleges have reported that some AP students, while doing well on the exam, have been at a serious disadvantage because of inadequate laboratory experience. Meaningful laboratory work is important in fulfilling the requirements of a college level course of a laboratory science and in preparing a student for sophomore-level chemistry courses in college.

Because chemistry professors at some institutions ask to see a record of the laboratory work done by an AP student before making a decision about granting credit, placement, or both, in the chemistry program, students should keep a laboratory notebook that includes reports of their laboratory work in such a fashion that the reports can be readily available.

APPENDIX C

IB CHEMISTRY CURRICULUM

SCIENCES

(General criteria for all Science Subjects)

All IB Science subjects have a course based on the following model. All Science subjects studied at Hockerill, can be taken at Higher or Standard Level. All students study the Subject Specific Core (SSC). There is much significance placed on practical work, with a **minimum** requirement of 60 hours for Higher Level (81 hours for Design Technology) and 40 for Standard Level (55 for Design Technology). This includes a ten hour interdisciplinary science project, carried out at the end of the Summer Term in Year 12.

Standard Level courses include the SSC, 2 option choices, plus coursework, representing approximately 150 teaching hours over the two years.

Higher Level courses include the above plus Additional Higher level (AHL), representing approximately 240 teaching hours over two years.

The Assessment Criteria for all Sciences subjects is similar – 76% of the marks are based on the written examinations (64% for Design Technology), and 24% on practical assessment (36% for Design Technology). The practical work is moderated internally, and sampled by the IB.

STANDARD LEVEL SPECIFICATIONS

Component	Biology, Chemistry and Physics		Design Technology		Format
	Overall Weighting %	Duration (hours)	Overall Weighting %	Duration (hours)	
Paper 1	20	¾	20	¾	30 multiple choice questions on the SSC
Paper 2	32	1¼	24	1	**Section A:** one databased question and several short-answer questions on the SSC (all compulsory). **Section B:** one extended response question on the SSC (from a choice of three).
Paper 3	24	1	20	1	Several short-answer questions in each of the two options studied (all compulsory).
Coursework	24	40	36	55	A variety of practical tasks or projects, all of which must be recorded in a portfolio for submission in March of Year 13. The work is assessed using eight different criteria

HIGHER LEVEL SPECIFICATIONS

Component	Biology, Chemistry and Physics		Design Technology		Format
	Overall Weighting %	Duration (hours)	Overall Weighting %	Duration (hours)	
Paper 1	20	1	20	1	40 multiple choice questions on SSC and AHL material
Paper 2	36	2¼	24	1¾	**Section A**: one databased question and several short-answer questions on the SSC and AHL (all compulsory). **Section B:** two extended response questions on the SSC and AHL material (from a choice of four).
Paper 3	20	1¼	20	1¼	Several short-answer questions in each of the two options studied (all compulsory).
Coursework	24	60	36	81	A variety of practical tasks or projects, all of which must be recorded in a portfolio for submission in March of Year 13. The work is assessed using eight different criteria

CHEMISTRY

Chemistry is an experimental science that combines academic study with the acquisition of practical and investigational skills. It is often called the central science as chemical principles underpin both the physical environment in which we live and all biological systems.

The course is taught in a range of 'real-life' contexts such as developing fuels or what is in a medicine. Practical work is closely linked to the theory being studied. For example: comparison of energy released by burning a range of fuels or preparation of aspirin.

Course Details (Please read in conjunction with the General Science Criteria)

STANDARD LEVEL

SSC Topics: (80 hours)
Stoichiometry, Atomic Theory, Periodicity, Bonding, States of Matter, Energetics, Kinetics, Equilibrium, Acids and Bases, Oxidation and Reduction, Organic Chemistry.

Options: (30 hours) *Students will study two of the following:*
Higher Physical and Organic Chemistry, Medicines and Drugs, Human Biochemistry, Environmental Chemistry, Chemical Industries, Fuels and Energy.
Although some options appear on both Standard and Higher lists, Standard Level students only study approximately two thirds of the material in each option.

Coursework: (40 hours)

HIGHER LEVEL

SSC Topics: As above.

Additional Higher Level Material (AHL): (55 hours)
The topics are the same as the SSC topics above but are studied in much greater depth.

Options: (45 hours) *Students will study two of the following:*
Medicines and Drugs, Human Biochemistry, Environmental Chemistry, Chemical Industries, Fuels and Energy, Modern Analytical Chemistry, Further Organic Chemistry.

Note: A sound understanding of Mathematics is required for Higher Level Chemistry.

Career Opportunities

Chemistry is essential for Medicine, Veterinary Science, Dentistry and Pharmacy. It is also useful in Engineering, Food Technology, Microbiology and Public Health Services. Chemistry's balance of Mathematics and problem solving is also highly valued for courses such as Law and Accountancy.