Executive Summary

This project developed standards that reflect the content of International Baccalaureate Diploma courses. These standards represent the first time that IB courses have been translated into the language of academic content standards in order to explicitly delineate the content that is mastered and skills that are developed as a result of taking the full sequence of IB Diploma courses.

A primary reason for undertaking the project was to validate the degree to which IB courses develop content knowledge and academic skills necessary for college readiness. The other reason was to create a reference point to gauge the alignment between the IB curriculum and individual state content standards. The method used to determine the standards and their alignment with college readiness was a criterion-based judgment process whereby experts conducted repeated reviews of standard statements derived from the content of the following courses: Language A1, Theory of Knowledge, Extended Essay, Mathematical Studies, Mathematics Standard Level, Mathematics Higher Level, Biology, Chemistry, and Physics.

Once the IB standards were developed, they were then analyzed to determine their alignment with a widely accepted set of college-readiness standards, the Knowledge and Skills for University Success (KSUS) that resulted from the Standards for Success study conducted by the Center for Educational Policy Research (CEPR). The KSUS standards have been endorsed by 28 of the leading research universities in the U.S. as reflecting the faculty expectations at these institutions for students in entry-level courses. The analysis concluded that a high degree of alignment exists between the KSUS and the IB Standards. In some subject areas, complete alignment was observed. In science and mathematics, many IB standards exceeded the KSUS standards in challenge and content coverage.

The conclusion of the studies undertaken for this project is that students who are exposed to the IB curriculum are learning material that is highly aligned with the expectations that university faculty expect of incoming freshmen, and that in many cases, IB standards exceed those expectations.
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Center for Educational Research (CEPR) and the Educational Policy Improvement Center (EPIC)

Staff at the Center for Educational Policy Research (CEPR) and the Educational Policy Improvement Center (EPIC) seek to help policy makers and policy implementers alike do a better job of using educational policy as a tool to improve schooling and student learning. Both Centers’ staffs contributed to the research described in this report.

CEPR and EPIC work with federal agencies, state education departments, non-governmental organizations, private foundations, and school districts to support research on a range of issues in the areas of high school-to-college articulation, adequacy funding, large-scale assessment models, and other policy initiatives designed to improve student success.

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Project Goals

The goals of this project were to: 1) produce a set of standards that represented the content knowledge and cognitive skills students are expected to develop in IB Diploma courses; 2) analyze the alignment between those standards and a set of college readiness standards to validate that the IB Diploma Programme is at a level consistent with college readiness and to identify any potential areas where it may not be.

Project Rationale

Although the International Baccalaureate (IB) Diploma Programme is offered by many high schools in the United States and is considered to be challenging and rich in content, its content has not previously been analyzed to determine its alignment with college readiness standards or state educational standards in the U.S. Given the importance of academic content standards in recent educational reforms and the growing emphasis on improving college readiness among high school students, such an analysis is important as a means to help the IB Programme express its aims and objectives in a format that is consistent with state-level educational policies and practices in the United States and the general trend toward increased emphasis on college readiness for all students.

Each of the 50 states has established educational standards that drive the curriculum and assessments in the state. These state-level standards are frequently compared to one another and to standards developed by national U.S. standards-setting groups, such as the American Diploma Project (ADP), Standards for Success, ACT, and the College Board. State education departments increasingly expect all educational programs offered within a state to demonstrate its alignment with the state’s academic content standards. Postsecondary institutions, which are offering college-level credit for courses taken in high school or are giving students preference for admission based on programs such as IB, increasingly seek confirmation that the IB Diploma Programme is in fact well aligned with college readiness standards.

Historically, the IB Programme has employed a standardized curriculum delivered to all students regardless of country of origin, but that curriculum was not specifically tied to or
derived from an explicit set of educational standards. The IB relies on its course documents, with their detailed specification of course aims and goals, along with its end-of-course assessment system to create a high degree of internal consistency. For this reason, explicit standard statements have not been necessary. However, the educational landscape within the US has changed dramatically over the past 15 years, and educational standards are now the foundational element to all state and most district instructional frameworks. The IB Programme finds itself at a distinct disadvantage when it cannot compare its course content in an “apples-to-apples” fashion with state standards or to other college readiness standard systems. The creation of a unique set of IB academic content standards addresses these needs.

IB staff members will be able to use the standards developed in this project to demonstrate to educational agencies and organizations how IB students are prepared to meet state educational standards in ways that simultaneously prepare them for college. The alignment analysis conducted by this project will be a useful tool to confirm the tight connection between the IB Diploma courses and college readiness. In combination, these two products will be useful tools for use with legislators, state education department officials, and postsecondary admissions officers and faculty to demonstrate explicitly what IB students are learning and what they can do in relation to state standards and college readiness expectations.

**Research Methods and Process**

The primary research method employed by this project was a professional judgment model often referred to as convergent consensus. This method requires the repeated review of documents by experts who make changes at each review stage designed to move toward consensus agreement on a final document that achieves a set of pre-established goals. In this case, the goal was to develop a set of standards that represented the knowledge and skills students learn in IB courses.

The method followed a set of predetermined steps. An initial draft was generated by compiling initial drafts from a core set of content experts who were also experienced IB teachers. This initial draft was then reviewed, edited and revised in multiple phases by additional IB teachers who had experience in standards development. The IB teachers were involved in both initial
stages in order to ensure that the standards reflected the true content of the IB curriculum. As these experts edited the initial drafts, they did so with an eye toward ensuring that the standards could be easily understood by those unfamiliar with the IB and also viewed as valid by those familiar with the Diploma Programme.

The role of CEPR/EPIC staff researchers was to develop the online tools used by reviewers, recruit and train reviewers, synthesize all recommended changes, and work with consultants to revise the standards after each review. The multiple rounds of review, feedback and revisions continued until no additional significant changes were recommended by any of the reviewers.

Two final reviews were then conducted. First a broad cross-section of IB teachers and administrators without specific expertise in standards development was recruited to conduct a comprehensive review of the draft standards via a secure online website. They provided comments to CEPR/EPIC staff researchers, who synthesized the recommended changes and made the final edits to the standards. IB academic program staff in Cardiff, Wales conducted a second review. In it they were asked to examine the standards carefully to ensure that each set reflected any curricular changes that had occurred since the beginning of the project. CEPR/EPIC staff researchers and consultants then made final revisions. IB subsequently authorized the standards.

**Standards Development Process**

The standards development process involved multiple steps and stages, beginning with the selection of content experts to serve as reviewers. This was followed by the development of decision rules necessary for refining each draft version. Each is described as follows.

**Selection of Content Experts**

Staff at the IB nominated three content experts for the first of the multi-stage development and review process and 14 additional IB classroom teachers for the second round of reviews. A third group of reviewers recruited by both the New York and Vancouver offices of the IB reviewed and recommended modifications to the draft standards via a secure website. A fourth group of reviewers was recruited by staff at CEPR/EPIC for their experience writing educational standards for the Centers, state educational agencies and national organizations.
IB content experts were recruited for the final review. All reviewers used the following methods for providing their recommended edits.

The writing of draft standards was initiated using the IB course documents listed above. The writers reviewed hundreds of pages of IB Guides, Aims and Assessments before they created the first draft of the standards. Throughout the process they were reminded of the goal to create a thorough and accurate representation of the IB curricula. The initial result was a comprehensive list of standards representing the content areas and the key cognitive strategies taught to IB students.

Once all initial drafts of standards and key cognitive strategies were completed, the CEPR/EPIC research staff prepared the standards for review. A separate review document was created for each subject area. The documents included lists of the key cognitive strategy statements and content standards in a format that allowed reviewers to provide their comments and recommend edits.

**Reviews**

All reviewers conducted their reviews in the following manner. Each was trained in a 45-minute conference phone call. CEPR/EPIC staff developed the training and materials and conducted all group trainings by conference call. Trainees were directed to refer to the written materials provided and did several trial reviews together. After each, they discussed their decisions for their recommended revisions. Reviewers were trained to select one of the following choices to best represent their recommended change to each standard: *No Change, Simplify, Expand, Comment Only, Combine Habits, Rewrite Habit*. In addition, a comment section was included to allow them to easily provide their recommended changes to the text. They were also able to add new content standards or key cognitive strategies throughout the document. Each reviewer was asked to review and recommend changes to approximately 20 key cognitive strategies and 175 content standards per subject area.

Several of the reviewers commented about two general issues. First, for some of the subject areas, the order of the standards did not reflect the customary sequencing within the IB curriculum. Reviewers were encouraged to provide this feedback and staff researchers later
used it to reorder the standards. Second, some reviewers noted missing content. CEPR/EPIC staff encouraged them to propose additional standards in these missing areas.

After this review was completed and all recommended changes made, the draft standards were sent to a set of reviewers who had not taught the IB curriculum. These reviewers ensured that language of the standards was consistent with customary educational language used by state departments of education in the U.S. and provincial departments in Canada. This step was necessary to ensure that when the IB standards were aligned to the KSUS standards and later with state and provincial standards, the grain size and language would allow meaningful alignment. The primary goal of the modifications was to create a set of standards that best represented all reviewers’ comments. At each round of review, CEPR/EPIC research staff members analyzed the reviewer recommendations and made modifications following a set of predetermined decision rules.

**Decision Rules**

**Deleting Standards:** Standards were deleted when a majority of reviewers said that the standard was redundant, did not reflect the curriculum, or needed to be combined with another existing standard. If a minority of reviewers recommended deletion, the standard remained.

**Language:** Whenever a reviewer suggested text changes to clarify the standard, modifications were made. Staff researchers followed reviewer recommendations when simplifying or expanding a standard.

**Combining Standards:** If any reviewer indicated that two or more standards should be combined, standards were merged. The only exceptions were if the resulting change specifically conflicted with another reviewer’s comments, or if the change meant that the final standard would include more than one expectation in the same standard. If two reviewers recommended conflicting modifications, the judgment call rule was used. It is described next.

**Judgment Calls:** When two or more reviewers expressed conflicting ideas about how a standard should be modified, research staff chose the recommended language of the standard that would be most clearly understood by someone without knowledge of the IB curriculum.
Adding Standards: Occasionally, reviewers recommended additional standards and provided proposed language for those. Most of the standards provided by reviewers were included, except when it was clear that another reviewer’s recommended change sufficiently addressed the missing standard. When a reviewer noted a missing standard but offered no proposed language for the standard, the CEPR/EPIC researchers asked one of the project content consultants to write the additional standard.

Reordering Standards: When a reviewer recommended that a standard be moved because it was placed in the wrong subsection, the move was postponed until all of the reviewer changes were made. A single reviewer then reordered all the standards in each content area.

Special Case: Mathematics Standard Level/Higher Level

In mathematics, the IB curriculum specialists reviewed the Mathematics Standard Level/Mathematics Higher Level standards and recommended a large number of language edits to comply with the customary language of the IB curriculum, policies and practices. Because the IB curriculum is rooted in European traditions and practices, most of the recommended changes would have resulted in language and mathematical conventions uncommon in the U.S. and Canada, the intended audience for the final outcomes of the project. Furthermore, because the purpose of the project was to translate IB curriculum, practices and language into standards more accessible and understandable for those in North American universities and state and provincial governments unfamiliar with the IB Programme, many recommended edits were not incorporated. In consultation directly with IB (New York and Vancouver offices) and indirectly with IB (Cardiff), CEPR/EPIC staff ensured that all language was acceptable for the cultural context of mathematics in North America.

To ensure that no essential standard was deleted or revised inaccurately, CEPR/EPIC hired a specially trained mathematics consultant to evaluate each comment provided by IB program staff on the standards for Mathematics Standard Level and Mathematics Higher Level. This consultant was chosen because he received his mathematics training in Europe but has since taught for more than two decades in colleges and universities in the U.S. Using his knowledge of the language of mathematics on both sides of the Atlantic allowed him to carefully evaluate each recommended change to determine if it was consistent with common language and
practice in the U.S. All changes that would be understood by U.S. mathematics educators and mathematical errors noted by the IB program staff were corrected. Those recommended revisions that would confuse or mislead North American mathematics educators were not revised to comply with directives from IB staff.

**Source Documents Utilized**

The standards were derived from key documents that specify the content of IB courses. Following is a description of those documents.

**Language A1, Theory of Knowledge, Extended Essay**


The Extended Essay requirement is not embedded within the Language A1 curriculum, and many IB students produce work from the sciences when completing this course. However, the requirement aligns best with the KSUS standards in research, which are included in the English KSUS standards. So in anticipation of the eventual alignment with the English KSUS standards, the Extended Essay standards are presented with the LA1 standards. During the review phases, however, Extended Essay standards were reviewed by content experts in both Language A1 and in Biology.
Mathematics

Prior Knowledge (PK) standards, Process Objectives (PO), and Aims (A) associated with Mathematics SL, Mathematics HL and Mathematical Studies were used as the source documents for the Mathematics standards and key cognitive strategies including but not limited to Diploma Programme, Mathematical Studies SL, First Examinations 2006 and Mathematics HL First Examinations 2006.

Because students who take Mathematical Studies do not take either the SL or HL version of Mathematics, Mathematical Studies is presented separately. Students who enroll in Mathematical Studies are typically students in the arts or in disciplines less dependent on higher order math skills (e.g. sciences or computer science).

Science

Guides and Assessments associated with Biology (including Ecology), Chemistry, Physics and Environmental Systems were used as the source documents for the Science standards and key cognitive strategies documents including, but not limited to Biology for first examinations in 2003, Chemistry (February 2001) Physics (February 2001) Environmental Systems (February 2001). (Note: During the project, Environmental Systems was eliminated from the IB curriculum as a separate course. Much of the course content remains within the IB curriculum spread across other courses. The standards were revised during the project to reflect the changes. IB science content experts reviewed and ensured that all of the retained content on Environmental Systems was included in the final drafts of the IB standards presented in the appendices.)

When material occurred at both a “standard level” and a “higher level,” consultant experts were directed to choose the higher level because most students choose to master the higher level content. Presenting the standard level would under-represent the curricular challenge. Conversely all IB students also take at least one of several science Options topics, most often chosen by their teacher or school. Because students have several alternative contents from which to choose and not all IB students learn the same Options materials, no science Options curricula are included here. Essentially, the standards presented in this report for science
represent the content that all IB students are expected to master, acknowledging that all IB students master additional science content in Options topics as well.

Structure of the Standards

Each content area consists of two types of standards: content standards that identify the skills and knowledge expected in the subject, and key cognitive strategies that describe ways of knowing and thinking about the subject. Content standards derive most often from the IB Assessment statements. Key cognitive strategies were deduced primarily from the IB Aims.

Final Version of IB Standards

The final version of the IB standards is presented in Appendix A of this report and organized by subject area: Language A1, Extended Essay, Theory of Knowledge, Mathematical Studies, Mathematics Standard level/Higher Level, Biology, Chemistry, and Physics. Content experts for each subject were encouraged to use a standards-writing approach that would yield the most accurate representation of their respective subject areas. Consequently, the mathematics and science standards include a larger number of standards than those of Language A1, Extended Essay and Theory of Knowledge. For the latter standards, IB teachers, content experts and standards writers serving as consultants chose to emphasize the themes of these portions of the IB curriculum rather than the detailed standards written by the mathematicians and scientists.

Language A1 consists of a total of 10 content standards, Extended Essay consists of a total of 12 content standards, and Theory of Knowledge consists of a total of 15 content standards. They are broad in scope to reflect the “big ideas” of these subjects and the variety of content taught within these themes. Mathematical Studies consists of a total of 73 detailed content standards in the following eight topics: 1) use of a graphing calculator, 2) numbers and algebra, 3) sets, logic and probability, 4) functions, 5) geometry and trigonometry, 6) statistics, 7) introductory differential calculus and 8) financial mathematics. Mathematics Standard-level consists of 64 content standards across six topics and an additional 38 standards for students who take the Higher-level version of the course. The six topics of the standard-level standards describe what students learn in: 1) equations and graphs, 2) circular functions and
trigonometry, 3) matrices, 4) statistics and probability, 5) calculus: derivatives and integrals, and 6) multi-variable calculus: vectors. The higher-level standards also include a section on proofs, sequences, series and complex numbers in addition to the additional content in the same topics as listed above for the standard-level standards.

Physics consists of 31 content standards in the following six topics: 1) notation and mathematics, 2) classical motion, 3) heat and thermodynamics, 4) electricity and magnetism, 5) energy, power and climate change, and 6) waves and vibrations. Chemistry consists of 47 content standards in the following 13 topics: 1) structure of an atom, 2) electronic structure, 3) periodic properties and the periodic table, 4) the mole, 5) chemical equations, 6) bonding, intermolecular forces, and properties of substances, 7) equilibrium, 8) acids and bases, 9) kinetics, 10) enthalpy, entropy, and free energy, 11) electrochemistry, 12) organic chemistry and biochemistry, and 13) measurement and data processing. Biology consists of 19 content standards in the following seven topics: 1) the chemistry of life, 2) all functions of life occur at the cellular level, 3) cell reproduction and heredity, 4) ecology, evolution and the diversity of life, 5) multi-cellular organisms and organ systems, 6) methodologies and tools of biological studies, and 7) science and society. Lab Process Skills consists of 30 standards in the following two broad topics: 1) be able to carry out the scientific method to investigate a scientific question and 2) work within the context of a scientific community and the standards set by the global community of scientific investigators.

Examples of IB content standards in:

Language A1—Articulate ideas in writing and speaking with clarity, coherence, conciseness, precision, and fluency.

Extended Essay—Formulate and clearly state a research question or hypothesis that fits the scope of the research and allows a focused study to be conducted.

Theory of Knowledge—Recognize, apply, and be able to distinguish among different kinds of knowledge—factual, applied, and understood.
Mathematical Studies-- *Use the graphs and properties of exponential functions, including basic concepts of asymptotic behavior, to solve problems involving growth and decay, including population growth, radioactive decay and heating and cooling.*

Mathematical Standard Level/Higher Level-- *Find solutions of first-order differential equations by separation of variables.*

Physics-- *Apply the concepts of force, speed and acceleration to motion in a circle.*

Chemistry-- *Be able to solve quantitative stoichiometry problems using balanced chemical equations for reactions and products in solid, liquid, gaseous and aqueous phases.*

Biology-- *Understand how the study of biology contributes to the health of the citizens of the world and how biological research improves the diagnosis, treatment, and prevention of globally important diseases.*

Lab Process Skills-- *Be able to generate an investigable question and its possible answer.*

In addition to the content standards in each subject are, developers also included standards to reflect the key cognitive strategies of the IB curriculum. Key cognitive strategies are the intellectual behaviors that lead to ways of thinking that develop cognitive strategies and a disciplined approach to thinking. Developed over a long period of time they are practiced behaviors that become a habitual way of working toward a more thoughtful, intentional and intelligent approach to learning. They include intellectual openness, inquisitiveness, analysis, reasoning, argumentation, proof, interpretation, precision, accuracy and problem solving. (*Redefining College Readiness*, 2007—available at https://www.epiconline.org/publications/dr._david_conley)

Examples of IB **key cognitive strategies standards** in:

Language A1-- *Understand that cultural biases affect our perceptions of artistic works.*

Extended Essay-- *Formulate and clearly state a research question or hypothesis that fits the scope of the research and allows a focused study to be conducted.*
Theory of Knowledge-- *Develop a curiosity about the nature of knowledge, an appreciation of its richness and diversity, and an understanding of the empowerment that follows from reflecting on it.*

Math-- *Select and use appropriate mathematical strategies and techniques to solve problems.*

Science -- *Seeks to know and be able to apply the body of knowledge, methods and techniques that characterize science and technology.*

**Alignment with KSUS College-Ready Standards**

After the IB standards were developed, reviewed, and authorized by IB, a separate study was conducted to determine the degree to which they aligned with the Knowledge and Skills for University Success (KSUS) college-ready standards. Content experts who originally helped to develop the KSUS standards performed the alignment. All are university faculty members in the respective content areas.

The Knowledge and Skills for University Success (KSUS) college-ready standards are a comprehensive set of standards describing what university faculty expect in students prepared to succeed in entry-level courses. Published in 2003, the KSUS standards were the result of a development process in which more than 400 faculty and staff members from 20 leading research universities, all members of the Association of American Universities, participated in extensive meetings and reviews. They identified and developed standards to indicate what students must know and be able to do in order to succeed in entry-level courses at their institutions. The KSUS standards are divided into subject-area groups covering English, mathematics, natural sciences, social sciences, second languages and the arts. For a complete listing of the KSUS standards, go to: [http://www.s4s.org/cepr.uus.php](http://www.s4s.org/cepr.uus.php).

The IB standards were found to be highly aligned with the KSUS standards. Of the 73 KSUS standards in English only seven KSUS standards were not aligned with the IB standards across Language A1, Extended Essay and Theory of Knowledge. In general those KSUS standards for which the faculty alignment experts could detect no alignment were generally of a grain-size more detailed than the IB standards. For example, the KSUS standard, *use feedback from others to revise written work*, was not found among the IB standards. This may be an important component of the IB writing curriculum but the IB standards developers and
reviewers did not include it because it describes a writing strategy at a more detailed grain-size than the other IB standards. Similarly in mathematics, of the 83 KSUS standards only a few were not aligned to the IB standards, and most of these were strategies for conducting mathematics. For example, in the mathematical reasoning portion of the KSUS standards, the standard: *recognize when a proposed solution does not work, analyze why and use the analysis to seek a valid solution* was not found among the IB Mathematical Studies standards. A likely explanation for this is that this KSUS standard is written at a smaller grain-size than the majority of the IB standards.

In science the pattern changes slightly. Chemistry, biology and the concepts of environmental science all align completely with the KSUS standards. For the small number of physics KSUS standards --for which no alignment was detected with the IB standards—a few were unexpected. For example, the KSUS standard: *Understand the basic principles of optics* was not detected. This concept of physics may not be included in the IB curriculum or simply may be missing in the IB standards representing it. Recommendations at the conclusion of this report suggest the physics curriculum should be reviewed for these possible omissions.

The complete set of aligned IB standards to the college-ready Knowledge and Skills for University Success is presented in Appendix B of this report. Table 1 explains how the standards alignment results are presented.

<table>
<thead>
<tr>
<th>IB Content Area</th>
<th>Aligned to KSUS Subject Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Language A1</td>
<td>English</td>
</tr>
<tr>
<td>Theory of Knowledge</td>
<td>English</td>
</tr>
<tr>
<td>Extended Essay</td>
<td>English</td>
</tr>
<tr>
<td>Mathematical Studies</td>
<td>Mathematics</td>
</tr>
<tr>
<td>Mathematics Standard Level</td>
<td>Mathematics</td>
</tr>
<tr>
<td>Mathematics Higher Level</td>
<td>Mathematics</td>
</tr>
<tr>
<td>Biology</td>
<td>Natural Sciences</td>
</tr>
</tbody>
</table>
(Note: The Theory of Knowledge and Extended Essay content areas were aligned to the English KSUS standards because they correspond most closely to two sections of the English KSUS standards: Critical Thinking and Research Writing).

Three KSUS content experts aligned the IB key cognitive strategies to the KSUS standards. These experts have undergone extensive training by CEPR/EPIC in alignment procedures and have utilized these standards and procedures for previous alignment analyses as directed by CEPR/EPIC staff. The alignment for each subject is included in the appendices at the end of this report. Alignment results fell into three categories: (1) IB exceeds KSUS in challenge and or content, (2) IB and KSUS are aligned, or (3) IB partially aligns to KSUS (shown in Figure 1).

**Presentation Display**

The display used here for presentation of these alignment findings was chosen after many other options were considered and discarded. A sample of an alignment in Chemistry is presented in Figure 1 and described below. It important to note however, that when the alignment content consultants produced the alignments they did so using large poster size charts. These charts displayed the IB standards along the top column headers and the KSUS standards as the row headers. The faculty produced a judgment for each cell. These judgments were converted to the following format for ease of presentation with this report.
Figure 1. Sample of Alignment Chart

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Understand the real number system and its properties.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IB standards exceed KSUS standards</td>
<td>IB standards are equal to KSUS standards in content and challenge.</td>
<td>IB standards partially align with KSUS standards</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Understand the terms and know how to calculate an empirical formula and/or molecular formula of a given compound.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IB – CHEMISTRY – CHEMICAL EQUATIONS</td>
<td>IB standards exceed KSUS standards</td>
<td>IB standards are equal to KSUS standards in content and challenge.</td>
<td>IB standards partially align with KSUS standards</td>
<td></td>
</tr>
<tr>
<td>14. Know how to balance a variety of chemical reactions and use state symbols correctly</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Be able to solve quantitative stoichiometry problems using balanced chemical equations for reactions and products in solid, liquid, gaseous and aqueous phases.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Solve problems and analyze graphs related to the ideal gas equation.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the sample presented in Figure 1 above, each KSUS standard is listed in numerical order on a blue background at the beginning of the section. (Note: KSUS was used as the foundational set of standards to show how/where IB aligns to this accepted set of college-ready standards. See previous description presented elsewhere in this report of the creation and endorsement of the Knowledge and Skills for University Success standards.)

On the alignment figure, red indicates there is no alignment between that section of the IB standards and the particular individual KSUS standard displayed directly above it. In the first column, dark green shows a point of alignment where the IB standard exceeds what is
expected in the corresponding KSUS standard. In the third column, light green shows where the IB standard only partially aligns with the corresponding KSUS standard. In the middle column, white indicates alignment between the IB and the KSUS standard.

In the chemistry example shown above, there are four IB standards that exceed this individual KSUS standard. The first comes from the Chemistry-Mole section of the IB standards. The other three IB standards that exceed this KSUS standard all come from the Chemistry-Chemical Equations section of the IB standards. No IB standards show either full or partial alignment with this individual KSUS standard in this example so the white and light green cells of the chart are vacant.

Alignment Findings

This section will present findings from each of the content and cognitive strategies alignments. Presentation will be grouped so that the explanation and interpretation here parallels the display presented in the appendices. Five sections of IB standards will be presented first (and in Appendix B). Language A1 Content, Language A1 Key Cognitive Strategies, Extended Essay Content, Extended Essay Key Cognitive Strategies and Theory of Knowledge Content and Strategies.

Content standards present the knowledge expected. Key cognitive strategies are critical skills students develop over time as they engage with challenging content. Sometimes implied rather than stated directly, these habits are the ways students think about content and about learning. Furthermore, they include important skills such as critical reasoning, analysis, interpretation, and ways of knowing. The IB standards include both content standards and key cognitive strategies.

IB Language A1, Extended Essay and Theory of Knowledge aligned to KSUS English

When examining the alignment presented in Appendix B, it is apparent that the KSUS is a longer list of standards than is the list of IB standards. KSUS includes 73 standards across four sections, reading and comprehension, writing, research and critical thinking. The IB Language A1 standards include 12 content standards and six key cognitive strategies.
The Extended Essay standards also include 12 content standards and six key cognitive strategies. The Theory of Knowledge standards include 15 content and key cognitive strategies standards. (Note: The nature of the Theory of Knowledge course prohibited separating the content from the cognitive strategies so they were coupled.) The chart in Appendix B shows the IB and the KSUS standards align almost completely.

When the Language A1 IB standards are aligned to the English KSUS standards all 12 align with at least one KSUS English standard and many align with more. Although the IB standards are fewer, they appear to be comprehensive. Two of the four sections of the KSUS standards show complete alignment with content taught in the IB curriculum: Critical Thinking and Research. Of the 73 English KSUS standards, only seven standards show no alignment with any of the IB standards. This finding indicates that the IB curriculum may not include content represented by the following seven KSUS standards:

<table>
<thead>
<tr>
<th>KSUS</th>
<th>Reading and Comprehension</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exercise a variety of strategies to understand the origins and meanings of new words, including analysis of word roots and the determination of word derivations.</td>
</tr>
<tr>
<td></td>
<td>Use monitoring and self-correction, as well as reading aloud, as means to ensure comprehension.</td>
</tr>
<tr>
<td></td>
<td>Understand vocabulary and content, including subject-area terminology; connotative and denotative meanings; and idiomatic meanings.</td>
</tr>
<tr>
<td></td>
<td>Exercise a variety of strategies to understand the origins and meaning of new words, including recognition of cognates and contextual clues.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>KSUS</th>
<th>Writing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Employ basic editing skills proficiently to identify obvious mechanical errors, clarify and improve the structure of the piece and sharpen language and meaning</td>
</tr>
<tr>
<td></td>
<td>Reassess appropriateness of writing in light of genre, purpose and audience.</td>
</tr>
<tr>
<td></td>
<td>Use feedback from others to revise written work.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>KSUS</th>
<th>Research</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>
The findings show alignment between all other 66 English KSUS standards and the IB standards in Language A1, Extended Essay, and Theory of Knowledge. This is an important finding. The KSUS standards have been used for alignments with state educational standards, national standards such as the American Diploma Program and with the curriculum of individual high schools and districts. In these other studies, the two areas most often found to be poorly aligned between secondary and post-secondary education are in the areas of Research and Critical Thinking. However, both areas were found to be completely aligned with IB standards indicating that the secondary education standards of IB and the post-secondary standards of KSUS are well aligned. IB students who complete the Language A1, Theory of Knowledge and Extended Essay portions of the IB curriculum will have opportunities to learn and to master the content and key cognitive strategies expected of college and university faculty members as evidenced in the KSUS standards; standards endorsed by 28 of the leading research universities in the U.S.

Interestingly, of the seven KSUS standards where no alignment could be detected among the IB standards, each appears to be a different type of standard from those on the IB lists as mentioned briefly above. The lack of alignment may be the result of these differences. The seven KSUS standards represent instructional practices and strategies used either by the teacher or the student, and at a grain size much smaller than those of the IB standards (e.g. Use feedback from others to revise written work). An absence of alignment between these and the newly authorized IB standards should not be an area of concern. Several explanations are reasonable. It is possible that the IB curriculum provides opportunities for students to learn and master these content areas but that IB standards developers chose not to include these more detailed types of standards on their list, a list that emphasizes more “broad stroke” standards. Additionally, it is possible that many of these are mastered in earlier years so including them with standards for the IB Programme (covering only the last two years of secondary
instruction) was considered inappropriate. Regardless, there is a nearly complete match between the knowledge and skills expected by university faculty members of their entering students and the IB curriculum as evidenced by the standards. Furthermore, when the alignments are examined closely, the IB curriculum appears to exceed the challenge and scope of many of the KSUS standards. (See Appendix B.)

IB Mathematical Studies and Mathematical SL/HL aligned to KSUS Mathematics

The mathematics curriculum is divided into three subsections to reflect different math aptitudes and goals among IB Programme students. Mathematical Studies is taken primarily by students who excel in the arts and humanities. Mathematics Standard Level or Mathematics Higher Level are courses taken by students who will likely major in health professions, social studies, mathematics, science or engineering in college.

There are 73 standards representing the content of the Mathematical Studies course and 83 KSUS standards in mathematics including a section on mathematical reasoning.

When the Mathematical Studies IB standards were aligned to the mathematics KSUS standards the majority were found to align with at least one KSUS mathematics standard, and many aligned with more. Of the 83 KSUS standards in mathematics, only 11 show no alignment with any of the IB standards. Six of these 11 are in the area of mathematical reasoning. Those KSUS standards for which no alignment could be found are:

<table>
<thead>
<tr>
<th>KSUS</th>
<th>Computation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calculate using absolute value.</td>
</tr>
<tr>
<td>KSUS</td>
<td>Algebra</td>
</tr>
<tr>
<td></td>
<td>All align.</td>
</tr>
<tr>
<td>KSUS</td>
<td>Trigonometry</td>
</tr>
<tr>
<td></td>
<td>All align.</td>
</tr>
<tr>
<td>KSUS</td>
<td>Geometry</td>
</tr>
</tbody>
</table>

*International Baccalaureate Standards Development and Alignment Project: Final Report*
| Know properties of similarity, congruence and parallel lines cut by a transversal. |
| Understand the ideas behind simple geometric proofs and are able to develop and write simple geometric proofs (e.g., the Pythagoras theorem; that there are 180 degrees in a triangle; and that the area of a triangle is half the base times the height). |
| Use similar triangles to find unknown angle measurements and lengths of sides. |
| Recognize geometric translations and transformations algebraically. |

### KSUS Mathematical Reasoning

| Use a variety of strategies to revise solution processes. |
| Are willing to experiment with problems that have multiple solution methods. |
| Show an understanding of how to modify patterns to obtain different results. |
| Show an understanding of how to modify solution strategies to obtain different results. |
| Recognize when a proposed solution does not work, analyze why and use the analysis to seek a valid solution. |
| Know that mathematics has played (and continues to play) an important role in the evolution of disciplines as diverse as science, engineering, music and philosophy. |

### KSUS Statistics

| All align. |

The IB curriculum shows complete alignment with three of the six sections of the KSUS math standards (algebra, trigonometry, and statistics). More than half of the unaligned standards are in the mathematical reasoning section. Another four are in geometry (although these may have not been included in the IB standards if the content is taught to IB students in the Middle Years Programme (grades 7-10 for North American students) rather than in the IB Diploma Programme. All KSUS standards for which no alignment could be found with the IB standards should be reviewed carefully by IB curriculum developers in the next curricular review to consider revisions to the curriculum (and the associated standards). The goal for this review would be to improve the alignment between the mathematical studies curriculum and
mathematical reasoning and geometry. Doing so will allow more IB students to acquire the thinking skills expected by faculty at colleges and universities in the U.S. as evidenced in the KSUS college-ready standards.

Of special note is the complete alignment between mathematical studies and the algebra section of the KSUS. A large section of the KSUS standards are devoted to the study and acquisition of algebra skills. This emphasis is intentional because college faculty members know that strong algebra skills are closely linked with success in college math and science courses. In this alignment report, there was alignment between the IB mathematical studies standards and all 24 KSUS algebra standards. This bodes well for IB students succeeding in college, especially when many of the KSUS algebra standards are expected by college faculty only for those students who will eventually major in math, computer science, natural sciences or engineering. Yet the IB course that so closely aligned to these KSUS standards was a course taken primarily by students who will major in the arts and humanities. So if they change their majors, IB’s mathematical studies course will have prepared them to succeed in the “hard sciences” as well.

All students who complete IB mathematics standard level have the opportunity to learn the content represented by the IB mathematics standard level set of standards. Additionally some students will choose a more advanced version of the course represented by the IB mathematics higher level set of standards. The majority of standards in each of the two sets showed not only nearly complete alignment with the KSUS standards but the alignment demonstrated that IB standards exceeded the KSUS standards in content and challenge level. Findings are presented in Appendix B of this report.

For the 14 KSUS standards for which no alignment could be detected, the majority of standards were from the mathematical reasoning section of the KSUS standards. One statistics standard also showed no alignment. All are presented in the table below.

<table>
<thead>
<tr>
<th>KSUS Mathematical Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use inductive reasoning in basic arguments.</td>
</tr>
<tr>
<td>Use a variety of strategies to revise solution processes.</td>
</tr>
<tr>
<td>Understand the uses of both proof and counterexample in problem solutions and are able to conduct simple proofs.</td>
</tr>
<tr>
<td>Recognize the accuracy of an estimation.</td>
</tr>
<tr>
<td>Know how to make and use estimations.</td>
</tr>
<tr>
<td>Recognize when the results produced are unreasonable or represent misinformation.</td>
</tr>
<tr>
<td>Use calculators for systematic trial-and-error problem solving.</td>
</tr>
<tr>
<td>Know how to use specific instances of general facts, as well as how to look for general results that extend particular results.</td>
</tr>
<tr>
<td>Are willing to experiment with problems that have multiple solution methods.</td>
</tr>
<tr>
<td>Demonstrate an understanding of the mathematical ideas behind the steps of a solution, as well as the solution.</td>
</tr>
<tr>
<td>Show an understanding of how to modify patterns to obtain different results.</td>
</tr>
<tr>
<td>Show an understanding of how to modify solution strategies to obtain different results.</td>
</tr>
<tr>
<td>Recognize when a proposed solution does not work, analyze why and use the analysis to seek a valid solution.</td>
</tr>
</tbody>
</table>

**KSUS Statistics**

Understand curve-fitting techniques (e.g., median-fit line and regression line) for various applications (e.g., making predictions).

A similar pattern of incomplete alignment with the KSUS standards in mathematical reasoning can be seen with the higher level IB mathematics standards as well. However, those students who enroll in the higher level of the same course, will have the opportunity to learn more of the content represented by the KSUS in the area of mathematical reasoning because only seven KSUS standards in mathematical reasoning could not be aligned to the IB standards once both the standard level and the higher level IB standards were aligned. (The same standard from the statistics section of the KSUS continued to show no alignment even once the IB higher
level mathematics standards were aligned.) The KSUS standards not aligned with either standard level or higher level mathematics are presented in the table below.

<table>
<thead>
<tr>
<th>KSUS Mathematical Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use a variety of strategies to revise solution processes.</td>
</tr>
<tr>
<td>Use calculators for systematic trial-and-error problem solving.</td>
</tr>
<tr>
<td>Are willing to experiment with problems that have multiple solution methods.</td>
</tr>
<tr>
<td>Demonstrate an understanding of the mathematical ideas behind the steps of a solution, as well as the solution.</td>
</tr>
<tr>
<td>Show an understanding of how to modify patterns to obtain different results.</td>
</tr>
<tr>
<td>Show an understanding of how to modify solution strategies to obtain different results.</td>
</tr>
<tr>
<td>Recognize when a proposed solution does not work, analyze why and use the analysis to seek a valid solution.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>KSUS Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understand curve-fitting techniques (e.g., median-fit line and regression line) for various applications (e.g., making predictions).</td>
</tr>
</tbody>
</table>

**IB Science (Chemistry, Physics, Biology) aligned to KSUS Natural Sciences**

The IB Science curriculum includes Biology, Chemistry and Physics.

(Note: The former environmental systems curriculum has been added to the other science courses. These curricular changes occurred after this project began. Consequently content specialists at IB assisted with the revisions to the standards to ensure that the final standards are accurate representations of the present curriculum.)

Students do not typically take all three science courses in the 11th and 12th grades of the IB Diploma Programme but make selections from the list. As expected, each of these three courses aligned to the corresponding KSUS content standards in ways that will be described in the following sections. The IB science curriculum (if used in totality – Biology, Chemistry, and
Physics) aligned with each of the General Foundational Skills and the Science and Society standards of the KSUS standards. For all alignments, the KSUS standards were used as the benchmark to indicate how well IB students are prepared for what will be expected of them when they enroll as college freshmen. Analysis of the alignments is presented next.

**Chemistry**

The alignment between the IB chemistry standards and KSUS chemistry standards showed complete alignment for each KSUS standard and for many, the IB standard represented expectations in chemistry that exceeded the expectations for entering freshmen by university faculty. **Faculty alignment experts found alignment among the IB standards for each KSUS chemistry standard.**

**Environmental Science**

Of the six environmental science standards within KSUS, **there is evidence that all are taught in the IB science curriculum.** This is an important finding because it verifies that even though IB has eliminated the specific course (Environmental Systems) from the IB science curriculum, the content expected of entering freshmen by the professors who will teach them has been retained within the curriculum of the other remaining science courses.

**Physics**

The IB physics curriculum—as represented by the IB standards developed for this project—are nearly completely aligned with what will be expected of IB graduates when they enroll in colleges and universities. There are five KSUS physics standards for which there is no evidence that the IB curriculum includes this academic content:

<table>
<thead>
<tr>
<th>KSUS Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understand basic principles of optics.</td>
</tr>
<tr>
<td>Know the range of the electromagnetic spectrum, for example: Radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, x-rays and gamma rays.</td>
</tr>
<tr>
<td>Understand the general concepts related to the theory of special relativity. For example: In contrast to moving objects, the speed of light is the same for all observers, no matter how they...</td>
</tr>
</tbody>
</table>
or the light source happens to be moving. Nothing can travel faster than the speed of light.

Know the constituent particles that make up atoms (i.e., protons, neutrons and electrons) and have a general understanding of physical locations of each (i.e., protons and neutrons in the core nucleus and electrons in a cloud “far” away from the nucleus).

Know the meaning of density.

Several of these standards were quite unexpected. For example, it is difficult to imagine an IB student completing a physics course without knowledge of either the “particles that make up atoms” or the “meaning of density.” If this material is expected knowledge to be learned by IB physics students, it would be important to add these to the IB physics standards before a public release.

**Biology**

The IB biology curriculum is perfectly aligned with the biology expected of entering college freshmen. In biology there is evidence that the IB curriculum includes content that addresses each KSUS standard. Stated differently, the IB biology curriculum includes all academic content expected by university science faculty as described in the KSUS standards.

**KSUS General Foundational Skills and KSUS Science and Society**

There are two general science portions of the KSUS standards: General Foundational Skills (primarily the math skills expected by university science faculty) and the relationship between Science and Society. Because of the broader scope of these two sections of the KSUS standards, it was important to determine if the combination of the IB biology, physics and chemistry standards showed complete alignment with these two general sections of the KSUS college-ready standards. After alignments were completed by the alignment faculty, there was convincing evidence that if an IB student were to take all three science courses, they would have the opportunity to learn and master all of the KSUS standards in the General Foundational Skills and the Science and Society sections. No KSUS standard in either the General Foundational Skills or in the relationship between Science and Society
remained unaligned with IB after all three IB science courses were aligned to the KSUS college-ready standards.

**The Lab Process Skills**

The IB standards for Lab Process Skills are presented separately from the three science sub-disciplines. We attempted alignment between these and the KSUS content standards but without much success. The Lab Process Skills of the IB standards are used in the IB curricula as a way of proceeding and conducting lab activities in each of the science courses rather than directly associated with a particular sub-discipline. The Lab Process Skills include methods for data collection, hypothesis testing, interpretation of data, researcher collaboration and ethical work habits. They demonstrate the commitment of the IB curriculum developers and instructors to teaching students to “think like scientists,” something known to be highly associated with college success in science courses but not easily detected using the methodology selected for this study. **As displayed in Appendix B, a few of these IB Lab Process standards aligned with the KSUS science standards. But the finding that many did not should not be interpreted as an indication that they are unimportant.** The contrary is more likely. College and university faculty expect students in the science courses to know how to conduct scientific inquiry, gather data, develop and test hypotheses and interpret findings. The IB Diploma Programme has documented these expectations in a written format unavailable in the KSUS standards. Because the university faculty members who developed the KSUS standards chose not to include their expectations for lab activities alignment was inevitably unlikely.

CEPR/EPIC staff researchers know from other Center projects that these approaches to scientific inquiry are valued among science faculty at U.S. colleges and universities. See **Appendix A** for the complete list of Lab Process Skills standards of IB and **Appendix B** for the few standards that align with KSUS General Foundational Skills and Science and Society standards.

**The Options**

As described earlier, when considering the IB science curriculum it is important to note that not all IB students take all three sciences. Furthermore, for each science course students take,
they receive additional science material presented as Options within the course. Options content is not included in this standards development or alignment process because the specific Options material learned is the decision of the instructor or the school. It would be misleading to include the content of all the Options here because no student receives instruction in all the Options. However, it is important to note that all IB students receive content in additional science curricula beyond what is presented here.

**Recommendations**

We note in places partial or no alignment between IB standards and KSUS standards. For these areas, we recommend that IB curriculum specialists scrutinize the items. If they determine that the IB curriculum includes this content, they may elect to add additional standards before the standards are distributed widely. If they determine that they are not taught, they may want to consider revising the curriculum to include these few or to explain why they are not taught. This is especially so for the standards in mathematical reasoning.

Second, in the sciences, the Lab Process Skills could not be aligned to the KSUS because the KSUS standards do not include standards applicable to lab activities. The Lab Process Skills can be validated by results from subsequent EPIC studies of college classrooms nationwide conducted subsequent to the KSUS study. IB may wish to engage in an additional post hoc analysis to confirm the relationship between Lab Process Skills and current practices in a broad range of college classrooms.

Finally, we recommend that the IB standards be utilized to conduct planned alignment analyses that compare the IB standards to state content standards and to demonstrate to educational agencies, state and provincial departments of education and colleges and universities in North America how well the IB Diploma Programme is aligned with the knowledge and skill necessary for college success.

When considering the future of the IB Standards, we recommend that IB standards be updated and reviewed on the IB course revision cycle. The standards presented here represent current practices and content of IB curricula, but as each course is updated, the corresponding standards should be updated as well.
Appendix A: IB Standards
Language A1 Content Standards

1. Develop the specific skills in close reading and textual analysis as well as the general interpretive, analytical, and critical thinking skills necessary for independent and personal responses to literature.
2. Demonstrate a thorough knowledge of the thought and feeling expressed in the works studied.
3. Compare the techniques and styles used by authors to convey their subjects by looking at a range of works from different periods, genres, styles, and cultural contexts.
4. Write and speak about literature in a variety of styles and situations, including formal assessments.
5. Demonstrate the ability to choose a topic and complete an assignment or timed exam according to given set of criteria or instructions.
6. Demonstrate a command of the language and literary features appropriate for interpreting and analyzing literature.
7. Articulate ideas in writing and speaking with clarity, coherence, conciseness, precision, and fluency.
8. Structure ideas and arguments in a focused, logical, sustained, and persuasive way.
9. Support ideas and arguments with precise and relevant examples, including specific references to the texts.
10. Demonstrate an effective choice of style and register (vocabulary, tone, sentence structure, and idiom) appropriate to the occasion.
Language A1 Key Cognitive Strategies

1. Understand and appreciate that human creativity and artistic ingenuity take many forms, including literary forms.
2. Understand that cultural biases affect our perceptions of artistic works.
3. Develop an appreciation of and lifelong interest in literature as a study of the complex human pursuits, anxieties, joys, and fears.
4. Understand and appreciate literary works as products of art and their authors as craftsmen whose methods of production can be analyzed in a variety of ways and on a variety of levels.
5. Understand and appreciate literary works as products of historical, political, economic, and cultural factors.
6. Develop tolerance, empathy, and genuine respect for literary perspectives from different cultures and the ways they represent and shape common human experience.
**Extended Essay Content Standards**

1. Develop curiosity about a topic in order to investigate it in depth.
2. Evaluate a subject for its suitability as a research topic.
3. Formulate and clearly state a research question or hypothesis that fits the scope of the research and allows a focused study to be conducted.
4. Display the ability to add original, insightful thinking while attempting to answer the research question.
5. Develop a systematic, scholarly process of gathering information and evidence to answer the research question.
6. Display a high degree of understanding of relevant research material, sources, and data.
7. Be able to gather, organize, evaluate, summarize, and synthesize disparate sources of information (textual, oral, graphic, visual, and personal) to answer the research question.
8. Develop a convincing answer to the research question.
9. Construct a clear, logical, well-organized argument with an introduction that includes the importance, background, context, research questions, and thesis, and a conclusion that is relevant to the research question and consistent with the thesis.
10. Effectively use visual elements (tables, graphs, illustrations, etc) to depict information, data, or trends.
11. Construct an effective abstract that clearly states the research question, the scope of the investigation, and the conclusion(s) reached.
12. Use the correct format for a research paper appropriate to the subject matter.
Extended Essay Key Cognitive Strategies

1. Understand the importance of a topic that is both interesting and challenging and sufficiently narrow to examine in depth.
2. Understand the components and intent of a research question.
3. Recognize that the appropriate research process is determined by the nature of the subject area.
4. Know that reading and researching is an active process that includes taking notes, evaluating sources, and synthesizing information.
5. Understand that perspective and bias are present in source material and also affect the researcher’s perception of source material.
6. Understand that the type of audience defines scope, format, and content of the presented research.
Theory of Knowledge
Key Cognitive Strategies and Content Standards

1. Develop a curiosity about the nature of knowledge, an appreciation of its richness and diversity, and an understanding of the empowerment that follows from reflecting on it.
2. Develop an awareness of how communities and individuals construct and critically examine knowledge.
3. Understand the relationships among disciplines of human study.
4. Understand the connection between knowledge issues and international controversies.
5. Realize the importance of self-awareness in deepening one’s understanding of the world.
6. Develop an awareness of personal and ideological assumptions based on parental influences, religious persuasions, and political leanings.
7. Develop a sense of personal responsibility, originating from recognition of the relationships between knowledge, the community and the individual as citizen of the world.
8. Define the many and varied relationships between the knower, ways of knowing, and areas of knowledge.
9. Recognize, apply, and be able to distinguish among different kinds of knowledge—factual, applied, and understood.
10. Connect theoretical discussions of knowledge to real-life experiences and to subjects studied.
11. Critically examine the underlying assumptions and implications of one’s own knowledge claims and the knowledge claims of others, without egocentric or ethnocentric bias.
12. Generate questions, explanations, possible solutions, and alternative ideas in response to issues in the various areas of knowledge, ways of knowing, and students’ own experiences as learners.
13. Formulate and communicate ideas in essays and presentations clearly and responsibly with due regard for factual accuracy, intellectual honesty, and assignment or assessment specifications (focus on prompt/title, references to TOK diagram and other sources, adherence to word limit).
14. Apply aforementioned TOK skills to a concrete, contemporary issue.
15. Demonstrate recognition, understanding, and critical analysis of knowledge issues appropriate to a given topic, treating divergent points of view.
Mathematical Studies

Use of a Graphing Calculator
1. Use a graphing calculator to perform arithmetic calculations.
2. Use a graphing calculator to graph a variety of functions with an appropriate “window” and locate points to a given accuracy.
3. Use a graphing calculator to enter and manipulate data in lists.

Numbers and Algebra
4. Distinguish between and use natural numbers, integers, rational numbers, and real numbers.
5. Estimate solutions and make calculations with an appreciation for the reasonableness of the results.
6. Find and use percentage error.
7. Perform operations, with and without a calculator, with numbers expressed in scientific notation, including very large or very small numbers in scientific, economic and other applications.
8. Interpret and use the International System of units (SI) and other basic units including Celsius and Fahrenheit scales and conversions of units.
9. Know and use basic concepts of arithmetic and geometric sequences and series, including the general formula for the nth term and the sum of the first n terms, in applications, including simple and compound interest.
10. Solve pairs of linear equations in two variables using analytical and graphical methods.
11. Solve quadratic equations by factorization and find solutions by using a graphing calculator.
12. Know the meaning of and use zeros and factors when solving equations.

Sets, Logic, and Probability
13. Use verbal, symbolic, and Venn diagram descriptions interchangeably in logic and set theory.
14. Use in verbal and symbolic form compound statements: implication, equivalence, negation, conjunction, disjunction, and exclusive disjunction.
15. Use of truth tables to provide proofs for the properties of connectives.
17. Know the meaning of and use of implication, converse, inverse, and contrapositive statements.
18. Determine the logical equivalence of statements.
19. Know and use basic concepts of sample space, event, complementary event, and equally likely events.
20. Use Venn diagrams, tree diagrams and tables of outcomes to solve problems in probability.
21. Know and use the concept of independent events, including \( P(A \cap B) = P(A)P(B) \).
22. Know and use the concept of conditional probability, including \( P(A/B) = \frac{P(A \cap B)}{P(B)} \).
Functions
23. Know and use the basic concepts of a function as a mapping, including domain, range, and mapping diagrams.
24. Know and use the graphs and properties of linear functions \( f(x) = mx + c \).
25. Apply linear functions in applications, such as temperature conversion and car rental charges.
26. Analyze and graph the quadratic function \( f(x) = ax^2 + bx + c \), recognizing the axis of symmetry \( x = \frac{-b}{2a} \), the vertex, and intercepts.
27. Know and use the graphs and properties of exponential functions: \( f(x) = ax \), \( f(x) = a^\lambda x \) and \( f(x) = ka^\lambda x + c \), where \( k \neq 0, a, c \) and \( \lambda \) are rational numbers and \( a > 0 \) and \( a \neq 1 \).
28. Use the graphs and properties of exponential functions, including basic concepts of asymptotic behavior, to solve problems involving growth and decay, including population growth, radioactive decay and heating and cooling.
29. Know the graphs and properties of the sine and cosine functions \( f(x) = a \sin bx + c \) and \( f(x) = a \cos bx + c \) where \( a, b, c \) are rational numbers including finding the amplitude and period.
30. Know and apply the graphs and properties of sine and cosine functions to periodic phenomena, including tides, day length, and rotating wheels.
32. Sketch and analyze some simple unfamiliar functions using a graphic display calculator.
33. Solve equations involving simple combinations of unfamiliar functions using a graphic display calculator.

Geometry and Trigonometry
34. Use of coordinates in two dimensions, points, lines, midpoints, intersecting lines and distances between points.
35. Know and use the algebraic equation of a line in two dimensions, in both forms \( y = mx + c \) and \( ax + by + d = 0 \) where \( m = \text{gradient} \) and \( c = \text{y intercept} \).
36. Know and use the properties of parallel and perpendicular lines, including the use of \( m_1 = m_2 \) for parallel lines and \( m_1 \cdot m_2 = -1 \) for perpendicular lines.
37. Know and use concepts in right-angle trigonometry including the use of Pythagoras’ Theorem.
38. Know and use the right-triangle definitions of sine, cosine, and tangent.
39. Find values of inverse trigonometric functions using the graphing calculator.
40. Solve triangles using the Laws of Sine and Cosine.
41. Find the area of a triangle using the trigonometric formula \( A = \frac{1}{2} ab \sin C \).
42. Draw sufficient, well-labeled diagrams from verbal statements to support solutions.
43. Know and use the geometry of three-dimensional shapes, including surface area and volume for cuboids, right prisms, square-based right pyramids, cylinders, spheres, hemispheres, and cones.
44. Find the lengths of lines joining vertices with vertices, vertices with midpoints, and midpoints with midpoints in simple regular solids.
45. Find the size of an angle between two lines and the size of an angle between a line and a plane in simple regular solids.
Statistics
46. Understand the difference between discrete and continuous data.
47. Use frequency polygons, histograms, stem-and-leaf diagrams, frequency tables and box-and-whisker plots to depict distributions of discrete or continuous data, identifying mid-interval values and upper and lower boundaries.
48. Calculate and use measures of central tendency on a set of simple discrete data, including mean, median, and mode.
49. Calculate and use measures of central tendency on a set of grouped discrete or grouped continuous data, including approximate mean, 50th percentile and modal group.
50. Use of cumulative frequency tables and curves for grouped discrete or continuous data to find median, interquartile range and percentiles.
51. Understand the significance and obtain values for the standard deviation of a set of data using a graphing calculator.
52. Approximate lines of best fit in a scatter diagram by eye, passing through the mean point.
53. Interpret positive, negative and zero correlations in problems with bivariate data.
54. Know and use Pearson’s product-moment correlation coefficient $r$ in problems with bivariate data, including an awareness that $S_{xy}$ represents the covariance of the variables $X$ and $Y$.
\[ y - y = \frac{S_{xy}}{S_{x}^{2}} (x - x) \]
55. Use the formula to find the regression line for $y$ on $x$.
56. Use a regression line for prediction purposes, with an understanding of the effect of outliers and being aware that extrapolation (the use of a regression line beyond the region of the data) should not be used.
57. Obtain the equation of a regression line and the correlation coefficient from raw data using a graphing calculator.
58. Know and use concepts relating to the chi-square test for independence: formulation of null and alternative hypotheses; commonly used significance levels (1%, 5%, 10%); $h$ by $k$ contingency tables where $h, k \leq 4$; expected frequencies; degrees of freedom; tables of critical values; and $p$-values (with both the upper and lower one-tailed tests, but not with two-tailed tests).
59. Obtain a chi-square value from raw data using a graphing calculator.

Introductory Differential Calculus
60. Understand and use values of the derivative as the changing slope of a curve.
61. Know and use the limit definition for the derivative applied to a particular function, and calculate its difference quotient for given values of $h$ and $x$.
62. Know and use the rule that $f(x) = ax^n$ $\Rightarrow$ $f'(x) = anx^{n-1} \in Z$ to find the derivatives of polynomial functions.
63. Find the slope (gradient) of a curve of a function at a given point.
64. Use the derivative to find an equation of the tangent line at a given point.
65. Use the derivative to identify increasing and decreasing functions by finding values of $x$ where $f'(x) > 0$, $f'(x) < 0$, and $f'(x) = 0$, and interpreting this graphically.
66. Identifying values of $x$ for which $f'(x) = 0$ and finding the coordinates of local maximum and minimum points.
67. Application of the derivative to solve optimization problems.

Financial Mathematics

68. Perform currency conversions including transactions involving commissions.

69. Understand and use the simple interest formula $I = \frac{C r n}{100}$ where $C =$ capital, $r =$ rate, $n =$ number of time periods, $I =$ interest.

70. Understand and use the compound interest formula $I = C \times \left(1 + \frac{r}{100k}\right)^{kn} - C$ where $C =$ capital, $r\% =$ nominal interest rate, $I =$ Interest, $n =$ number of years, $k =$ number of compounding periods in a single year. Compound interest can be calculated yearly, half-yearly, quarterly, monthly or daily.

71. Application of the compound interest formula to depreciation problems.

72. Find $n$, the number of time periods in compound interest problems using iterative methods, successive approximation, or using a graphing calculator.

73. Construct and use tables involving loan and repayment methods, investments and savings, and inflation.
Mathematics: Standard Level

Algebra: Equations and Graphs
1. Use the laws of exponents and logarithms to write equations and to model and solve problems in applications, such as compound interest and exponential growth-and-decay models.
2. Use principles of transformations on functions to perform transformations on graphs: translations, vertical and horizontal stretches, reflections about the x-axis and y-axis, or combinations of these.
3. Use a graphing calculator to investigate key features of graphs, such as minimum and maximum points; roots of equations; zeros of functions; and vertical and horizontal asymptotes.
4. Perform algebraic operations on functions including composition and inversion of one-to-one functions.
5. Analyze and graph quadratic functions when given in different forms including $y = ax^2 + bx + c$, $y - k = a(x - h)^2$, and $y = a(x - p)(x - q)$ exploiting their respective features.
6. Analyze and graph basic functions including its inverse, and rational functions.
7. Factor polynomials and divide polynomials with possible remainder, and apply to the solutions of polynomial equations and inequalities including the graphical significance of repeated roots.

Algebra: Circular Functions and Trigonometry
9. Know and use radian measures of angles as decimals, or in terms of $\pi$.
10. Find the length of an arc, the area of a sector and the measure of an angle in a circle.
11. Know and use the definition of cos, sin and tan in terms of the unit circle.
12. Express lines through the origin as $y = x \tan \theta$ with gradient of $\tan \theta$.
13. Use the circular functions sin, cos, and tan, their domains and ranges, their periodic natures, and their graphs, to model and solve problems involving periodic phenomena.
14. Know and use the double-angle formulas: $\sin 2\theta = 2 \sin \theta \cos \theta$ and $\cos 2\theta = \cos^2 \theta - \sin^2 \theta$.
15. Find and interpret solutions, both analytically and graphically, of trigonometric equations over a finite interval, including those of the type $a \sin[(x + c)] = k$ and equations leading to quadratic equations in, for example, sin.
17. Apply triangle trigonometry concepts to applications in two dimensions, such as navigation.

Algebra: Matrices
18. Use matrices and matrix operations to store and process data.
19. Solve matrix equations involving addition, subtraction, and multiplication by a scalar.
20. Calculate the determinant of 2x2 and 3x3 matrices.
21. Find the inverse of a non-singular 2x2 matrix without a calculator.
22. Use the inverse matrices to solve systems of up to three linear equations with a unique solution.
Statistics and Probability
23. Present discrete and continuous data using frequency tables, frequency diagrams, histograms and box-and-whisker plots.
24. Calculate and use measures of central tendency on a set of data: mean, median, and mode.
25. Calculate and use measures for range, quartiles and inter-quartile range on a set of data.
26. Understand the significance and obtain values for variance and standard deviation for data using a graphing calculator.
27. Estimate a mean or standard deviation using mid-interval values for grouped data.
28. Use cumulative frequency tables and graphs to estimate medians, quartiles, and percentiles.
29. Use counting principles, including permutations and combinations, in simple applications.
30. Use Venn diagrams, tree diagrams, and tables of outcomes to solve problems.
31. Know and use the concepts of combined events, including \( P(A \cup B) = P(A) + P(B) - P(A \cap B) \) and that the “or” operator is not exclusive.
32. Know and use concepts of conditional probability, including the definition \( P(A/B) = P(AB)/P(B) \).
33. Know and use concepts of independent events, including the formula \( P(AB) = P(A)P(B) \).
34. Know and use the concepts of discrete random variables and their probability distributions to solve problems in probability.
35. Know and use the formula \( E(X) = \Sigma xp(X = x) \) in applications that would include, for example, games of chance.
36. Know and use basic properties of the binomial distributions.
37. Know and use properties of the normal distribution to solve problems in probability.

Calculus: Derivatives and Integrals
38. Understand and use ideas of limits and convergence informally.
39. Know and use the limit-definition to find the derivative of a polynomial function.
40. Interpret and use the derivative as a new function.
41. Use the derivative to find the equations of tangent lines and normal lines to a graph.
42. Find derivatives of sums, real multiples, and products and quotients of functions.
43. Know and use the chain rule.
44. Use the first and second derivatives to study and graph functions, including tangents and normals to the graph as well as its curvature.
45. Use the first and second derivative in optimization problems, including profit, area, and volume.
46. Understand and use indefinite integration as anti-differentiation.
47. Know and use the indefinite integrals of \( x^n \) (\( n \) is rational), sinx, cosx, \( 1/x \), \( e^x \).
48. Know and use the technique of integration by substitution.
49. Use a boundary condition to determine the constant term in anti-differentiation.
50. Use definite integrals to find areas under curves (between the curve and the x-axis), and areas between curves.
51. Use definite integrals to find volumes of revolution about the x-axis.
52. Solve kinematic problems involving displacement, velocity, and acceleration, including the understanding that area under the velocity-time graph represents distance traveled.
53. Know and use the Riemann Sum definition of the Integral in applications, and know and use The Fundamental Theorem of Calculus.

**Multi-Variable Calculus: Vectors**

54. Know and use basic concepts of vectors as displacements in the plane and in three dimensions.

55. Know and use algebraic and geometric methods to find the sum or difference of vectors, unit vectors, the negative of a vector, scalar multiples of a vector, and the magnitude of a vector.

56. Use vectors to find the distance between two points in three dimensions.

57. Know and use vectors in column and standard \(\mathbf{i}, \mathbf{j}, \mathbf{k}\) component forms.

58. Use position vectors to find a vector between two points.

59. Calculate the scalar product of two vectors (also known as “dot” or “inner” product).

60. Understand and use vector concepts of perpendicular and parallel vectors.

61. Use the vector equation of a line in distance-time-velocity applications.

62. Use vectors to measure the angle between two lines.

63. Use vectors to distinguish between coincident and parallel lines.

64. Use vectors to find points where lines intersect in two and three dimensions, knowing that non-parallel lines may not intersect in three dimensions.
Mathematics: Higher Level

Algebra: Proofs, sequences, series and complex numbers
65. Form and prove conjectures using mathematical induction.
66. Find the $n^{th}$ term and the sum of a finite arithmetic or geometric series to solve problems in applications, such as compounded interest and population growth.
67. Find the sum of an infinite geometric series, possibly expressed in sigma notation.
68. Know and use the binomial theorem in the expansion of $(a + b)^n$ where $n$ is a positive integer, using Pascal’s triangle or a graphing calculator.
69. Manipulate and plot complex numbers in their Cartesian form, $z = a + bi$, and in their polar form $=r(\cos + i \sin)$, with an awareness that $=r(\cos + i \sin)$ can be written as $z = re^{i\theta}$.
70. Prove and use De Moivre’s theorem to find powers and roots of complex numbers.
71. Find the graphs of functions involving absolute values $y = |f(x)|$ and $y = f(|x|)$, from $y = f(x)$.
72. Conjugate roots of polynomials with real coefficients.
73. Solve absolute value inequalities, analytically and graphically.

Algebra: Trigonometry
74. Know and use the definitions of sec, csc, and cot, in terms of sin and cos.
75. Use and prove compound-angle identities, including $\sin(A \pm B)$, $\cos(A \pm B)$, and $\tan(A \pm B)$.
76. Know and use the inverse trigonometric functions: arcsin, arccos, and arctan; and their domains, ranges and graphs.
77. Use trigonometric identities and factorization to solve equations, both analytically and graphically.
78. Apply concepts of triangle trigonometry to problems in two and three dimensions including such applications as navigation.

Algebra: Matrices
79. Know and use the theorem that $\det AB = (\det A)(\det B)$.
80. Solve a system of linear equations using augmented matrices and row reduction.

Statistics and Probability
81. Understand that the population variance is generally unknown and that the sample variance serves as an unbiased estimator of this quantity.
82. Use Bayes’ theorem applied to two events A and B: $P(B/A) = \frac{P(B)P(A/B)}{P(B)P(A/B) + P(B')P(A/B')}$
83. Define and use probability-density functions.
84. Know and use concepts of mean, mode, median, variance, standard deviation, and expected value in applications that include games of chance.
85. Find the variance of a binomial distribution.
86. Know and use properties of the Poisson Distribution to solve problems in probability including its mean and variance.
Calculus: Derivatives and Integrals
87. Know and use the derivatives of $a^x$ and $\log_a x$.
88. Know and use the derivatives of arcsin $x$, arccos $x$, and arctan $x$.
89. Apply the chain rule to solve problems involving related rates of change.
90. Use implicit differentiation.
91. Interpret an indefinite integral graphically as a family of curves.
92. Use definite integrals to find volumes of solids of revolution about the y-axis.
93. Use integration by parts to integrate functions, including functions that require repeated integration.
94. Find solutions of first-order differential equations by separation of variables.

Multi-Variable Calculus: Vectors
95. Know and use the Cauchy-Schwartz inequality.
96. Represent equations of lines in parametric and Cartesian forms.
97. Find the vector product of two vectors, (cross product), including its determinant form.
98. Use the geometric interpretation of the magnitude of the vector product to find areas of triangles and parallelograms.
99. Use vectors to represent a plane in the form $r = a + \lambda b + \mu c$.
100. Represent a plane using the Cartesian equation $ax + by + cz = d$.
101. Use a normal vector to obtain the equation of a plane in the form $r \cdot n = a \cdot n$.
102. Use vectors to find intersections: of a line with one plane, of two planes, or of three planes, knowing that three planes may intersect in a point, in a line, not at all, or be coincident.
103. Use the inverse matrix method or the row reduction method (Gauss method) to find the intersection of three planes.
104. Use vectors to find the angle between a line and a plane and between two planes.
Mathematics Key Cognitive Strategies

A. Appreciation and Structure of Mathematics
   1. Appreciate the multicultural and historical perspectives of mathematical discoveries and learning, and the mathematicians involved.
   2. Appreciate the elegance, power and usefulness of mathematics.
   3. Appreciate the (relative) universality of mathematics as a means of communication.
   4. Appreciate the connections within and amongst the various branches of mathematical inquiry.

B. Thinking, Reasoning, and Learning Mathematically
   1. Employ and refine powers of abstraction and generalization.
   2. Develop logical, critical and creative thinking.
   3. Recognize and express patterns and structures.

C. Problems and Models
   1. Use mathematical concepts to formulate problems and develop models.
   2. Select and use appropriate mathematical strategies and techniques to solve problems.
   3. Develop patience and persistence in problem solving.
   4. Know the limitation of technological devices.

D. Communicating in Mathematics
   1. Communicate clear and coherent mathematical arguments and expositions in a variety of contexts.
Chemistry Content Standards

Structure of an Atom
1. Describe the basic composition of atoms and the properties of the three main sub atomic particles.
2. Describe the properties of different isotopes of the same element and determine their composition from mass and atomic numbers.
3. Understand the operation of the mass spectrometer and how it can be used to determine the isotopic abundance of an element.
4. Distinguish between atomic mass, molecular mass and formula mass, and understand the concept of relative atomic (or molecular) mass.

Electronic Structure
5. Describe the electronic structure of atoms in terms of main energy levels.
6. Define ionization energy and understand the evidence that ionization energies provide for electronic structure.
7. Describe the relationships between an atom’s electron configuration, position on the periodic table, and chemical properties.
8. Describe atomic emission spectral data and its relevance to electronic structure.

Periodic Properties and the Periodic Table
9. Understand the structure of the periodic table.
10. Use the periodic table to predict and describe properties of elements and their atoms.

The Mole
11. Understand the meaning of the mole, relative atomic (and molecular) mass and molar mass.
12. Understand the terms and know how to calculate an empirical formula and/or molecular formula of a given compound.

Chemical Equations
13. Understand the basic changes that take place at the molecular level in chemical reactions.
14. Know how to balance a variety of chemical reactions and use state symbols correctly.
15. Be able to solve quantitative stoichiometry problems using balanced chemical equations for reactions and products in solid, liquid, gaseous and aqueous phases.
16. Solve problems and analyze graphs related to the ideal gas equation.

Bonding, Intermolecular Forces, and Properties of Substances
17. Know and compare the major bonding models.
18. Use the VSEPR principle to derive the shapes of molecules.
19. Know and compare the structure of the isotopes of carbon, silicon and silicon dioxide.
20. Describe the intermolecular forces and their effects on physical properties of substances.
21. Predict the relative values of melting and boiling points, volatility, conductivity, solubility, and reactivity based on the different types of bonding and intermolecular attractions in substances.
Equilibrium
22. Describe an equilibrium system in terms of its qualitative and quantitative characteristics.
23. Describe the factors that may impact equilibria.

Acids and Bases
24. Describe the behavior of strong and weak acids and bases in aqueous solution.
25. Know the Bronsted-Lowry and Lewis theories of acids and bases.
26. Know the meaning of pH and understand the pH scale.
27. Understand acid-base reactions and interpret acid-base experimental data.

Kinetics
28. Explain the action of the factors that affect reaction kinetics using the collision theory and Maxwell-Boltzman energy distribution.
29. Understand how to measure and analyze data from chemical reactions.

Enthalpy, Entropy, and Free Energy
30. Understand the concept of enthalpy as it applies to chemical reactions.
31. Use experimental methods to determine enthalpy changes in chemical reactions.
32. Use a variety of methods to calculate enthalpy changes in chemical reactions.
33. Apply Hess’s Law to determine unknown enthalpy change values for a range of systems.

Electrochemistry
34. Understand a range of redox reactions in terms of reduction and oxidation and balance redox equations.
35. Describe the components of an electrochemical cell.
36. Distinguish between voltaic and electrolytic cells.
37. Describe the characteristics and uses of electrolytic cells.
38. Know how to determine the feasibility of a redox reaction from a given reactivity series.

Organic Chemistry and Biochemistry
39. Describe the features and trends of a homologous series.
40. Distinguish between empirical, molecular and structural formulas.
41. Apply IUPAC conventions to name non-cyclic organic compounds up to C6 and to classify compounds as primary, secondary and tertiary.
42. Know structural formulas for the isomers of the non-cyclic organic compounds up to C6.
43. Know some characteristic properties and reactions of non-cyclic organic molecules.
44. Know the meaning of and draw representations to show SN1 and SN2 mechanisms.
45. Plan a sequence of reactions in order to obtain a target organic molecule.

Measurement and Data Processing
46. Construct graphical representations to collect and analyze results of scientific investigation.
47. Identify the uncertainty in experimental measurements and state the uncertainty in calculated results as absolute and percentage values.
Physics Content Standards

Notation and Mathematics
1. Use graphical representations to collect and analyze results of scientific investigation.
2. Identify the uncertainty in experimental measurements.
3. Use estimation, scientific notation and significant figures for a uniform representation of measured quantities and results of calculations.
4. State the magnitudes of sizes, masses and times that occur in the universe.
5. Demonstrate problem-solving skills.
6. Use the International System (SI) of units to convert between fundamental and derived units of measurement.
7. Describe quantities that carry information on magnitude, unit of measurement and direction as vectors and use vector properties to manipulate two or more vectors.

Classical Motion (Newton's Laws, Momentum, Energy)
8. Describe diverse motion of objects using the equations of motion and their graphical representations.
9. Use Newton’s laws as an alternative means to describe the motion of objects.
10. Compare and contrast the concepts of mass, weight and inertia.
11. Use momentum and the conservation of momentum to describe the motion of objects due to interactions and/or collisions.
12. Use the kinetic and potential energy concepts and the principle of conservation of energy to describe motion of objects and energy transformations.
13. Distinguish between and apply the concepts of work, energy, power and efficiency.
14. Apply the concepts of force, speed and acceleration to motion in a circle.

Heat and Thermodynamics
15. Use the meaning of temperature and explain the construction of a scale of temperature.
16. Describe the processes of thermal energy transfer.
17. Consider the thermal properties of matter in relation to heat capacity, latent heat and evaporation.
18. Use the ideal gas law and kinetic theory of gases to describe an ideal gas both macroscopically and at the molecular level.
19. Use the thermal conductivity, heat capacity and specific-heat capacity concepts to analyze heat transfer.

Electricity and Magnetism (Static and Dynamic)
20. Use basic properties of charged particles and Coulomb's law to describe, illustrate and calculate electric forces, electric fields and electric potentials.
21. Describe magnetic fields and calculate the magnitude and direction of magnetic forces on moving charges.
22. Describe and calculate current, resistance, voltage, and power for various DC and AC circuits.
Energy, Power and Climate Change
23. Construct and analyze energy flow diagrams.
24. Compare and contrast world energy sources.
25. Compare different methods of fossil and non-fossil fuel power production
26. Consider the causes and implications of the greenhouse effect and global warming.

Waves and Vibrations
27. Describe oscillations. Define the particular case of simple harmonic motion, use the equations for displacement, velocity and energy within a SHM system.
28. Describe and use the physical and mathematical conditions relating to resonance.
29. Describe waves using wavelength, frequency and other basic parameters and use these parameters to calculate and visualize the transmission of waves through different media.
30. Use the principle of superposition of waves to explain and calculate standing wave patterns and beat frequencies.
31. Use the laws of reflection, refraction and diffraction to determine the path traveled by a wave and to determine interference patterns.
Biology Content Standards

The Chemistry of Life
1. Understand how the relationship between the properties of water and its uses in living organisms makes life on earth possible.
2. Know that life depends on highly regulated chemical reactions within all cells and understand the importance of enzymes and redox reactions to cell metabolism.

All Functions of Life Occur at the Cellular Level
3. Know that all living organisms are composed of cells, that the cell is the smallest unit of life and that all cells are formed from other cells.
4. Understand that there are many different kinds of cells, but that all cells share certain fundamental structural and functional characteristics.
5. Understand why cells must exchange substances with their surroundings and know how cells regulate the passage of substances across biological membranes.
6. Understand how energy flows through living organisms as they release and utilize energy from the environment.

Cell Reproduction and Heredity
7. Understand how cells divide to reproduce and know why the new generation of cells is genetically identical to the parent cell.
8. Understand how characteristics are passed from one generation to the next and that variations of a characteristic are due to the inheritance of a different version of the same gene.
9. Understand how the structure of DNA relates to its function as the store of genetic information. Know how this information is accessed and used by the cell when required for specific cell activities.
10. Know why the genetic code is a universal code used by all organisms and understand how technology makes use of this.

Ecology, Evolution and the Diversity of Life
11. Understand that evolution is an on-going process and understand the evidence that it is responsible for the biological change that leads to the diversity of life on Earth.
12. Understand how organisms are classified into groups based on similar physical and genetic characteristics and know how these characteristics indicate how different groups of organisms are related.
13. Understand the need for organisms to utilize energy and raw materials from the environment and understand why the success of an organism or a population of organisms depends on the availability of adequate resources.

Multi-cellular Organisms and Organ Systems
14. Understand that all living organisms regulate their internal environment and know the means by which organisms regulate the necessary exchange of substances with their surroundings.
15. Know that complex, multicellular organisms rely on specialized cells, tissues and organ systems; to maintain their internal environment, to respond to their surroundings and to reproduce.
Methodologies and Tools of Biological Studies

16. Be familiar with tools and techniques and their use in the study of biology. Understand the importance of traditional approaches such as microscopy and also of the continued development of new techniques based on molecular biology and DNA analysis.

17. Understand that biology is a quantitative science and that mathematical reasoning and statistical analysis are essential to the study of living organisms and the environment.

Science and Society

18. Understand how the study of biology contributes to the health of the citizens of the world and how biological research improves the diagnosis, treatment, and prevention of globally important diseases.

19. Understand the impact of human societies on the world environment and the importance of biological research in the effort to minimize the negative effect of humans on the ecosystem.
Science Key Cognitive Strategies

A. Seeks to know and be able to apply the body of knowledge, methods and techniques that characterize science and technology.
   1. Acquire experimental and investigative scientific skills in order to creatively examine scientific problems.
   2. Use information technology in the study of science.
   3. Actively analyzes, evaluates, and synthesizes scientific information.

B. Understand that the contemporary practice of science is often collaborative and multidisciplinary.
   1. Understand the need for, and the value of, effective collaboration and communication among scientists during scientific activities.
   2. Understand the relationship between scientific disciplines and that the process of science often involves an interaction between scientists of two or more scientific disciplines.
   3. Appreciate how information technology facilitates the study and communication of science.

C. Understand scientific study in a global context.
   1. Appreciate that major achievements in science often are accomplished by efforts of groups of scientists from different parts of the world.
   2. Understand that some scientific questions have global importance, but local and national perspectives can influence how they are approached.

D. Understand the interplay between science, technology and society.
   1. Be aware of the moral, ethical, social, economic and environmental implications of using science and technology.
   2. Understand the possibilities and limitations associated with science and the scientists who study it.

E. Understand that the practice of science requires self-motivation and self-evaluation.
   1. Approach learning in a principled manner, taking responsibility for one’s own learning.
   2. Develop a strong intrinsic desire to inquire and to learn.
Laboratory Process Skills

A. Be able to carry out the scientific method to investigate a scientific question.

1. Be able to generate an investigable question and its possible answer.
   a. Define a problem or research question.
   b. Demonstrate how to formulate a hypothesis or prediction.

2. Be able to design an appropriate experimental method.
   a. Select the appropriate apparatus or materials.
   b. Design a method to collect sufficient relevant data.
   c. Select independent, dependent, and controlled variables.
   d. Design a method to control variables.

3. Be able to work safely and in accord with environmental regulations.
   a. Follow laboratory instructions accurately and seek assistance when required.
   b. Perform laboratory procedures and use equipment competently and safely.
   c. Use appropriate handling and disposal methods for any hazardous materials.
   d. Perform laboratory work with regard to its impact on the environment.

4. Be able to accurately collect and record data.
   a. Collect and record raw data, including units and uncertainties where appropriate.
   b. Organize and present raw data for easy interpretation.
   c. Process raw data accurately, using mathematical and graphical approaches where appropriate.

5. Be able to interpret, evaluate, and present experimental data and methods.
   a. Evaluate procedures and results, recognizing limitations and errors, and provide realistic suggestions for improving an experiment.
   b. Draw valid conclusions based on the correct interpretation of the results and compare to literature values where appropriate.
   c. Present processed data, taking into account errors and uncertainties.
   d. Understand and describe the environmental impact of an investigation.

6. Be able to use information and communication technology in practical work.
   a. Use ICT applications to assist in processing and understanding data: data logging in an experiment, software for plotting graphs, spreadsheet for data processing, database, computer modeling/simulation, etc.

B. Work within the context of a scientific community and the standards set by the global community of scientific investigators.

1. Demonstrate self-motivation and perseverance in completing a laboratory investigation.

2. Collaborate effectively with others on a team by acknowledging their views, exchanging ideas with others, and integrating new ideas.

3. Work in an ethical manner by recognizing the work of collaborators, and by accurately and honestly presenting data.

4. Work in an ethical manner by designing labs/experiments and investigations in laboratories or in fieldwork that obtain informed consent from human participants, inflict no stress or pain on humans or animals, and do no damage to the local or global environment.