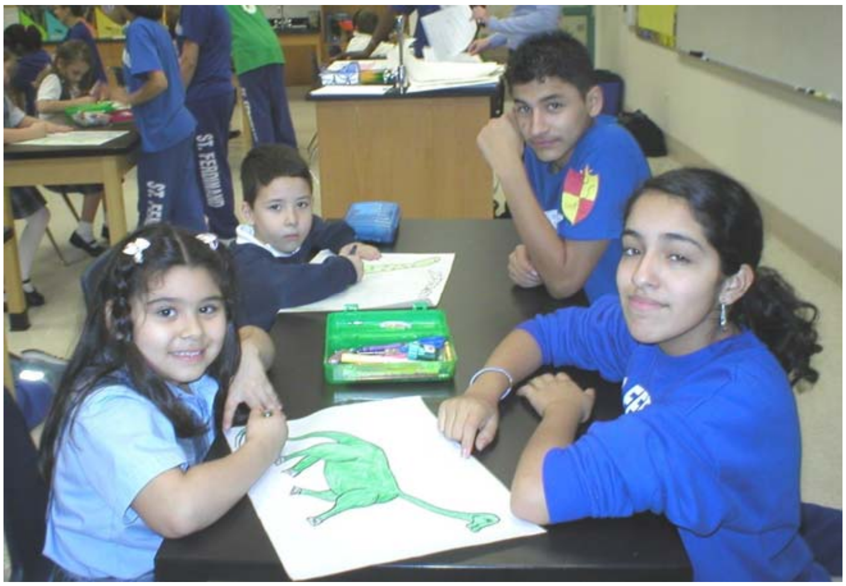
Comparing the Archdiocese of Chicago Science Curriculum with the TerraNova Assessment

BSCS Evaluation Report (ER 2006-8 May)



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May 25, 2006

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Table of Contents

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Executive Summary

In May 2005, the Office of Catholic Schools for the Archdiocese of Chicago published the new *Science Curriculum* (Office of Catholic Schools, 2005). The curriculum development process occurred over one and a half years, with input from the archdiocese's science teachers and administrators, curriculum and content professionals, and external reviewers. The development and implementation of *The Science Curriculum* is a collaborative effort with the Biological Sciences Curriculum Study (BSCS).

Several teachers have inquired, astutely, how closely *The Science Curriculum* aligns with measures of student achievement. This metric in archdiocesan schools is the *TerraNova* exam (second edition, CTB/McGraw-Hill, 2001). The question is important in that assessment is the second step in the process of backward design (Wiggins & McTighe, 1998). The assessment determines what serves as evidence of student learning for a given outcome. Defining such outcomes, or standards, is the purpose of *The Science Curriculum*.

This report compares several features of the new *Science Curriculum* with the *TerraNova* exam. Key findings are the following:

- Content in *The Science Curriculum* aligns closely with content assessed in the *TerraNova* exam. This is because each used, during development, a progression of content as is found in other science standards and in typical instructional materials.
- Student performance is assessed beyond traditional subjects in Goal 12. Other content areas include scientific inquiry (Goal 11) and for technology, science, and society and for the history and nature of science (Goal 13). The latter goals constitute from about 38 percent to nearly 50 percent (grade seven) of the total score in science. These goals can be met with subtle changes to existing science activities.
- Items in life sciences are tested proportionally less from grades four to eight, while items in physical sciences generally increase from grades four to eight. Weighting in earth and space sciences is about the same each year.
- The exam format is roughly two-thirds multiple-choice and one-third constructed-response items (i.e., open-ended responses). The constructed-response format gives the most comprehensive data about student understanding and best enables students to integrate subjects. It also implies that teachers should use analogous assessment formats in their classes to help prepare students.

Analysis of *The Science Curriculum* and the *TerraNova* Assessment

1. Developing The Science Curriculum

In May 2005, the Office of Catholic Schools for the Archdiocese of Chicago published the new *Science Curriculum* (Office of Catholic Schools, 2005). The development of *The Science Curriculum* was a collaborative effort with the Biological Sciences Curriculum Study (BSCS) of Colorado Springs, Colorado. This process occurred over one and a half years, with input from archdiocese science teachers and administrators, curriculum and content professionals, and external reviewers.

The format for *The Science Curriculum* is constructed around the three goals of the *Illinois Learning Standards for Science* (goals 11, 12, 13). Using these goals as headings, a Science Standards Framework in the curriculum organizes the standards, or benchmarks (i.e., "outcomes"), by content area within grade-level bands from early elementary through high school. This framework helps teachers, students, and parents see major concepts in science developed through grades K–12. A grade-level alignment gives priority to benchmarks to help focus on major concepts, lists assessment ideas for each benchmark, and illustrates connections to subjects other than science.

2. The TerraNova *Framework*

Students in the archdiocese are tested at grades three, five, and seven, with some schools testing each year from grades three to eight. Students receive the multiple assessments form of the exam in the subjects of reading and language arts, mathematics, science, and social studies. Many items in mathematics and science, and a small number (or zero) of items in reading and language arts, are constructed-response items (i.e., open-ended responses). Other versions of the exam do not have constructed-response items and are entirely multiple choice (selected responses).

Constructed-response items require more time to grade, yet they can provide more comprehensive information to teachers on student understanding in one or more areas of learning. Student skills required to successfully answer the constructed-response items should transfer between the subject areas of reading and language arts, mathematics, science, and social studies. This is described further in section 4.

3. Comparison with The Science Curriculum

TerraNova items in science are divided into six content areas, or objectives, as shown in table 1. These objectives align directly with the content standards of the archdiocese's *Science Curriculum*. The reason is that both the *TerraNova* and *The Science Curriculum* incorporate ideas from experienced classroom teachers as well as other comprehensive standards in science (e.g., National Research Council, 1996). The content areas with their matching goal in *The Science Curriculum* are listed in table 1.

Table 1.

***TerraNova* content areas (objectives)**	**Goal**
Science inquiry	Goal 11
Physical sciences	Goal 12
Life sciences	Goal 12
Earth and space sciences	Goal 12
Science and technology	Goal 13
Personal and social perspectives in science	Goal 13

One way to analyze the *TerraNova* exam is to graph the distribution of items over grades three through eight in each content area (figure 1). The main observation is that the *TerraNova* exam does not appear to be weighted disproportionately toward the traditional areas such as the life, physical, and earth and space sciences. Items represent all content areas.

The number of items over grades three through eight generally decreases for life sciences, increases for physical sciences, and remains unchanged for earth and space sciences. In fact, a substantial part of the test at all grade levels lies in the content areas of science inquiry, science and technology, and personal and social perspectives in science. These are goals 11 and 13 in *The Science Curriculum*.

There is a caveat regarding placing items in these categories. One does not know how items were classified in cases of overlapping content. For example, would an item on river floodplains fall under ecology (life sciences) or water dynamics (earth sciences)? Or would an item for a graph showing the mass of melted ice versus time fall under data interpretation (science inquiry) or properties of matter (physical sciences)? An item could be assessing student understanding in more than one content area. Similarly, items for goals 11 and 13 likely have a context within the content.

Overall, graphs of the number of items show proportional representation across all areas of *The Science Curriculum*. This can be shown with items grouped by Goal 11 (inquiry), Goal 12 (life, physical, and earth and space sciences), and Goal 13 (science, technology, and society). Figure 2 shows that while much of the *TerraNova* lies in Goal 12's content areas, the combined goals 11 and 13 constitute from about 40 percent (grade four) to nearly 50 percent (grade seven) of the test. Thus, classes that focus on traditional fields of science (life sciences, physical sciences, and earth and space sciences), or a small number of activities during the year, may not do well on the substantial parts of the exam addressing scientific inquiry (Goal 11) and topics related to science, technology, and society, or the history and nature of science (Goal 13).

Fields, or areas, within the six science content areas (i.e., subskills in table 2) also closely match fields found in *The Science Curriculum*. At first glance, it might appear that life sciences are the most heavily represented, with several fields. This is only really true at grades four and five (figure 1). While more fields are defined in life sciences, the average number of items per field in grades three through eight is less in life sciences than in earth and space or physical sciences.

The concentration of items in life sciences (figure 3a) occurs in the areas of habitat and adaptation (grade three), life cycles and taxonomy (grade four), and ecology (grades four and five). Earth and space sciences (figure 3b) does not show such concentrations of items, except perhaps in the solar system (grades four and eight). Items in physical sciences (figure 3c) are generally distributed uniformly, except for only four items total on motion and force (grades six, seven, and eight) and a focus on structure and properties of matter at grade eight.

Depending on the sampling methods used, educational researchers require four to six items to assess student understanding of a given standard or a given subject area. Using that criterion, the data in figure 1 suggest that the exam gives an accurate estimate from grades three through eight for science inquiry and the physical, life, and earth and space sciences.

In contrast, items in the *TerraNova* framework in two areas—science and technology, and personal and social perspectives in science—may not provide an accurate measure of student understanding due to the limited number of items (figure 1). However, these content areas can give a valid measure if the two areas are pooled into a single group. By doing this, the content would then align very well with topics in Goal 13 of the archdiocese's *Science Curriculum* (figure 2). Combining items from the two areas (science and technology, and personal and social perspectives in science) would be expected to give a valid sampling of student understanding for Goal 13 in *The Science Curriculum*.

4. Problem Solving in Science

The *TerraNova* assessment also offers an alignment of items based on the Rankin-Hughes Framework of Thinking Skills (Rankin & Hughes, 1987). These thinking skills align with a natural sequence in analysis and problem solving in science and other subjects (e.g., Bransford, Brown, & Cocking, 1999). In other forms, this framework matches elements of the "scientific method" or with the abilities of scientific inquiry (e.g., National Research Council, 1996). The thinking skills framework articulates a sequence where the students generally progress to higher-order thinking skills:

- Gather observations
- Organize information
- Analyze information
- Generate ideas
- Synthesize elements
- Evaluate outcomes

Regarding the archdiocese's *Science Curriculum*, these thinking skills align with Goal 11. Categorizing items in the *TerraNova* exam by these thinking skills across the sciences emphasizes the multidisciplinary nature of science and that all aspects of science use and rely upon analytical thinking (Goal 11). One would expect then that assessment items would measure student performance across these areas.

In contrast, the disaggregation of *TerraNova* items by CTB/McGraw-Hill suggests that test items in science cluster within the first three thinking skills. At grades three, five, and seven, it would appear that the *TerraNova* assessment does not have enough items to assess student abilities to generate ideas, to synthesize elements, and to evaluate outcomes (CTB/McGraw-Hill, 2001, pp. 222–230). Several explanations may account for this apparent discrepancy, but they cannot be evaluated further at this time.

Conclusions

1. TerraNova *Alignment with* The Science Curriculum

In summary, yes, the archdiocese's *Science Curriculum* aligns very well with the *TerraNova* exam. This is probably because each uses similar documents and teacher professional experiences in its development. Goals 11, 12, and 13 of the archdiocese's *Science Curriculum* include explicitly the *TerraNova* objectives 19–24 of science inquiry; the physical, life, and earth and space sciences; science and technology; and personal and social perspectives in science.

A significant part of the *TerraNova* exam resides within goals 11 and 13. Depending on grade level, goals 11 and 13 constitute nearly 40 percent to 50 percent of the *TerraNova* exam. The highest percentage of items classified in goals 11 and 13 are at grade seven. Teachers need to be sure to address the standards of goals 11 and 13 in their planning and teaching. This can often be accomplished by subtle shifts in teaching practice and by integrating topics in science, technology, and society, and the nature and history of science into current activities.

The distribution of items across the fields in content areas emphasizes the need for students to have comprehensive experiences in science each year. Assessed content is weighted slightly toward life sciences in the early grades, but by middle school, students need experience across the life, physical, and earth and space sciences.

Several curricular models outline how students in grades six to eight can learn science. Some programs move through one of the content areas (life, physical, or earth and space sciences) per year. Other programs offer experience with each of the three content areas each year. The distribution of *TerraNova* items across content areas each year in middle school would appear to align most closely with instructional materials that emphasize some experience each year in all three content areas.

The Science Curriculum, at the middle and high school levels, shows standards for Goal 12 grouped by content or subject area (i.e., life sciences, physical sciences, earth and space sciences). It is most practical to group standards this way since different instructional materials or programs that are "integrated" will place different content at different grade levels. Thus, as emphasized also in *The Science Curriculum*, it is incumbent upon faculty to discuss articulation across grades six through eight at the school level. This is particularly important for schools with instructional materials that separate the life, physical, and earth and space sciences by year over grades six to eight. This point is also clearly spelled out in the introduction to *The Science Curriculum* in the section "Using the Science Curriculum in Your School" (Office of Catholic Schools, 2005, p. ix).

One goal of *The Science Curriculum* does not align explicitly with the science component of the *TerraNova* assessment, and it is not part of the *Illinois Learning Standards for Science*. Still, it is a very important standard. This is Goal 11C, where students "*Use skills and abilities of math, writing, and dialogue (e.g., speaking, listening) to convey understandings of science.*" This standard has students use numeracy, organization of data, manipulation of data, representation in math, writing, dialogue, models, and diagrams to demonstrate understandings in science.

For teachers, the best way to assess these skills is with constructed-response items in class. Multiple-choice tests will limit the ability of students to use math and language arts skills in science. Thus, teachers should try to use open-ended or constructed-response assessments in their classes. This will benefit students on the *TerraNova* exam. Moreover, using these instructional approaches in science will benefit students in other areas of the assessment such as reading, writing, and mathematics.

2. Using Backward Design

Backward design is an approach for designing coherent curricula for students in any subject (Wiggins & McTighe, 1998). *The Science Curriculum* emphasizes what students should know, understand, and be able to do in science. Defining such standards, or outcomes, is the first step in backward design of curricula. The *TerraNova* assessment is the key measure for evaluating whether students have achieved those outcomes. Identifying such evidence by assessments is the second step in backward design. A goal of this report is to summarize the alignment of the standards and the assessment.

The third step of backward design is developing meaningful learning experiences for students. Knowing broadly the parameters of the assessment, as outlined in this report, the learning experiences in classrooms can then be designed such that students are successful in the performance assessment (i.e., the *TerraNova*). The sample weekly planner (Appendix A) reflects the backward design approach by first indicating standards addressed, and then second the parts of assessment. After these steps, the teacher plans the learning experiences for students. This is the bottom part of the planner.

Another important concept in backward design is identifying “big ideas” in science – those concepts and principles that will lead to enduring understandings for students. These are indicated by level of priority (“L1” for most important concepts) in *The Science Curriculum*. These concepts are developed as standards at multiple grade levels, and likewise, are tested at multiple grade levels.

3. Implications for Teaching Science

Teaching with standards such as in *The Science Curriculum* is the best way to expose students to a progressive array of science concepts that is important to students and to society. Thus, by using the standards, teachers are not merely “teaching to the test,” but teaching “with the test.” Both the science standards and the assessment can help inform instruction.

Goal 11 helps students understand the process of science. Traditionally, this has been called “the scientific method,” which can be portrayed in a linear fashion. But that is not how science, or how learning, really occurs. In reality, Goal 11 embodies cycles of questioning, observing, analyzing, interpreting, revising, and sharing. These cycles of learning may occur at the daily, weekly, and monthly scales. Developing an understanding of this iterative, actual scientific process will help teachers teach science better.

As is possible, teachers should be encouraged to develop and use constructed-response items in preK through eighth science as formative assessments. These skills are a basic part of expressing understandings in science or other subject areas. These items allow teachers to comprehensively evaluate student progress, not only in understanding science content, but also in using creativity, performing more complex operations, and solving problems. Using constructed-response questions in science will also help students complete such items in math, reading, and writing.

Author Bio

Steve Getty is a Science Educator and Research Associate at the Biological Sciences Curriculum Study (BSCS) in Colorado Springs, Colorado. He is Project Director for the Archdiocese of Chicago Science Curriculum Project. He has also been a curriculum developer with the high school program, *BSCS Science: An Inquiry Approach*, and worked on recent revisions of six other K-12 programs. Steve has led a variety of professional development initiatives, and has several on-going projects in educational research.

Steve has a B.S. from the University of Notre Dame, and a Ph.D. in Geological Sciences from Brown University. He has held research positions at Harvard University, the University of California, Berkeley, and the University of New Mexico. His areas of research include the evolution of mountain belts, radiometric age dating, and chemical tracers in Earth Systems. Prior to joining BSCS, Steve had a 3-year teaching position as Visiting Professor of Geology at The Colorado College in Colorado Springs, Colorado. He has also directed the summer institute for Masters of Arts in Teaching in science education for in-service teachers at The Colorado College.

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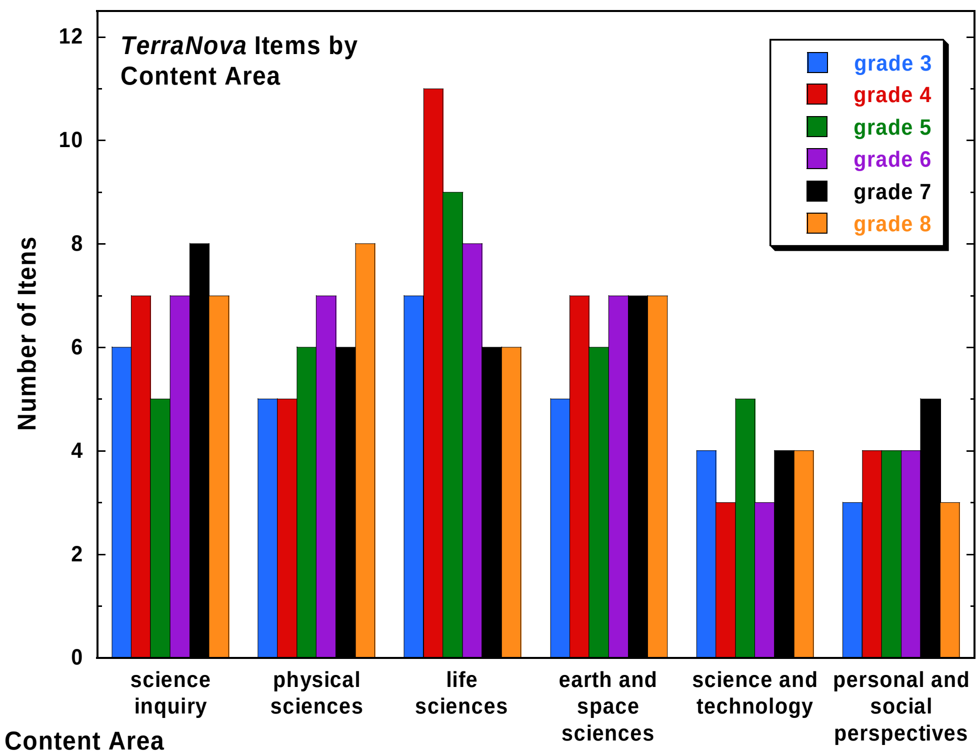

Figure 1. Number of *TerraNova* items per science content area by grade. Except for grades four and five in life sciences, items are distributed fairly evenly across content areas and grade levels.

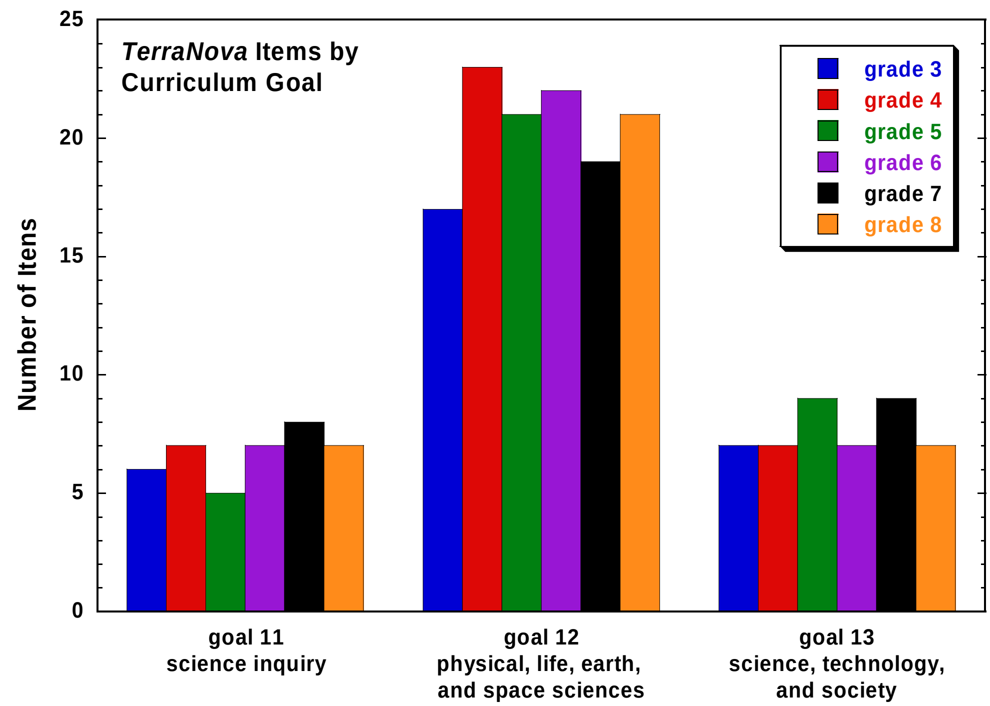

Figure 2. Number of *TerraNova* items per goal in the archdiocese's *Science Curriculum* by grade. Items are distributed evenly per goal by grade.

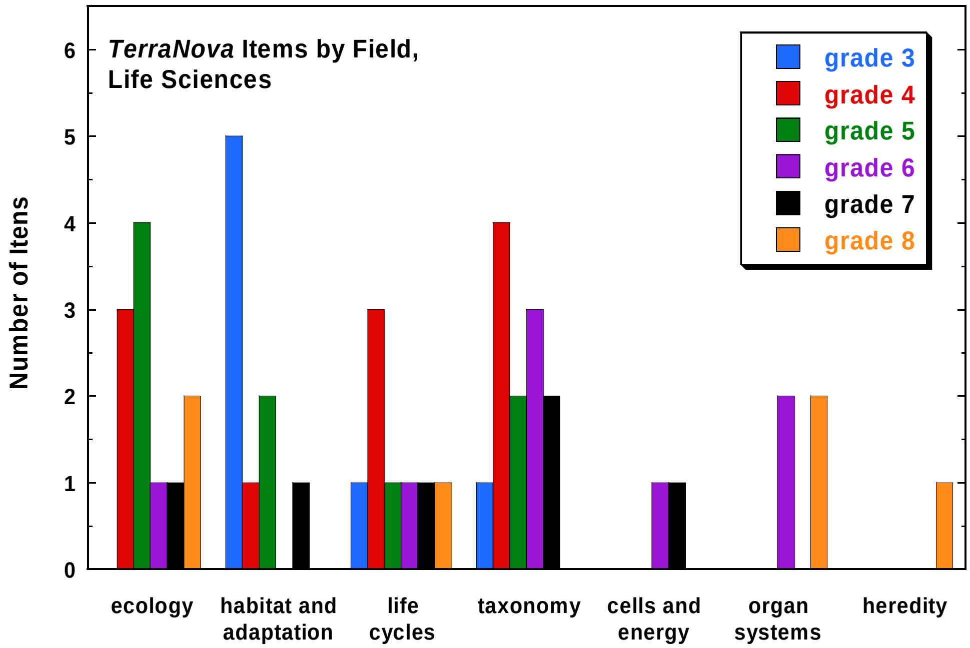

Figure 3a. *TerraNova* items per field in life sciences by grade. Life sciences appears to be tested more heavily at early grades, particularly in ecology, habitat and adaptation, and taxonomy.

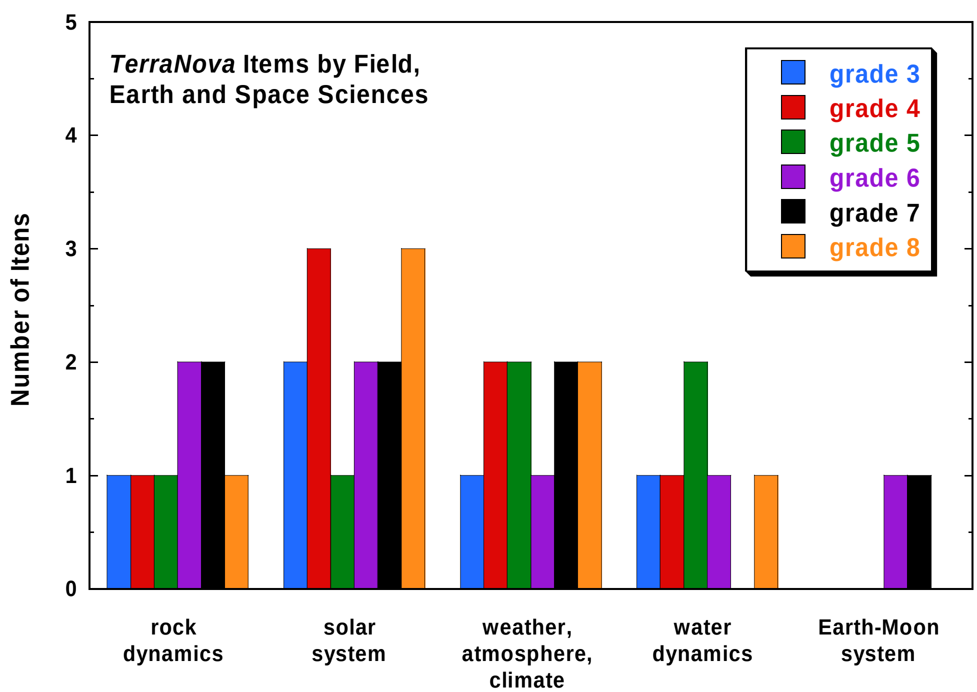

Figure 3b. *TerraNova* items per field in earth and space sciences by grade. Earth and space sciences is tested comparably at all grades (see also figure 1).

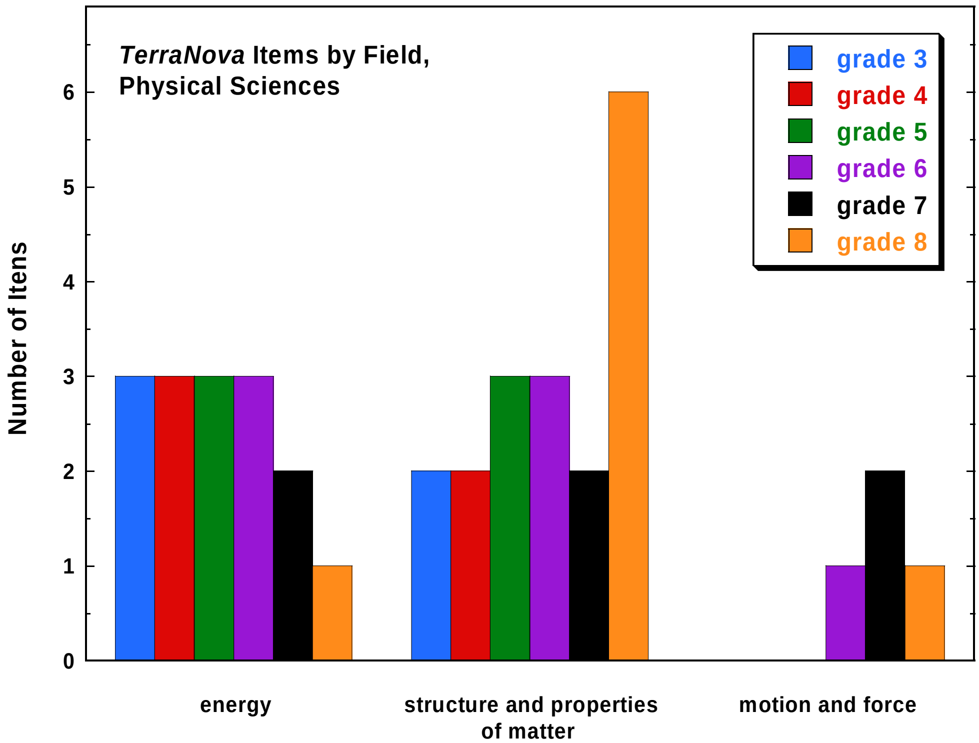

Figure 3c. *TerraNova* items per field in physical sciences by grade. Physical sciences is tested more heavily in later grades, particularly in grade eight for items classified as structure and properties of matter.

Weekly Curriculum Plan for Science

1. Learner Outcomes (Standards/Benchmarks)

Standards (IL) *11* *12* *13*

Critical
Significant
Useful

Teacher:
Grade:
Room:
Date:

Content-Specific Outcomes:
(Students will be able to ……..)

2. Evidence of Student Learning (Assessment)

Key Vocabulary:

3. Learning Experiences, Instruction

Weekly Overview (Topic):

	Student Learning Activities	Key Resources (Matl/Text/Visuals/Tech)	Curriculum Connections	Homework
M				
T				
W				
Th				
F				

Teacher Notes:

TerraNova weakness to address in grade _____ is:___________________________________

School Goal: School-wide (pK-8) alignment of OCS Science Curriculum with texts, tests, and classes

Level 13

Science	Item Number		
Objectives **subskills**	**Multiple Assessments**	**Complete Battery Plus Complete Battery**	**Survey**
19 Science Inquiry			
data interpretation	7,14,24,29	7,15,21,22	7,14
methods and design	11,13	13,14,23	11,13
20 Physical Science			
energy	3,12,15	3,32,34	3,12,15
motions and forces			
structure and properties of matter	8,25	8,10	8
21 Life Science			
ecology		18,19	
habitat and adaptation	4,16,18,22,27	4,17,25,35	4,16,18
life cycles	6	6	6
taxonomy	26	16	
cells and energy			
organ systems			
heredity			
22 Earth and Space Science			
rock dynamics	19	31	19
solar system	2,20	2,20,30,33	2,20
weather, atmosphere, climate	17	28	17
water dynamics	30	29	
Earth-moon systems			
23 Science and Technology			
careers			
design of technology	9	9,26	9
science and technology		27	
use of technology	1,21,23	1	1
24 Personal and Social Perspectives in Science			
environment		11,24	
health	10,28	12	10
resources	5	5	5
technology and society			

Level 14

Science	Item Number		
Objectives **subskills**	**Multiple Assessments**	**Complete Battery Plus Complete Battery**	**Survey**
19 Science Inquiry			
data interpretation	4,7,16,26	4,7,16,19	4,7,16
methods and design	5,23,34	5,32,33,34	5,23
20 Physical Science			
energy	3,22,33	3,26,40	3,22
motions and forces			
structure and properties of matter	9,17	9,17,39	9,17
21 Life Science			
ecology	24,25,36	31,37	24,25
habitat and adaptation	12	12,24,35	12
life cycles	10,11,21	10,11,25	10,11,21
taxonomy	6,30,31,35	6	6
cells and energy			
organ systems			
heredity			
22 Earth and Space Science			
rock dynamics	13	13	13
solar system	18,19,37	18,22,28	18,19
weather, atmosphere, climate	20,29	23,30,38	20
water dynamics	8	8,36	8
Earth-moon systems			
23 Science and Technology			
careers			
design of technology	1,2,28	1,2,29	1,2
science and technology			
use of technology		20	
24 Personal and Social Perspectives in Science			
environment		21	
health	14,27	14,27	14
resources	15,32	15	15
technology and society			

Level 15

Science	Item Number		
Objectives **subskills**	**Multiple Assessments**	**Complete Battery Plus Complete Battery**	**Survey**
19 Science Inquiry			
data interpretation	6,30	8,17	6
methods and design	1,15,17	1,14,19,21,24,39	1,15,17
20 Physical Science			
energy	5,7,24	5,7,15,26,40	5,7,24
motions and forces			
structure and properties of matter	21,25,33	25,37	21,25
21 Life Science			
ecology	4,23,34,35	4,32	4,23
habitat and adaptation	18,29	13,22,23	18
life cycles	10	10	10
taxonomy	9,13	9,11,38	9,13
cells and energy			
organ systems			
heredity			
22 Earth and Space Science			
rock dynamics	11	12,34	11
solar system	14	18	14
weather, atmosphere, climate	19,32	28,30	19
water dynamics	16,20	20,29	16,20
Earth-moon systems			
23 Science and Technology			
careers			
design of technology	8,12,26	6,27,31	8,12
science and technology		35	
use of technology	2,28	2	2
24 Personal and Social Perspectives in Science			
environment	27		
health	31	16	
resources	3	3,33	3
technology and society	22	36	22

Level 16

Science	Item Number		
Objectives **subskills**	**Multiple Assessments**	**Complete Battery Plus Complete Battery**	**Survey**
19 Science Inquiry			
data interpretation	5,9,26,27	1,5,9,23,31	5,9
methods and design	4,15,22	4,13,29,30	4,15,22
20 Physical Science			
energy	7,21,32	10,28	7,21
motions and forces	23	34	23
structure and properties of matter	17,20,29	20,21,27,32	17,20
21 Life Science			
ecology	13	16,17	13
habitat and adaptation		25	
life cycles	6	6	6
taxonomy	19,30,35	18,26	19
cells and energy	2	3	2
organ systems	11,14	14,15	11,14
heredity			
22 Earth and Space Science			
rock dynamics	12,18	12,22	12,18
solar system	10,31	11,39	10
weather, atmosphere, climate	16	19	16
water dynamics	36	35	
Earth-moon systems	24	36	24
23 Science and Technology			
careers		38	
design of technology	1	2	1
science and technology			
use of technology	8,28	8,24	8
24 Personal and Social Perspectives in Science			
environment	25,33,34	33,37,40	25
health	3	7	3
resources			
technology and society			

Level 17

Science	Item Number		
Objectives **subskills**	**Multiple Assessments**	**Complete Battery Plus Complete Battery**	**Survey**
19 Science Inquiry			
data interpretation	5,6,7,34	5,6,7,13,35	5,6,7
methods and design	3,8,14,36	3,8,18,29,36	3,8,14
20 Physical Science			
energy	4,16	4,21	4,16
motions and forces	22,35	24,27	22
structure and properties of matter	25,31	30,40	25
21 Life Science			
ecology	29	38	
habitat and adaptation	11	12,15	11
life cycles		14	
taxonomy	12,20	16,25	12,20
cells and energy	21	26	21
organ systems	2	2,20	2
heredity			
22 Earth and Space Science			
rock dynamics	17,28	22,34	17
solar system	19,23	10,28,33	19,23
weather, atmosphere, climate	24,33	37	24
water dynamics		39	
Earth-moon systems	30		
23 Science and Technology			
careers			
design of technology	1,10,13,27	1,11,17	1,10,13
science and technology		31	
use of technology			
24 Personal and Social Perspectives in Science			
environment	32	32	
health	9,15,18,26	9,19,23	9,15,18
resources			
technology and society			

Level 18

Science	Item Number		
Objectives **subskills**	**Multiple Assessments**	**Complete Battery Plus Complete Battery**	**Survey**
19 Science Inquiry			
data interpretation	1,4,11,26,34	1,4,9,14,19	1,4,11
methods and design	10,20	13,24,28	10,20
20 Physical Science			
energy	25	38	25
motions and forces	24	37	24
structure and properties of matter	2,13,18,22,28,31	2,16,26,31,36	2,13,18,22
21 Life Science			
ecology	12,21	15,29,30	12,21
habitat and adaptation		11	
life cycles	19	27	19
taxonomy			
cells and energy		34	
organ systems	7,32	7	7
heredity	5	5	5
22 Earth and Space Science			
rock dynamics	23	33	23
solar system	17,27,33	10,25	17
weather, atmosphere, climate	6,9	6,12	6,9
water dynamics	29	21,35	
Earth-moon systems			
23 Science and Technology			
careers		32	
design of technology	16,30	23,39	16
science and technology	35	22	
use of technology	8	8	8
24 Personal and Social Perspectives in Science			
environment	14	17,20	14
health	3	3	3
resources		40	
technology and society	15	18	15