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ABSTRACT

This paper presents findings of a study on the gap between high-school academic content standards and the knowledge and skills needed for success in entry-level university courses. The study had two parts. The first described the development of standards of knowledge and skills for university success (KSUS) through a combination of a modified version of the Delphi method and content analysis to establish their validity as a reference point for analyzing state academic-content standards. The KSUS standards were developed from data collected from 400 faculty members and administrators from 20 universities. Additional data were derived from content analysis of examples of student work. The second part of the study employed content-alignment analysis in a pilot study of one state's standards in reading, mathematics, and science: The state of Washington's essential academic learning requirements were analyzed against the KSUS standards. The results are described in narration, supplemented in tabular form. The KSUS, included in an appendix, represent the only comprehensive statement of university entry-level skills in a standards-like format. The pilot analysis demonstrated one strategy that can be employed to identify the degree of alignment between state and university academic-content standards. (Contains 15 references.) (WFA)

What Is the Alignment Between Knowledge and Skill for University Success and State Academic Content Standards?

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This paper presents research findings generated by Standards for Success (S4S), a collaborative research project sponsored by the Association of American Universities (AAU) and by The Pew Charitable Trusts. The goal of the research is to identify the gap between high school academic content standards developed over the past decade and the knowledge and skills needed for success in entry-level university courses. Are expectations aligned across the two systems? Will state academic content standards help prepare students to succeed in entry-level university courses? What effects on the university general education curriculum will standards for entry-level courses have?

Theoretical Framework

This study is situated in relation to certain established concepts from organizational theory in the area of organizational linkages. Weick, in particular, has established a number of important constructs related to linkages across organizational boundaries, most notably the concept of "loose coupling" (Weick, 1976). Standards-based approaches call into question Weick's contention that educational institutions in the United States are by their very nature loosely coupled.

Standards have a potential norming effect on educational programs across institutional boundaries. DiMaggio and Powell (1983) highlighted the power and influence of "institutional isomorphism," the tendency of organizations to look to other similar organizations for examples of normative behavior and limits of legitimacy. Levitt and March (1988) continued and expanded this theoretical concept to broader notions of organizational learning and the effect of common meaning on such learning. The standard-setting activities undertaken in this study are designed to create a point of legitimacy that would allow for connections between high school standards and university standards. If this succeeds, loose coupling theories will need to be reexamined to take into account formal linkages of this nature. Standards-based reform will have demonstrated the power of institutional isomorphism if schools accept standards across system boundaries as a common reference point.

A second, related body of theory on organizational alignment has arisen from the policy literature. Most notable is the concept of policy coherence (Fuhrman, 1993), which states that educational systems that receive consistent policy messages focused on student learning will perform better than those that do not. The signals that are sent by formal policies to organizations and across organizational boundaries within a linked system such as education have potentially significant effects on organizational functioning. Emerging theories that seek to explain the student transition from high school to college (Bragg & National Center for Research in Vocational Education Berkeley CA., 1999) and how state policy affects connections between high schools and colleges (Conley, in press) also serve to ground the study's conceptual framework.

Methods of inquiry and data sources

This is a multi-method study in two parts. Part one describes the development of Knowledge and Skills for University Success (KSUS) standards through a combination of a modified version of the Delphi method and content analysis in order to establish their validity as a reference point for analyzing state academic content standards. The second part of the study employs content alignment analysis in a pilot study of one state's standards in Reading, Mathematics, and Science.

The KSUS standards were developed from data collected initially through nine meetings at leading American research universities that are members of the AAU.

Participants came from a total of 20 AAU universities. The meetings were known collectively as the National Conversation on Key Knowledge and Skills for University Success. Sessions were designed to generate two types of statements: 1) key knowledge by discipline; 2) cognitive skills and abilities that cut across disciplines. Trained facilitators (usually a faculty from hosting institution and the particular discipline) began each session by asking the following two questions within each group: 1) What content knowledge do students need to have to be successful in your entry-level course? 2) What are the more general cognitive skills that students need if they are to be successful in a university environment?

Data collected at the National Conversation meetings were subjected to a modified version of the Delphi method, a technique for reaching consensus among experts on a topic (Linstone & Turoff, 1975). Nine National Conversation meetings were held at universities that are members of the Association of American Universities (AAU). Approximately 400 faculty members and administrators who work with incoming students identified the key knowledge and skills needed for success in entry-level courses at the 20 institutions represented at the meetings. Participating universities included the Universities of California, Berkeley; Illinois; Iowa; Michigan; Minnesota; Nebraska; Wisconsin; Harvard University; Indiana University; New York University; Pennsylvania State University; Rutgers, and the Massachusetts Institute of Technology.

The input received at each successive meeting was analyzed and compiled, then sent to participants in that meeting for their review. Results from the first six meetings were then subjected to topical analysis to identify elements that appeared most frequently. These preliminary findings were reviewed by Mid-Continent Research for

Education and Learning (McREL), an external consulting group with expertise in academic content standards, with the goal of identifying areas of congruence with existing state and national content standard documents and of stating the preliminary results in language that paralleled such standards. These revised knowledge and skill statements were then reviewed at three subsequent meetings at AAU universities. The scope, magnitude and frequency of recommended changes decreased at each subsequent meeting until many of the suggestions were for changes in grammar, formatting, or individual word choice. This revised set of standards was then submitted to a Content Review Panel consisting of professors and instructors from AAU universities with particular expertise and content knowledge, most of whom had previously participated in a National Conversation meeting at their campus. The version of the standards that incorporated the Content Review Panel's recommendations was labeled the draft KSUS standards. These were then sent to all 400 participants in the National Conversation as well as to AAU university presidents, who were asked to review the standards. Minor changes were made based on suggestions received from these reviewers. The draft KSUS standards where the versions used for analyzing state assessments. The final version of the Knowledge and Skills for University Success incorporated minor changes suggested by raters. The final version was ultimately endorsed by a total of 28 AAU institutions out of its 60 American members.

Additional data were derived from content analysis of examples of student work submitted by faculty from participating institutions. Using a rating sheet, participants scored each piece of work individually to rate how representative it was of desired key knowledge and skills. Work samples were then linked to specific KSUS standards to illustrate the cognitive challenge associated with the KSUS.

Course outlines and syllabi were a final source of data to triangulate and validate the KSUS standards. University faculty from participating institutions submitted these artifacts from their entry-level courses. Content analysis was employed to ascertain the specific knowledge and skill required to succeed in the course and the match between course requirements and the KSUS standards. This process helped validate that the knowledge and skills faculty said were needed for success in university courses were actually evident in course syllabi and assignments. Participants also analyzed and rated state high school content standards from one to three states, including their home state. Using a three-point scale, participants rated each standard statement as "critical," "useful," or "not useful" for success in entry-level university courses.

As a summary activity, project staff and national consultants analyzed the "fit" between the KSUS standards and individual state standards using a process adapted from Webb (1997, 1999, 2002) in which cognitive complexity, range and breadth of coverage were ascertained.

Results

Key knowledge and skills standards were expressed in three formats: 1) a taxonomy of key academic content knowledge and skills in five disciplines; 2) a narrative statement of the cognitive skills that cut across disciplines including the habits of mind that students should seek to develop; and 3) a set of examples of student work from university courses designed to illustrate the challenge level associated with each KSUS statement.

The KSUS standards have three levels of detail: Standard, objective, sub-objective. Length restrictions prevent an exposition of all the KSUS standards for all disciplines. An example from mathematics and English is presented below:

II. ALGEBRA

A. The student will know and apply basic algebraic concepts.

- A.1. Use the distributive property to multiply polynomials.
- A.2. Divide low degree polynomials (e.g., long division).
- A.3. Factor polynomials (e.g., difference of squares, perfect square trinomials, difference of two cubes, and trinomials like $x^2 + 3x + 2$).
- A.4. Add, subtract, multiply, divide, and simplify rational expressions including finding common denominators.
- A.5. Understand properties and basic theorems of exponents and roots (e.g., $(x^2)(x^3)=x^5$ and $(\sqrt{x})^3 = x^{3/2}$).
- A.6. Understand properties and basic theorems of logarithms (to bases 2, 10, and e).
- A.7 Know how to compose and decompose functions and find inverses of basic functions.

I. READING AND COMPREHENSION

A. The student will use reading skills and strategies to understand literature and informational texts.

- A.1. Use reading skills and strategies to understand a variety of informational texts: instructions for software, job descriptions, college applications, historical documents, government publications, newspapers, textbooks.
- A.2. Use monitoring and self-correction methods and know when to read aloud.
- A.3. Engage critically with the text: annotating, questioning, agreeing or disagreeing, summarizing, critiquing, formulating own responses.
- A.4. Understand narrative terminology: author versus narrator, historical versus implied author, historical versus present-day reader.
- A.5. Use reading skills and strategies to understand a variety of types of literature: epic piece (Iliad) or lyric poem, narrative novels, and philosophical pieces
- A.6. Understand plot and character development in literature, including characters' motives, causes for actions, and the credibility of events.
- A.7. Understand vocabulary and content: subject-area terminology, connotative and denotative meanings, idiomatic meanings.
- A.8. Understand basic beliefs, perspectives, and philosophical assumptions underlying an author's work: point of view, attitude, or values conveyed by specific use of language.
- A.9. Use a variety of strategies to understand the origins and meanings of new words: analyzing word roots and affixes, recognizing cognates, using context clues, determining word derivations.

A.10. Make supported inferences and draw conclusions based on textual features: evidence in text, format, language use, expository structures, arguments used.

Major headings from the cross-cutting skills and attitudes include but are not limited to the following: writing skills, analytic and critical thinking skills, inquisitiveness, ability to accept criticism, willingness to edit and revise work to reach high quality standards, research skills, ability to evaluate information critically and form opinions based on information, intellectual curiosity, openness, ability to work with peers, ability to use technology successfully.

English, mathematics and second languages standards captured a relatively clear and distinct set of attributes associated with each respective discipline. Science and social sciences reflected the relative complexity of these areas, each of which comprises a series of distinct academic disciplines. The standards in these two content areas were grouped into the skills that cut across the disciplines within the area along with accompanying listings of the key knowledge attributes for each discipline within the area.

Pilot Analysis of One State's Standards Using KSUS

The KSUS standards were used in a pilot study to ascertain the relative challenge level of one state's standards in comparison with university expectations. The state of Washington's Essential Academic Learning Requirements (EALRs) in Mathematics, Reading, and Science were analyzed against the KSUS standards in Mathematics, English, and Natural Sciences.

The data were subjected to a content alignment analysis methodology (Webb, 1999; Impara, 2001). Each state standard was compared with the KSUS standards to determine the matches that existed. This is known as Categorical Concurrence. Based on the set of standards for which concurrence was found, a second analysis was conducted. The Depth of Knowledge for each state standard was determined and then compared to the depth of knowledge for the corresponding KSUS standard. Through this process it was possible to ascertain the degree to which first, the standards aligned, and second, the degree to which cognitive challenge was properly sequenced between the state standards and the KSUS standards. Range and breadth of knowledge were also computed, but are not included in this paper.

The depth of knowledge categories are based on those developed by Marzano (2001). Marzano's New Taxonomy is hierarchical — one level builds off of another, so that each level requires progressively more cognitive skill, effort, and sophistication. The hierarchy is based on the conception that each level requires more sophisticated processing in short-term memory before information is moved to long-term memory. This empirically derived framework is based on brain research and on cognitive and information processing sciences. See Appendix A for a detailed description of the model.

The New Taxonomy consists of the following six levels:

1. Retrieval
2. Comprehension
3. Analysis
4. Utilization
5. Goal setting and monitoring
6. Self system thinking

Only the first five levels were used to rate the EALRs. The sixth, self system thinking, does not have a comparable category in the KSUS against which the EALRs were compared.

Five raters with experience teaching entry-level university courses with backgrounds and expertise in standards system development and rating were trained using a technique similar to that used to train Advanced Placement scorers. Through such training, discussion, and guidance by the facilitator with reference to scoring protocols and criteria, the raters were able to attain an inter-rater reliability on the math EALRs of .68 at 4th grade, .69 at 7th grade, and .81 at 10th grade, demonstrating adequate consistency in their judgments at the 4th- and 7th-grade levels and strong consistency at the 10th-grade level. These reliabilities are representative of the range in ratings evidenced in similar rating activities.

Mathematics

The comparison of the Mathematics K–10 EALRs to the university-level Knowledge and Skills for University Success (KSUS) in Mathematics described in Appendix B reveals a consistent correspondence between Benchmark Level 3 10th-grade Mathematics EALRs and the university-level Knowledge and Skills for University Success (KSUS) in Mathematics. Twenty-seven of the K–10 EALRs for which a correspondence was found with a university-level KSUS matched at the same rating level. In 25 cases, the K–10 EALR was higher than the corresponding university-level KSUS, and in 8 cases, the K–10 EALR was lower than the corresponding university-level KSUS. Thirty EALRs in math did not have a corresponding KSUS aligned with them.

The categorical concurrence index for Mathematics is .67, which exceeds the .50 criterion level necessary to state that the concurrence between the two sets of standards is adequate. The depth of knowledge ratio was 25:27:8: progressive cognitive challenge, equal cognitive challenge, inverted cognitive challenge. By this measure, the challenge progression was appropriate for 85% of the EALRs in relationship to the KSUS. These two findings indicate the Washington EALR content standards in Mathematics meet the criteria necessary to designate them adequately aligned with the KSUS Mathematics standards.

Table 1 contains an analysis of percentage of content items (benchmarks/ objectives) across topics into which the Mathematics EALRs fall in comparison to the weighting that other national reports and the KSUS Mathematics standards give to these topics.

Table 1. Percentage of Mathematics Content Items (Benchmarks/Objectives) Across Topics: Grade 10

Grade 10	EALRs	NCTM	NAEP	New Standards	KSUS
Number Sense	13	21	10	15	17
Measurement	12	6	28	8.5	2
Geometry	9	14	15	11	16
Trigonometry	0	1	2	1	5
Probability & Statistics	13	22	25	19	4
Algebra	9	18	35	19	27
Problem Solving	15	5	0	5	14
Reasoning	10	5	0		5
Math Language	9	4	0	13	8
Connections	10	4	0	7.5	2
Total	100	100	100	100	100

Reading

The comparison of the 10th-grade Reading EALRs to the university-level Knowledge and Skills for University Success described in Appendix C reveals a consistent relationship between Benchmark Level 3 10th-grade Reading EALRs and university-level Knowledge and Skills for University Success (KSUS) standards in English. Thirty-two of the EALRs for which a correspondence was found with a KSUS match at the same rating level. In eight cases, the 10th-grade Reading EALRs are higher than the corresponding university-level KSUS in English; in five cases, the 10th-grade EALRs are lower than the corresponding university-level KSUS. Fourteen 10th-grade EALRs in Reading do not have a corresponding university-level KSUS in English that aligns with them.

The categorical concurrence index for Reading is .76, which exceeds the .50 criterion level necessary to find that the concurrence between the two sets of standards is adequate. The depth of knowledge ratio was 8:32:5: progressive cognitive challenge, equal cognitive challenge, inverted cognitive challenge. By this measure, the challenge progression was appropriate for 90% of the EALRs in relationship to the KSUS. These two findings indicate the Washington EALR content standards in Reading meet the criteria necessary to designate them adequately aligned with the KSUS English standards.

Table 3 contains an analysis of percentage of content items (benchmarks/ objectives) across topics into which the Reading EALRs fall in comparison to the weighting that other national reports and the KSUS English standards give to these topics.

Table 3. Percentage of Reading Content Items (Benchmarks/ Objectives) Across Topics: Grade 10

Grade 10	EALRs	CBE	NAEP	New Standards High	KSUS
Comprehension	40	11	0**	17	19
Informational Texts*	26	22	65	45	25
Literature	14	50	35	38	50
Evaluating Reading Progress	10	0	0	0	0
Word Meaning	10	17	0**	0	6
Total	100	100	100	100	100

Science

The comparison of the Science 10th-grade EALRs to the university-level Knowledge and Skills for University Success in Natural Science described in Appendix D reveals a consistent relationship between Benchmark Level 3 10th-grade EALRs and the university-level Knowledge and Skills for University Success (KSUS). Thirty-one of the EALRS for which a correspondence was found with one or more KSUS matched at the same rating level. In 4 cases, the grade 10 EALR was higher than the corresponding university-level KSUS and in 13 cases, the 10th-grade EALR was lower than the corresponding university-level KSUS. Three science EALRs did not have a corresponding KSUS that aligned with them.

The categorical concurrence index for Science is .96, which greatly exceeds the .50 criterion level necessary to state that the concurrence between the two sets of standards is adequate. The depth of knowledge ratio was 4:31:13: progressive cognitive challenge, equal cognitive challenge, inverted cognitive challenge. By this measure, the challenge progression was appropriate for 73% of the EALRs in relationship to the KSUS. These two findings indicate the Washington EALR content standards in Science meet the criteria necessary to designate them adequately aligned with the KSUS Natural Science standards.

Table 3 contains an analysis of percentage of content items (benchmarks/ objectives) across topics into which the Science EALRs fall in comparison to the weighting that other national reports and the KSUS Natural Science standards give to these topics.

Table 3. Percentage of Science Content Items (Benchmarks/Objectives) Across Topics: Grade 10

<table>
<tr><th>Grade 10</th><th>EALRs</th><th>NSES*</th><th>NAEP*</th><th>AAAS*</th><th>KSUS</th></tr>
<tr><td>Physical Science</td><td>21</td><td>29</td><td>13</td><td>18</td><td>44</td></tr>
<tr><td>Earth/Space Science</td><td>17</td><td>14</td><td>13</td><td>7</td><td>7</td></tr>
<tr><td>Life Science</td><td>19</td><td>30</td><td>13</td><td>21</td><td>31</td></tr>
<tr><td>Scientific Inquiry</td><td>10</td><td>6</td><td>46**</td><td>5</td><td>1</td></tr>
<tr><td>Nature of Science</td><td>12</td><td>7</td><td rowspan="3">9</td><td>2</td><td>6</td></tr>
<tr><td>Historical Perspectives</td><td>2</td><td>4</td><td>27</td><td>1</td></tr>
<tr><td>Science, Society, and Technology</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td>Technology</td><td>12</td><td>2</td><td>6</td><td>11</td><td>1</td></tr>
<tr><td>Total</td><td>100</td><td>100</td><td>100</td><td>100</td><td>101</td></tr>
</table>

*9–12 grade range
**includes practical reasoning

Conclusion/significance

This study is significant for the following reasons: 1) the KSUS represent the first and only comprehensive statement of university entrance-level skills that is presented in a standards-like format, rather than in terms of required courses or broad generalizations about general academic preparation. Interestingly, and somewhat ironically, higher education faculty have not been involved systematically in standards development (except as experts on what K-12 should do) as states have rushed to put content standards and assessments in place.

The KSUS standards and accompanying analyses of state standards can be useful to states as they seek to develop better standards and to align their assessments more closely with university entrance expectations. Given that few state standards development processes paid much attention to university requirements, it seems likely that as these systems begin to influence high school instruction, states will wish to remedy this potential deficit, if for no other reason than to cause students to take state assessments more seriously. State assessments are beginning to take hold and drive teaching. If state standards and assessments are not well aligned with university admissions expectations, the likelihood is increased that high schools will increasingly become divided into two communities; students who have passed state assessments and can focus on a college preparatory curriculum, and students who have not passed the assessments and who are focused on a test-preparation curriculum. Given that 63 percent of students go directly from high school to some form of postsecondary education (Conditions of Education 2001), the pressures within the high school curriculum will grow for some sort of resolution of two potentially competing systems. The need will be greatest at inner-city schools where the gap between performance on state tests and high school grades is the most dramatic (Wolf, 1998). In such schools, students run the risk of meeting university entrance requirements based on the courses they take and grades they receive, but still being unable to pass state assessments. Such students are poorly served by both state standards and university entrance requirements in such a situation.

The pilot analysis of state standards demonstrates one strategy that can be employed to begin to identify the degree of alignment between state and university academic content standards. Systematic content analysis can identify the degree to which alignment exists and the specific areas in which expectations may differ. The results can then be fed back into the standards development process as states revise their standards over time. This is important to do because state standards form the domain from which state assessment items must be selected. If state assessments are ever to align in any significant fashion with the requirements for postsecondary success, state content standards must first be aligned.

The third area of significance pertains to universities themselves. These findings will help universities to gauge the discrepancy or match between what they say they want their incoming students to be able to do and what actually occurs in the freshman curriculum. These broadly generalizable findings extend beyond any individual institution and can serve as a resource for individual campuses as they review their general education programs of study. This is important to do because university standards should not be expressions of "wish lists," but rather empirically grounded descriptions of what is actually required to succeed subsequent to admission. Specific standards create accountability for universities to ensure that entry-level courses actually build upon the knowledge and skills identified as key prerequisites to success.

The fourth and final area of significance of the study is its contribution to the extremely limited research base that exists on the topic of the connections between high school and college expectations. Most studies in this area seek to examine the effects of course requirements or completion of various courses of study on college performance and utilize the metric of predictive validity. Few have explored the perceptions of faculty or analyze the actual practices taking place in college classrooms. Even fewer have analyzed the relationship between state high school standards and university success standards. This area of analysis is now opened up much wider by the existence of the Knowledge and Skills for University Success standards and emerging analytic techniques of the type demonstrated in this study and in similar studies in which state assessment items were analyzed in relation to KSUS standards (Conley & Brown, 2003).

If American classrooms are being influenced by state standards and assessments, it is increasingly important to understand the expectations and standards of universities in particular so that the energy students and teachers expend meeting standards is consistent with the future plans of students who plan to attend postsecondary learning. This understanding of differential expectations is also important to policy makers who oversee standards systems and their evolution.

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Appendix A: Summary: Depth of Knowledge Categories

Level 1: Retrieval

Recall:

The standard requires the student to identify or recognize features of information, but does not necessarily require understanding of the structure of knowledge or of the ability to differentiate critical from non-critical components.

Execution:

The standard requires the student to perform a procedure without significant error, but does not necessarily require that the student understand how and why the procedure works.

Level 2: Comprehension

Synthesis:

The standard requires the student to identify the basic structure of knowledge and the critical, as opposed to non-critical characteristics of that structure.

Representation:

The standard requires the student to identify or recognize features of information, but does not necessarily require the student to understand the structure of knowledge or require that the student be able to differentiate critical from non-critical components.

Level 3: Analysis

Matching:

The standard requires the student to identify important similarities and differences between knowledge.

Classifying:

The standard requires the student to identify superordinate and subordinate categories related to knowledge.

Analyzing Error:

The standard requires the student to identify errors in the presentation or use of knowledge.

Generalizing:

The standard requires the student to construct new generalizations or principles based on knowledge.

Specifying:

The standard requires the student to identify specific applications or logical consequences of knowledge.

Level 4: Utilization

Decision Making:

The standard requires the student to use the knowledge to make decisions or expects the student to be able to make decisions about the use of the knowledge.

Problem Solving:

The standard expects the student to use the knowledge to solve problems or to solve problems about the knowledge.

Experimental Inquiry:

The standard requires the student to use the knowledge to generate and test hypotheses or to generate and test hypotheses about the knowledge.

Investigation:

The standard requires the student to use the knowledge to conduct investigations or to conduct investigations about the knowledge.

Level 5: Goal Setting and Monitoring

Goal Setting:

The standard requires the student to set a plan for goals relative to the knowledge.

Monitoring Process:

The standard requires the student to monitor the execution of the knowledge.

Monitoring Clarity:

The standard requires the student to determine the extent to which he or she has clarity about the knowledge.

Monitoring Accuracy:

The standard requires the student to determine the extent to which he or she has an accurate understanding of the knowledge.

Note: Adapted from *Designing a New Taxonomy of Educational Objectives* (2000), Experts in Assessment Series, by Robert Marzano, Thousand Oaks, CA: Corwin Press.

Appendix B: Concurrence and Depth of Knowledge Between 10th Grade Mathematics EALRs and KSUS Mathematics Standards

K–10 Mathematics EALRs	DOK EALR Rating (1–5)	University-level KSUS	DOK KSUS Rating (1–5)
understand and use properties and symbolic representations of rational numbers, powers, and roots	2	IA.3. use radicals correctly. IA.6. know terminology for complex numbers, integers, rational numbers, irrational numbers, and complex numbers.	2 1
understand concepts of and use processes involving prime and composite numbers, factors and multiples, and divisibility	2	IA.1. apply arithmetic operations with fractions and integers (e.g., add and subtract by finding a common denominator, multiply and divide, reduce, and perform long division without a calculator).	1
understand operations on rational numbers, powers, and roots	2	IA.2. use exponents and scientific notation. IA.3. use radicals correctly.	1 2
compute with rational numbers, powers, and roots	1	IA.2. use exponents and scientific notation. IA.3. use radicals correctly.	1 2
use estimation to predict computation results and to determine the reasonableness of answers involving real numbers, *for example, estimating*	3	IA.4. understand relative magnitude. VD.3. recognize the accuracy of an estimation.	1 3
understand how changes in dimension affect perimeter, area, and volume	2	IVA.2. know how to figure area and perimeter of basic figures.	1
measure objects and events directly or use indirect methods *such as finding the volume of a cone given its height and diameter*	2	IVA.7. know basic formulas for volume and surface area for three-dimensional objects.	1
calculate rate and other derived and indirect measurements	2	IA.1. apply arithmetic operations with fractions and integers (e.g., add and subtract by finding a common denominator, multiply and divide, reduce, and perform long division without a calculator). IE.1. recognize which type of expression best fits the context of a basic application (e.g., linear equation to solve distance/time problems; quadratic equation to explain the motion of a falling object; or compound interest as an exponential function).	1 3
understand and use properties of symmetry, congruence, and similarity	3	IVA.1. know properties of similarity, congruence, and parallel lines cut by a transversal. IVA.5. use similar triangles to find unknown angle measurements and lengths of sides.	2 3

K–10 Mathematics EALRs	DOK EALR Rating (1–5)	University-level KSUS	DOK KSUS Rating (1–5)
understand and use coordinate grids	2	IVB.1. know geometric properties of lines (e.g., slope and midpoint of a line segment).	1
understand and use appropriate counting procedures to determine probabilities	3	IIF.1. know formal notation (e.g., sigma notation and factorial notation).	2
calculate and use the different measures of central tendency, variability, and range as appropriate to describe data	2	VIA.2. use variability and measures of central tendency (e.g., standard deviation, range, and mode) in external problems.	3
translate among tabular, symbolic, and graphical representations of relations using =, π, >, <, ≥, £	2	IB.1. understand the uses of mathematical symbols as well as the limitations on their appropriate uses (e.g., equal signs, parentheses, superscripts, and subscripts). IIC.3. represent functions, patterns, and relationships in different ways (e.g., statements, formulas, and graphs).	2 3
use variables to write expressions, equations, and inequalities	3	IA.7. use the correct order of arithmetic operations, particularly demonstrating facility with the Distributive Law. IB.1. understand the uses of mathematical symbols as well as the limitations on their appropriate uses (e.g., equal signs, parentheses, superscripts, and subscripts). IIE.1. recognize which type of expression best fits the context of a basic application (e.g., linear equation to solve distance/time problems; quadratic equation to explain the motion of a falling object; or compound interest as an exponential function).	2 2 3
simplify and evaluate expressions and formulas	1	IA.2. use exponents and scientific notation. IA.3. use radicals correctly.	1 2
search systematically for patterns in complex situations	3	VG.3. show an understanding of how to modify patterns to obtain different results.	4
use multiple strategies	3	VG.1. are willing to experiment with problems that have multiple solution methods. VG.4. show an understanding of how to modify solution strategies to obtain different results.	4 4
apply viable strategies and appropriate concepts and procedures to construct a solution	4	VA.1. use inductive reasoning in basic arguments. VA.2. use deductive reasoning in basic arguments.	3 3
test conjectures by formulating a proof or by constructing a counterexample	4	VA.2. use deductive reasoning in basic arguments.	3

K–10 Mathematics EALRs	DOK EALR Rating (1–5)	University-level KSUS	DOK KSUS Rating (1–5)
		VA.7. understand the uses of both proof and counterexample in problem solutions and are able to conduct simple proofs.	4
support arguments and justify results using inductive and deductive reasoning	4	VA.1. use inductive reasoning in basic arguments.	3
express complex ideas and situations using mathematical language and notation in appropriate and efficient forms	3	VB.1. translate simple statements into equations (e.g., "Bill is twice as old as John" expressed by the equation b=2j). VB.2. understand the role of written symbols in representing mathematical ideas and the precise use of special symbols of mathematics.	2 2
explain or represent complex mathematical ideas and information in ways appropriate for audience and purpose	4	IB.1. understand the uses of mathematical symbols as well as the limitations on their appropriate uses (e.g., equal signs, parentheses, superscripts, and subscripts). IIC.3. represent functions, patterns, and relationships in different ways (e.g., statements, formulas, and graphs). VB.2. understand the role of written symbols in representing mathematical ideas and the precise use of special symbols of mathematics.	2 3 2
extend mathematical patterns and ideas to other disciplines	4	VH.1. know that mathematical applications are used in other fields (e.g. carbon dating, exponential growth, predator/prey models, periodic motion and the interactions of waves, and amortization tables).	2
apply mathematical thinking and modeling in other disciplines	4	VH.1. know that mathematical applications are used in other fields (e.g. carbon dating, exponential growth, predator/prey models, periodic motion and the interactions of waves, and amortization tables).	2
identify situations in which mathematics can be used to solve problems with local, national, or international implications *such as calculating resources necessary for interstate highway maintenance*	3	VH.1. know that mathematical applications are used in other fields (e.g. carbon dating, exponential growth, predator/prey models, periodic motion and the interactions of waves, and amortization tables).	2

Appendix C: Concurrence and Depth of Knowledge Between 10th Grade English/Language Arts EALRs and KSUS English Standards

10th-Grade Reading EALRs	DOK EALR Rating (1–5)	University-level KSUS	DOK KSUS Rating (1–5)
readily use a variety of strategies to comprehend words and ideas in complex texts including self-correcting, re-reading, reading-on, and slowing down	3	IB.2. use monitoring and self-correction, as well as reading aloud, as means to ensure comprehension.	2
understand and apply reading strategies including word origins, word roots, prefixes, suffixes; making predictions; and verifying and revising understanding while reading	3	IA.6. exercise a variety of strategies to understand the origins and meanings of new words, including analysis of word roots and affixes; recognition of cognates and contextual clues; and the determination of word derivations. IB.4. exercise a variety of strategies to understand the origins and meanings of new words, including the analysis of word roots and affixes; recognition of cognates and contextual clues; and the determination of word derivations.	2 2
identify literary devices (exaggeration, irony, humor, dialogue, devices that develop characterization, tension, and mood)	2	IA.2. recognize and comprehend narrative terminology and techniques, such as author versus narrator, historical versus implied author, and historical versus present-day reader. IA.4. understand plot and character development in literature, including character motive, causes for actions, and the credibility of events.	2 3
analyze literary elements (plot, characters, setting, theme, point of view, conflict, resolution)	3	IA.1. engage in an analytic process to enhance comprehension and create personal meaning when reading text. This includes the ability to annotate, question, agree or disagree, summarize, critique, and formulate a personal response. IA.4. understand plot and character development in literature, including character motive, causes for actions, and the credibility of events.	3 5
read, analyze, and use informational materials to demonstrate understanding and expertise; analyze the validity of electronic information	3	IB.1. understand instructions for software, job descriptions, college applications, historical documents, government publications, newspapers, and textbooks. IIIB.5. are able to evaluate sources of information located on the Worldwide Web in particular to ascertain their credibility, origin, potential bias, and overall quality.	5 3
synthesize ideas from selections to make predictions and inferences about various texts	4	IA.7. make supported inferences and draw conclusions based on textual features, seeking such evidence in text, format, language use, expository structures, and arguments used.	3

draw conclusions based on the validity and accuracy of what is read	4	IA.7. make supported inferences and draw conclusions based on textual features, seeking such evidence in text, format, language use, expository structures, and arguments used.	3
organize information from resource materials and communicate findings effectively	3	IIIA.1. formulate research questions, refine topics, develop a plan for research, and organize what is known about the topic.	4
locate, analyze, and interpret material to investigate a question, topic, or issue (encyclopedia and other reference materials, pamphlets, book excerpts, newspaper and magazine articles, letters to an editor, etc.)	3	IIIA.1. formulate research questions, refine topics, develop a plan for research, and organize what is known about the topic. IIIB.1. collect information to develop a topic and support a thesis.	4 3
read, analyze, and interpret a full range of texts fluently (instructions, news articles, poetry, novels, short stories, professional-level materials that match career or academic interests, electronic information, etc.)	3	IIIB.3. use a variety of primary and secondary sources, print or electronic, including books, magazines, newspapers, journals, periodicals, and the Internet.	2
understand and follow complex information to perform tasks for a specific audience (schedules, maps, recipes, instructions, newspaper want ads, consumer reports, travel books, first aid or other manuals, catalogs, yellow pages, credit card or job applications, legal documents, etc.)	3	IB.1. understand instructions for software, job descriptions, college applications, historical documents, government publications, newspapers, and textbooks.	2
read, respond to, and evaluate a variety of traditional and contemporary literature (poetry, essays, short stories, novels, biographies, non-fiction narratives, plays)	3	IA.1. engage in an analytic process to enhance comprehension and create personal meaning when reading text. This includes the ability to annotate, question, agree or disagree, summarize, critique, and formulate a personal response. IA.3. use reading skills and strategies to understand a variety of types of literature, such as epic pieces (for instance, Iliad) and lyric poems, as well as narrative novels and philosophical pieces.	3 2
use appropriate reading strategies for interpreting technical and non-technical documents from different career settings *such as scanning, finding specific information, and inferring from data*	3	IB.2. use monitoring and self-correction, as well as reading aloud, as means to ensure comprehension.	2

Appendix D: Concurrence and Depth of Knowledge Between 10th Grade Science EALRs and KSUS Natural Science Standards

K–10 Science EALRs	DOK EALR Rating (1–5)	University-level KSUS	DOK KSUS Rating (1–5)
describe the average speed, direction of motion, and average acceleration of objects, *for example increasing, decreasing, or constant acceleration*	2	6B.1. understand Newton's laws as a classical description of motion. For example that: • a force is required to alter an object's motion • in the absence of force, or when forces are balanced, no change in motion is observed • forces are additive and the motion of an object is determined by the cumulative effect	3
understand many forms of energy as they are found in common situations on earth and in the universe	2	6A.1. understand the relationship between heat and temperature. For example: • that heat energy consists of the random motion and vibrations of atoms, molecules, and ions • the higher the temperature, the greater the atomic or molecular motion 6A.4. understand the distinction between kinetic (thermal, translational, and vibrational) and potential (gravitational and electrostatic) energy.	3 2
understand that total energy is conserved; analyze decreases and increases in energy during transfers, in terms of total energy conservation	3	6A.2. understand the conservation of energy and the First Law of Thermodynamics (i.e., energy cannot be created or destroyed but only changed from one form to another) and understand that energy must be transferred via work or heat. 6A.5. understand how energy can be transferred from one form to another.	3 5
explain how patterns and arrangements of landforms, oceans, and atmosphere are determined by natural forces and how the theory of plate tectonics accounts for movement over time	3	3A.1. know that the earth is a body in space whose environmental system (the atmosphere, lithosphere, cryosphere, hydrosphere, and biosphere) depends largely on the sun for light and heat, and that the current environment (e.g., geography and climate) is subject to change. 3B.1. are familiar with the history of the Earth.	3 2
describe how genetic information (DNA) in the cell is controlled at the molecular level, and provides genetic continuity between generations	2	4B.1. know the chemical and structural properties of DNA in heredity and protein synthesis (e.g., DNA synthesis, transcription, translation; mRNA and the genetic code; and effect of mutations). 4B.2. understand Mendel's laws of heredity (e.g., genes and alleles; genotype versus phenotype; segregation and independent assortment; and dominant versus recessive traits). Understand how Mendel's laws relate to the movement of chromosomes to gametes during meiosis, and understand the chromosomal basis of sex determination.	2 3

K–10 Science EALRs	DOK EALR Rating (1–5)	University-level KSUS	DOK KSUS Rating (1–5)
understand that patterns of movement in the plates that comprise the earth's surface are the result of outward transfer of the earth's internal heat, and that historical patterns of movement can be identified from clues in rock formations; describe how volcanoes and earthquakes in Washington State occur because of this interaction	2	3B.3. understand the processes of volcanism and erosion.	3
understand that the earth, planets, sun, and the rest of the celestial bodies in the universe are continuing to evolve because of interactions between matter and forces of nature	2	3A.1. know that the earth is a body in space whose environmental system (the atmosphere, lithosphere, cryosphere, hydrosphere, and biosphere) depends largely on the sun for light and heat, and that the current environment (e.g., geography and climate) is subject to change. 3B.1. are familiar with the history of the Earth. 3B.2. are familiar with the history of the solar system.	3 2 2
explain how organisms can sustain life by obtaining, transporting, transforming, releasing, and eliminating matter and energy	3	4A.12. know that in order to be alive, cells must exchange materials with their environment and/or with other cells. 4A.13. know that such exchanges involve a variety of mechanisms for transporting materials across a membrane, including diffusion, osmosis, and transport involving specialized membrane proteins 4.C.1. know that multicellular organisms have a variety of specialized cells, tissues, organs, and organ systems that each perform specialized functions (e.g., digestion, respiration, circulation, excretion, movement, control and coordination, protection from disease, and reproduction). Understand that the different organ systems are integrated to make	2 3 3
investigate and examine the scientific evidence used to develop theories for evolution, speciation, adaptation, and biological diversity	4	4D.2. understand the concept of natural selection (differential survival and reproduction of chance inherited variants, depending upon environmental conditions). 4D.3. understand the theory of evolution (e.g., the Earth's present-day life forms evolved from earlier, distinctly different species). Know that genetic change among individuals of populations is the raw material for evolution	2 3

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K–10 Science EALRs	DOK EALR Rating (1–5)	University-level KSUS	DOK KSUS Rating (1–5)
compare and contrast the complex factors (biotic and abiotic) that affect living organisms' interactions in biomes, ecosystems, communities, and populations	3	3C.1. understand the notion of habitats and their role in evolution. 4D.2. understand the concept of natural selection (differential survival and reproduction of chance inherited variants, depending upon environmental conditions).	3 2
study and analyze questions and related concepts that guide scientific investigations	3	1A.1. design and conduct scientific investigations during which they formulate and test hypotheses (formulate and clarify the method; identify the controls and variables; collect, organize, display, and analyze data; make revisions of hypotheses, methods, and explanations; present the results; and seek critiques from others).	4
use mathematics, computers and/or related technology to model the behavior of objects, events, or processes	3	1A.1. design and conduct scientific investigations during which they formulate and test hypotheses (formulate and clarify the method; identify the controls and variables; collect, organize, display, and analyze data; make revisions of hypotheses, methods, and explanations; present the results; and seek critiques from others). 1F.2. understand that a curve drawn in a certain location is fully equivalent to a set of algebraic	4 3
research, interpret, and defend scientific investigations, conclusions, or arguments; use data, logic, and analytical thinking as investigative tools; express ideas through oral, written, and mathematical expression	4	1A.1. design and conduct scientific investigations during which they formulate and test hypotheses (formulate and clarify the method; identify the controls and variables; collect, organize, display, and analyze data; make revisions of hypotheses, methods, and explanations; present the results; and seek critiques from others). 2.1. understand and use data represented in various ways (e.g., charts, tables, plots, and graphs).	4 3

K–10 Science EALRs	DOK EALR Rating (1–5)	University-level KSUS	DOK KSUS Rating (1–5)
analyze and explain why curiosity, honesty, openness, and skepticism are integral to scientific inquiry	3	2A.1. understand that science and the theories of science are not absolute and should be questioned and challenged. This includes the ideas that: • new theories will continue to replace current or older ones • scientific theories must stand up to the scrutiny of the entire scientific community • acceptable validation includes reproduction and internal consistency 2A.5. know that investigations and public communication among scientists must meet certain criteria in order to result in new understanding and methods. For example: • arguments must be logical and demonstrate consistency between natural phenomena revealed by investigations, as well as the historical body of scientific evidence • the methods and procedures used to obtain evidence must be clearly reported and reproducible to enhance opportunities for further investigation	4 3
identify and analyze factors that limit the extent of scientific investigation	3	2A.1. understand that science and the theories of science are not absolute and should be questioned and challenged. This includes the ideas that: • new theories will continue to replace current or older ones • scientific theories must stand up to the scrutiny of the entire scientific community • acceptable validation includes reproduction and internal consistency	4
compare, contrast, and critique divergent results from scientific investigations based on scientific arguments and explanations	3	2A.1. understand that science and the theories of science are not absolute and should be questioned and challenged. This includes the ideas that: • new theories will continue to replace current or older ones • scientific theories must stand up to the scrutiny of the entire scientific community • acceptable validation includes reproduction and internal consistency 2A.5. know that investigations and public communication among scientists must meet certain criteria in order to result in new understanding and methods. For example: • arguments must be logical and demonstrate consistency between natural phenomena revealed by investigations, as well as the	4 3

K–10 Science EALRs	DOK EALR Rating (1–5)	University-level KSUS	DOK KSUS Rating (1–5)
		historical body of scientific evidence • the methods and procedures used to obtain evidence must be clearly reported and reproducible to enhance opportunities for further investigation 1A.1. design and conduct scientific investigations during which they formulate and test hypotheses (formulate and clarify the method; identify the controls and variables; collect, organize, display, and analyze data; make revisions of hypotheses, methods, and explanations; present the results; and seek critiques from others).	4
analyze and evaluate the quality and standards of investigative design, processes, and procedures	3	1A.1. design and conduct scientific investigations during which they formulate and test hypotheses (formulate and clarify the method; identify the controls and variables; collect, organize, display, and analyze data; make revisions of hypotheses, methods, and explanations; present the results; and seek critiques from others). 2A.4. know that scientists throughout history have had many difficulties convincing their contemporaries to acknowledge what are now generally accepted scientific ideas	4 3
know that science involves testing, revising, and occasionally discarding theories; understand that scientific inquiry and investigation lead to a better understanding of the natural world and not to absolute truth	3	1A.1. design and conduct scientific investigations during which they formulate and test hypotheses (formulate and clarify the method; identify the controls and variables; collect, organize, display, and analyze data; make revisions of hypotheses, methods, and explanations; present the results; and seek critiques from others). 2A.2. know ways in which science and society influence each other. For example that: • scientific methods and the knowledge they produce may influence how people think about themselves and their world • technology can contribute to the solution of an individual or community problem • social and economic forces strongly influence which science and technology programs are pursued, invested in, and used	4 3

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