REFORM OF TEKS HIGH SCHOOL CHEMISTRY STANDARDS FOR BETTER COLLEGE AND CAREER PREPARATION

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HONORS THESIS

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By

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Abstract

During the 1980's, the concept of standards-based education was conceived after norm-referenced ranking in education was widely recognized as a flawed system to measure student success in the class room. Standards in primary and secondary education began to be implemented in some American states to hold school systems accountable for curricula and student performance. While establishing standards in secondary education is more controversial, it is necessary to ensure that high school diplomas are meaningful and represent a thorough knowledge and understanding of Mathematics, Science, Social Studies, and Language Arts that meets the needs of the modern work force. Standards in high school chemistry are no exception; these standards should include concepts and objectives that will prepare students for chemistry in college as well as careers or occupations that require a fundamental knowledge of chemistry. The Texas State Board of Education recently passed revised chemistry standards in March of 2009 which will replace the current Texas Essential Knowledge and Skills (TEKS) high school chemistry standards in the Fall of 2010. This study compares the revised and recently passed TEKS chemistry standards to the current TEKS chemistry standards that were adopted in 1998. Based on alignment, the revised TEKS chemistry standards more reflect the College and Career Readiness Standards, as well as the chemistry standards of other states renowned for exemplary education including New York, California, North Carolina, and Massachusetts.

Standards in Education

Content standards in education are a set of criteria for each subject, describing the fundamental concepts and areas of study expected to be taught by teachers and understood by students for a particular grade or level. Standards in education are established to hold school systems accountable by measuring how well students perform on a standardized scale. Without standards, curricula would differ from one school district to the next; creating an advantage or disadvantage for students based on the district to which they are assigned to. When these differences were noticed, state and national standards were implemented to avoid this problem.

History of Standards-based Education

During the late 1980's, the move toward standardization of education in the United States began to take place (1). The traditional education system based on norm-referenced ranking, where student success was based on average performance in a local setting, was recognized as an inadequate measure of student performance. Furthermore, norm-referenced ranking does not determine what concepts students have actually learned, instead they sort and rank students according to their scores which provides a pass or fail bell-curve based on the "average" performance (2). As a result, legislators, administrators, and educators of some states, including Arizona, California, Florida, Georgia, Minnesota, and Pennsylvania, began creating statewide standards describing what students should know and be able to do at specific levels of education to hold teachers and schools accountable (3). These academic standards later became the basis for assessments, curricula, and professional development for educators (1). Furthermore,

at the 1996 National Education Summit, three major priorities were set for all school systems nationwide: high academic standards and expectations of all students, more rigorous and challenging tests that are able to measure whether students are meeting those standards, and accountability systems which provide incentives and rewards for teachers, students, and parents for helping students reach those standards (4). Following the summit, several more states such as Colorado, Iowa, Michigan, and North Carolina, implemented education standards and the U.S. Department of Education mandated the National Research Council to create nationwide standards, as well (4)(5). In 2001, the No Child Left Behind Act was passed by Congress and signed by President George W. Bush on January 8, 2002. This law federally mandated standardized testing, encouraging accountability of all public schools in the U.S (6). Since 2002, some statewide standards have been or are in the process of being further reformed (7).

The Theory Behind Standards-based Education

The intent of standards-based education is that every student, regardless of age, race, gender, cultural or ethnic background, social status, disabilities, or family situation will have the opportunity to learn the same material as other students elsewhere. However, no student will be exempt from learning the material which is required to be promoted to the next grade level.

The actual theory is that every student who graduates will receive a meaningful diploma. Additionally, a diploma should serve as a guarantee that graduates possess a thorough knowledge in the four core academic subjects: English, Mathematics, Science, and Social Studies, relevant to future employment or higher education needs.

Chemistry in High School

The word chemistry makes some people cringe. While it is true that chemistry is a difficult subject, it can also be fun and interesting. Chemistry is all around you and it can be observed at almost any moment in everyday life. As written in the National Science Education Standards overview, “Everyone deserves to share in the excitement and personal fulfillment that can come from understanding and learning about the natural world,” (5). The opportunity to learn chemistry should be embraced, not dreaded.

The subject of chemistry is also important because it is an essential discipline for doctors, nurses, pharmacists, nutritionists, laboratory research scientists, biologists, industrialists, botanists, geneticists, etc. Getting a college degree for any of these occupations requires *at least* two courses in college chemistry. In addition, students who pursue a Bachelor’s degree in Texas are required to complete a natural science core in college, in which chemistry may be selected to fulfill that requirement (8). Therefore, students with a strong chemistry background from high school usually have a smoother and more successful transition into college chemistry (9). Furthermore, learning chemistry in high school is highly beneficial in many post high school trades or technical occupations, including but not limited to: cosmetology, culinary arts, housekeeping, landscaping, HV/AC, etc (9).

But what is considered a strong chemistry background? A broad scope of chemistry concepts would include atomic theories (Bohr and Rutherford), molecular structure, trends and characteristics of the periodic table, chemical bonding, models and shapes of molecules (VSPER theory), chemical names and formulas, the mole, acids and bases, chemical equations and reactions, stoichiometry, types of reactions, reaction rates,

chemical equilibrium, chemical thermodynamics, solutions, gas laws (Ideal, Boyles, and Charles), and nuclear chemistry. On a high school level, at least an introduction to each of these concepts should be taught in order to build a strong chemistry background for students with career goals whether it be pursuing higher education, trade school, or immediate employment.

In order to ensure that these chemistry concepts are being introduced in high school, states should include them all in their official educational standards for 9-12 chemistry. Some states, such as New York and California have already taken these measures, as will be discussed later. However, other states, such as Texas, do not have most of these chemistry concepts included in their *current* high school chemistry standards and are in the process of reforming them.

TEA and High School Chemistry Standards

The Texas Education Agency (TEA) is comprised of the Texas Commissioner of Education, the fifteen elected members of the State Board of Education, and select agency staff. One of TEA's roles and responsibilities is to oversee development of the statewide curriculum, meaning to pass or revise state education standards (10). The Texas education standards are also known as Texas Essential Knowledge and Skills (TEKS).

Currently, TEA holds school systems accountable for teaching TEKS and measures student mastery of these standards via TAKS (Texas Assessment of Knowledge and Skills) standardized testing. On a high school level, four TAKS exit-level tests are administered- Reading, English Language Arts, Science, and Social Studies; students must pass each TAKS test to graduate (11). The Science TAKS test is based on current IPC (Integrated Physics and Chemistry) and Biology TEKS standards, rather than all the current individual Physics, Chemistry, and Biology TEKS standards combined (12). This has created a large problem in high school chemistry classrooms across Texas. School systems expect students to do well on TAKS tests and in order to make sure that happens, high school chemistry teachers have been known to switch from teaching chemistry to teaching IPC in the middle of the Spring semester to prepare their students for the Science TAKS test. When high school chemistry teachers do this, they are depriving their students from learning and mastering necessary chemistry concepts that colleges and some occupations expect them to know out of high school (9). In 2007, Texas Senate bill 1031 was passed which required that by the 2011-2012 school year, twelve end-of-course (EOC) assessments in Algebra I, Algebra II, Geometry, Biology, Chemistry, Physics, English I, English II, English III, World Geography, World History and United States

History will be developed to replace the four current TAKS exit level tests (13). These EOC assessments will be based on the individual standards of those twelve courses. Currently, students will be expected to take all twelve EOC assessments; each score which will count towards 15% a student's overall grade per respective course. In order to graduate students must pass and complete all twelve courses; it is not yet clear whether students will have to pass all EOC assessments as well (13).

The current TEKS chemistry standards for high school were implemented on September 1, 1998. Since then, these standards have been criticized as too general, too facile, and have even been called a "joke" by some higher educators. In fact, many of the authors of the current TEKS chemistry standards are biology majors whom are quite far from chemistry experts (14). In 2006, efforts began to propose new revisions of the TEKS chemistry standards to TEA. In January 2009, final revisions were made and the proposal was sent to the Texas State Board of Education to be reviewed at the March 26-27 meeting. Following review, the new and revised high school chemistry TEKS standards were passed and said to be implemented beginning the 2010-2011 school year (15).

This study attempts to defend the new and revised TEKS chemistry standards as an improvement from the current TEKS chemistry standards in preparing high school students for chemistry in higher education or technical and trade occupations. Both the new and current TEKS chemistry standards will be compared, contrasted, and aligned to the Texas College and Career Readiness Standards in chemistry, as well as the chemistry high school standards of other states, including New York, California, Massachusetts, and North Carolina.

Current TEKS Chemistry Standards

The current TEKS chemistry standards include 37 concepts under 11 objectives: characteristics of matter, physical and chemical changes, atomic structure, gas behavior, chemical bonding, nuclear chemistry, oxidation-reduction reaction, chemical equations, solutions, colligative properties of solutions, acids and bases, and chemical reactions (16). Although this list of objectives may seem to suffice, many deficiencies have been overseen in the current TEKS chemistry standards.

First, the organization of the standards is poor and the wording is vague. Oxidation–reduction reactions, an objective in the current TEKS chemistry standards, are a type of reaction and are typically included in other chemistry standards under the objective of types of reactions. Another objective, “colligative properties of solutions” is usually entailed within the behavior of solutions objective in other chemistry standards. Furthermore, some concepts within the objectives almost do not relate to the chemistry objective at hand. For example, one concept under the chemical equations objective states, “The student is expected to identify common elements and compounds using scientific nomenclature.” The concept of chemical and molecular nomenclature is typically included in other chemistry standards under the chemical bonding objective. Some concepts are so vague that teachers may have difficulty comprehending what they are expected to teach. How are teachers supposed to teach their students the concept which is described, “Demonstrate electrical conductivity of acids and bases,”? Perhaps they are supposed to teach the complete dissociation of strong acids and bases, as well as the partial dissociation of weak acids and bases, but how can one be sure? The ambiguity

in the wording does not provide assurance, and teachers are left to interpret vague concepts the best they can.

Second, several of the concepts that make up a solid chemistry background are missing from these standards: trends and characteristics of the periodic table, models and shapes of molecules, chemical names and formulas, the mole and stoichiometry, reaction rates, chemical equilibrium, gas laws, and chemical thermodynamics (5, 17, 18). These concepts should be included in the standards.

Third, concepts such as characteristics of matter and physical and chemical changes should be included in the general science standards for primary education. These concepts should already be familiar to high school students before they ever walk into a chemistry classroom. High school chemistry teachers should not have to waste valuable time going over material that students have been going over since elementary school.

Fourth, many concepts are more physics or biology based than chemistry based and thus belong in biology, physics, or IPC standards, rather than the chemistry standards. These objectives include: “identify and measure energy transformations…”, “evaluate environmental issues associated with the storage, containment, and disposal of nuclear wastes…”, “evaluate the significance of water as a solvent in living organisms and in the environment…”, and “describe the effects of acids and bases on an ecological system…”

Finally, one notable objective which was experiment based could be perceived as too specific and too easy for a high school level: “analyze and measure common household products using a variety of indicators to classify the products as acids or bases…” This objective specifically uses chemistry as a tool, which is not unreasonable;

however, if a student does not learn the actual chemistry behind the application then the entire experiment might as well be considered worthless. In addition, teachers should be able to choose which experiments they would like to do to demonstrate specific concepts.

The current TEKS chemistry standards are not all bad, however. Some key chemistry concepts were included, and the standards for scientific processes were well outlined and up to par.

New and Revised TEKS Chemistry Standards

These TEKS chemistry standards include 42 concepts under 8 objectives: characteristics of matter, periodic table, atomic theory, types of bonds (ionic, metallic, covalent), quantitative chemistry (the mole and stoichiometry), behavior of gases and kinetic molecular theory, behavior of solutions, chemical thermodynamics, and nuclear chemistry (19).

The new TEKS chemistry standards are worded clearly and precisely with much detail and without ambiguity. Therefore, there is much less uncertainty about what teachers are expected to teach compared to the current TEKS chemistry standards. For example, a concept under the atomic theory objective states, "The student is expected to understand the experimental design and conclusions used in the development of modern atomic theory including Dalton's postulates, Thomson's discovery of electron properties, Rutherford's nuclear atom, and Bohr's nuclear atom."

All concepts within the new standards are parallel with the objectives they are listed under. Although the new chemistry standards are more organized, there is one noticeable flaw: objective 10, which states "The student understands and can apply the factors that influence the behavior of solutions…" This objective could be considered a generality in that it encompasses solutions and solubility, types of reactions, and acids, bases, and pH within 10 concepts. For organization purposes, these concepts should have been split into three separate objectives, rather than pooled into one.

The new and revised standards include thirteen calculations, whereas the old standards were completely devoid of calculations. Calculations are necessary in chemistry, especially when formulas illustrate a concept such as the mole, empirical and

molecular formulas, the ideal gas law, limiting reagents, etc. With calculations in the standards, students are expected to know how to use formulas rather than just memorize them.

The objectives and concepts within the new TEKS standards capture the essence of chemistry and leave out unnecessary concepts that are more biology or physics based. A strong chemistry background can be obtained if a student were to master these new high school chemistry TEKS standards which would benefit them in their post high school endeavors.

Alignment of Current and Revised Chemistry TEKS Standards with College and Career Readiness Standards

In 2006, the 79th Texas Legislature passed House Bill 1, "Advancement of College Readiness in Curriculum," which required TEA, the Texas Higher Education Coordinating Board (THEBC), and selected secondary and post-secondary faculty to collaborate and establish College Readiness Standards in English Language Arts, Mathematics, Science, and Social Studies (9). The final draft of the *Texas College Readiness Standards* was adopted by the Texas Higher Education Coordinating Board on January 24, 2008 (9). The purpose of these standards describes what high school graduating students must know to succeed in entry-level courses of higher education institutions in Texas without remedial courses (9). In early 2009, the THECB changed the name of these standards to the *Texas College and Career Readiness Standards*. Texas is one of the first states to actually adopt and implement standards of this kind (20). By implementing these standards, the Texas Higher Education Coordinating Board hopes the College and Career Readiness Standards will "pave the way to better alignment between the public and higher education curriculum"(20).

Alignment of the current and revised TEKS chemistry standards with the Texas College and Career Readiness standards was achieved by matching concept for concept. The College and Career Readiness Standards for chemistry comprise of 68 total concepts. While the wording was not exact from document to document, key words were used from these concepts for matching purposes.

The alignment of the current TEKS chemistry standards with the College and Career Readiness Standards was 22 of 68 concepts- 32.4%, and the alignment of the

revised standards was 38 of 68 concepts- 55.9%. The new and revised TEKS chemistry standards were almost two times more aligned than the current TEKS chemistry standards. While the ambiguity of the wording in the current TEKS standards may have played a factor in the low alignment percentage, the new and revised standards were still significantly higher.

Apparent from the alignment scores, several chemistry concepts were included in the College and Career Readiness Standards that were not in either the new and revised standards or the current standards. Some of these concepts including chemical equilibrium and Le Chatelier's Principle, phase diagrams and heating curves, and categories of biological molecules (proteins, carbohydrates, lipids, etc.) are especially suitable for a high school level in terms of difficulty. Therefore, they *should* absolutely be incorporated in the TEKS chemistry standards.

While the new and revised TEKS chemistry standards are just over 50% aligned to the Texas College and Career Readiness Standards, they are step in the right direction to better preparing high school student for post-secondary education endeavors.

Alignment of Current and Revised Chemistry TEKS Standards with High School Chemistry Standards in Other States

The new and current TEKS chemistry standards were aligned to the high school chemistry standards of New York, California, North Carolina, and Massachussetts, to compare the range of chemistry concepts by matching concept for concept. In addition, these specific states were chosen because they are home to many popular universities in the country; these universities likely expect their incoming freshman to possess a knowledge base which comprises of at least the standards of that state. Not all students whom graduate from a Texas public high school and go on to higher education will attend a Texas university, so it is important to evaluate how Texas measures up to other states in terms of high school standards.

New York

The high school chemistry standards of New York State included 113 total concepts (21). The standards were highly detailed and specific which produced such a large number of concepts. One highly noticeable difference between the New York chemistry standards and both TEKS chemistry standards was that the New York standards included an organic chemistry objective which included six concepts; all students taking high school chemistry in New York are expected to know those six organic chemistry concepts upon course completion (21). Those students are also required to take and pass the standardized Regents Chemistry test which includes organic chemistry (22).

The alignment of the current TEKS chemistry standards with the New York State high school chemistry standards was 23 of 113 concepts- 19.5%, and the alignment of the new and revised TEKS chemistry standards was 44 of 113 concepts- 38.9%.

California

The chemistry standards for secondary education in California comprised of 73 concepts (23). The concepts were clear, to the point, and not overly detailed. California also included organic chemistry in its standards but under an objective titled "Organic Chemistry and Biochemistry" (23). This objective is unique in that California is the only one out of the four states being compared to Texas which includes biochemistry in its high school chemistry standards. The organic chemistry and biochemistry objective contains six concepts which are tested in the Chemistry California Standardized Test (CST). CSTs are end-of-course exams which measure student performance of state standards and are administered by public schools in California. Students are not required to pass these tests in order to graduate (24).

The alignment of the current TEKS chemistry standards with California high school chemistry standards was 14 of 73 concepts- 19.2 %, and the alignment of the new and revised TEKS chemistry standards was 38 of 73 concepts- 52.1%.

North Carolina

The high school chemistry standards of North Carolina, like New York, were also highly detailed. The standards consisted of 92 specific concepts (25). One objective included in the standards, named "Chemtools", is unique to North Carolina. The

"Chemtools" objective reintroduces students to the mathematical side of chemistry such as scientific notation, significant figures, SI units, and percent error, which is essential in calculations of chemistry (25). Mastery of the North Carolina high school education standards is measured through standardized end-of-course exams, which high school students are required to take but not pass (26).

The alignment of the current TEKS chemistry standards with the North Carolina high school chemistry standards was 19 of 92 concepts- 20.7 %, and the alignment of the new and revised TEKS chemistry standards was 37 of 92 concepts- 40.2%.

Massachussetts

The Massachussetts high school chemistry standards comprise of 41 concepts; these concepts were general but also clear (27). Little, if any, ambiguity was noticed in the wording of the standards. The chemistry standards of Massachusetts are most similar to the TEKS standards in the number of concepts and in the specific concepts themselves. The Massachussetts standards do not include organic chemistry, biochemistry, or a review in mathematical tools. However, the standards uphold integrity in that they are sufficient in providing a decent high school chemistry background given the concepts which are included. These standards contain concepts which are not included in either of the TEKS chemistry standards, such as: single and double displacement reactions, entropy, Le Chatelier's Principle, and buffers (27). MCAS (Massachussetts Comprehensive Assessment System), the standardized testing system, requires all high school students to take and pass a MCAS exam for English Language Arts, Mathematics, and one exam in Biology, Chemistry, Physics, or Engineering/Technology (28).

The alignment of the current TEKS chemistry standards with the Massachussetts high school chemistry standards was 14 of 41 concepts- 34.2 %, and the alignment of the new and revised TEKS chemistry standards was 30 of 41 concepts- 73.2%.

The new and revised TEKS chemistry standards were approximately two times more aligned with the chemistry standards of New York, California, North Carolina, and Massachussetts, than the current TEKS standards. Although the new and revised standards contained five more concepts than the current standards which gave the new standards an advantage in the alignment determinations, the large discrepancy in alignments with each state demonstrated that the new and revised TEKS chemistry standards are far more comparable to other states. While the new and revised TEKS standards still trail behind New York, California, North Carolina, and Massachussetts, the implementation of the new and revised TEKS chemistry standards in the Fall of 2010 will be a step in the right direction toward becoming competitive with other states in chemistry education and education as a whole, as well as college and career readiness whether high school graduates stay in Texas or go on to another state.

The 2008 Education Report Card, measured by the U.S. Chamber or Commerce ranked Massachussetts as the #1 state. In addition, New York and North Carolina ranked higher than Texas. Massachussetts, California, and New York all earned an "A" in the "Rigor of Standards" section while Texas earned a "B" (29). This report card was based on the current TEKS standards and did not take into account the new and revised standards of subjects, such as chemistry, which have been passed recently. As Texas implements new standards and continues to reform TEKS standards of other subjects in

the coming years, the grade on our education report card as a state will without a doubt improve.

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