



## ALIGNING PRESERVICE TEACHER BASIC SCIENCE KNOWLEDGE WITH INTASC I AND NSTA CORE CONTENT STANDARDS

**Leonard A. Annetta**

**Sharon Dotger**

**ABSTRACT.** Training preservice teachers to develop a predisposition toward constructivist instruction is a major goal for many faculty in teacher education. One critical attribute of a constructivist teacher is a strong hold on pedagogical content knowledge. This study examined the prior knowledge of preservice science teachers and how that knowledge aligned with INTASC Standard I and the NSTA Core Knowledge Standards for science teachers. Basic content knowledge of twenty-four preservice teachers in an introductory science education course was assessed through released items from the grade 8 Trends in International Mathematics and Science Study (TIMSS) and the National Assessment of Educational Progress (NAEP) tests. Kruskal-Wallis analysis showed no significant differences in content knowledge across 3 content domains.

**KEYWORDS.** Teacher Training, Science Content Knowledge, Standards, Non-parametric Statistics, Misconceptions.

### INTRODUCTION

Ausubel (1968, p.406) stated, “The most important single factor influencing learning is what the learner already knows.” Ascertain this and teach him accordingly. This statement has been the driving force for those advocating constructivist teaching methods. Constructivist learning theory suggests that people construct personal understanding by modifying their existing concepts (or schema) when new evidence and an experience is presented. This implies that students do not simply accept what has been taught, but rather shift their understanding in response to what has been taught.

If teachers are to embody the constructivist learning theory, than they need to discard their naive conceptions of scientific phenomena and relearn the currently accepted explanations of scientific phenomena so they can teach their students accordingly. Teachers need to know and accept content, evaluate student ideas and understandings, and provide learning experiences to align students’ conceptions with scientific explanations. This is particularly true in the domain of earth science as more states are requiring earth science in their curricula with less formally trained earth science teachers (Dickerson, 2002; Veal, 2002). Many agencies and organizations have set benchmarks for tackling this problem.

*Purpose of the study*

The purpose of this study was to examine the basic content knowledge of preservice middle and secondary science teachers on 3 broad stratifications of science (life, physical and earth science) and how their existing knowledge aligned with INTASC Standard I and the NSTA Core Knowledge Standards. Preservice teachers are operationally defined as those students who do not yet have license to teach. This group of students consists of undergraduates (freshman-senior) and alternative licensure students (students with an earned bachelors degree returning to earn licensure). In North Carolina for example, teacher education programs are graduating students with the fulfilled requirements for a comprehensive science teacher license. However, the lack of emphasis on earth science during their training can pose a problem if preservice teachers are to someday instruct students on the basics of earth science and ultimately meet the standards set forth by federal and state agencies. It has been assumed that those with a richer background in specific science content domains would know and teach that content more effectively (Borko, 1996). The research question thus became: Do alternative licensure students possess greater earth science content knowledge according to INTASC standard I and the NSTA core knowledge standards than undergraduate preservice students?

**BACKGROUND**

Since the 1980's, secondary school preservice teacher education has focused on pedagogy with the assumption students already possess strong content knowledge. However, with teacher shortages in critical areas such as science and mathematics, preservice teacher graduates are often hired by school systems to teach subjects in which they are not domain experts. Recent legislation in the form of No Child Left Behind is requiring teachers to be highly qualified and therefore teacher educators must prepare preservice teachers to be just that. Teachers cannot effectively educate students on subjects they themselves aren't comfortable with or confident in (Ball, 1990). Borko (1996) reported that most teachers' content knowledge comes from what they absorbed from their disciplinary fields, while their pedagogy and understanding of communication comes from the field of education. This only emphasizes the literature that science educators approach problems differently than pure scientists due in part to the science educators pedagogical knowledge and understanding of the implications of learning science (Borko, 1996). If future teachers are misinformed or have poor understanding of specific concepts, it is quite likely they will perpetuate these naive conceptions to their students (Boyes, 1995).

*INTASC Standard I and the NSTA Core Knowledge Standards*

Licensing teachers to instruct students in basic science content has been a challenge for colleges and schools of education. There is never-ending discussion about the depth of content

knowledge students should learn across the content areas and how this should be balanced with pedagogy. What do teachers need to know in terms of content knowledge and pedagogy is often debatable. The Interstate New Teacher Assessment and Support Consortium (INTASC) and the National Science Teachers Association have set out to make these objectives clear for teachers of all grade levels and with all types of certification. What follows is an overview of the vision of these two agencies.

The Interstate New Teacher Assessment and Support Consortium (INTASC) is a collaboration of state and national educational organizations dedicated to reform the preparation, licensing, and professional development of teachers. The first INTASC principle focuses on teacher content knowledge and describes this knowledge as "...the central concepts, tools of inquiry, and structures of the discipline..." (p. 1). The principle is separated into knowledge, dispositions, and performances the teachers should be able to demonstrate. While the content-based standards are still under development, teachers should know the most important concepts and the methods used to generate these ideas. Additionally, teachers should understand that students' prior knowledge and their schema could influence their learning. Ultimately, this principle relates students' schema to the potential misconceptions they hold regarding the content.

With regard to dispositions, the first INTASC principle requires that teachers view knowledge as complex and ever evolving. This implies that teachers must evolve with new ideas and findings within their teaching discipline. Furthermore, teachers must appreciate multiple perspectives and can explain to their students how these perspectives are developed from the point of view of the knower. The teacher will also regularly demonstrate an enthusiasm for the subject matter and must be committed to continually learn about subject matter and the most effective ways for students to learn that subject.

Finally, the first INTASC principle outlines teachers' effective performances as including multiple representations and explanations that activate and build on students' schema. Teachers must also evaluate resources and materials according to their accuracy and completeness. They have to engage students in inquiry-style activities that require students to test hypotheses according to the acceptable scientific standards.

The NSTA Core Knowledge Standards are based on a review of the professional science education literature and on the goals set forth in the National Science Education Standards. These standards outline the knowledge that teachers ought to have about specific content in four areas of scientific study: biology, chemistry, earth sciences, and physics. Within each of these domains, numerous objectives describe the most important ideas teachers ought to understand and demonstrate throughout their preservice experiences.

*A call for strong science content knowledge*

Since the science education movement began in the 1960's, the study of student misconceptions about scientific phenomena have been prolific in the literature. Students develop these misconceptions as a result of either personal experience, from other people, or through the media (Ausubel, 1968; Driver, 1985). Driver (1985) reported that different people have different misconceptions in different areas of science.

In teacher education, it is critical to evaluate the conceptions of preservice teachers. If they have misconceptions, it is likely they will pass the incorrect content on to their future students. The result of persistent wrong conceptions about scientific phenomena is an ill-informed citizenry and a reduced possibility of appropriate preventive actions by these citizens against future problems (Boyes, 1995).

This is a cascading effect that has not been widely addressed. For example, an analysis of survey data indicated that the many pre-service high school teachers possess an array of misconceptions about the causes and effects of the greenhouse effect, ozone depletion, and acid rain (Khalid, 2003). The problem grows more complex due to mismatched concept and student developmental levels. Inaccuracies in textbooks, incorrect information provided by instructors, and student memorization of prior concepts without meaningful understanding of the basic concepts compounds the problem and ultimately creates a lineage of confused science concepts (Westbrook, 1992).

In earth science education, it is not well documented as to what preservice teachers know or what they are learning to prepare them to be effective teachers. Much of the literature on earth science has focused on what K-12 students know about earth science phenomena. There are a few exceptions to this as (Barba, 1992, 1993; Schoon, 1995; Stofflett, 1993; Trend, 2000, 2001) attempted to look into preservice teacher earth science knowledge. Gruber (1999-2000) reported that 79% of earth science teachers were not earth science majors. Furthermore, the National Assessment of Educational Progress (2000) reported that 19% of grade 8 teachers were earth science majors. Grade 8 is the level where earth science has traditionally been taught until recently integrated into the high school curriculum.

*Science Teacher Development*

What teachers know and do is the most important influence on what students learn (The National Commission on Teaching and America's Future, 1996). If we are to challenge students to deeper understanding and high order thinking, teachers need to have a thorough conceptual and pedagogical understanding of content (Enfield, 2000). This has become to be known as Pedagogical Content Knowledge (PCK). Shulman (1986) defined PCK as the understanding of what makes the learning of specific topics easy or difficult. Shulman (1987) elaborated on this definition as, PCK encompasses knowledge of students' preconceptions, understanding and

alternative conceptions of specific topics in the subject, knowledge of curriculum and standards, and finally instructional strategies and representations for teaching specific subject matter.

Veal (1999) suggested that PCK is a hierarchy that encompasses General PCK, Domain-specific PCK and Topic-specific PCK. General PCK refers to the different content disciplines (math, science, history, etc.). Domain-specific PCK is a branch of these disciplines. For example science domains are: chemistry, physics, biology, etc. Finally, Topic-specific PCK refers to the specific topics within each domain. For example in earth science, Topic-specific PCK would entail seismology, rocks and mineral properties, topography, etc. Teachers with knowledge in the Topic-specific PCK would most likely have an array of techniques and skills in the General and Domain-specific area.

Expert teachers are said to possess Topic-specific PCK (Reynolds, 1995; Shulman, 1987). Preservice teachers, and subsequently teachers in their early years of practice (who are not considered expert), have an expectation that there is a straightforward process for science teaching, not unlike the scientific method, and if they follow this process they will be effective science teachers (Smith, 2000). However, teaching is not straightforward, and neither is learning. Student learning ultimately results from a conglomerate of teacher traits, skills and practices, which when well developed lead to effectively teaching Topic-specific pedagogical content (Shymansky, 2000). It is at this juncture of teaching experience and PCK where teachers must be able to diagnose student misunderstandings and later prescribe strategies to combat such misunderstandings (Butler, 2003). When teachers learn to focus on student understanding, they recognize the need to modify their teaching practices. They become motivated to engage in the change process, and they begin to use student responses to assess whether they are teaching effectively (Harcombe, 2001). It is only at this point when teachers can be considered expert.

Arguably the most important component of PCK is science content knowledge. If a teacher is strong in pedagogy but lacks the science core knowledge to facilitate students beyond their misconceptions, then learning will most likely not occur. In licensing science teachers, it is critical we are preparing them to be highly qualified, helping them develop strong teaching methods and properly juxtapose their content knowledge to their pedagogy to elicit meaningful learning.

## **METHODS**

### *Sample*

A case study designed was used with twenty-four students enrolled in an introduction to science teaching course at a large, southeastern United States university were the sample of the study. The course design was 2-pronged: An introduction to teaching for science majors who are considering the teaching field as a profession; and an introduction to how the science students learn science content. The sample consisted of 19 undergraduates (1 freshman, 6 sophomores, 8

juniors and 4 seniors) and 5 alternative licensure students. Alternative licensure students are defined in this study as those students with a documented bachelors degree in a science domain and who have returned for teaching licensure.

### *Instrument and data collection*

The students in this course were challenged on their basic content knowledge in 3 critical areas of science taught in the middle and secondary schools (physical, life and earth science). Students were assessed as to what, if any, misconceptions they thought their future students had within these broad content areas prior to the administration of the instrument. Using 15 released grade 8 items from the 1995 and 2000 National Assessment of Education Progress (NAEP) and the Trends in Mathematics and Science Study (TIMSS) test; an instrument was designed to garner the knowledge these students possess in these domains and to challenge what they thought they already knew about these domains. Five items were used to gain insight into student knowledge of life science, 6 from physical science and 4 from earth science. These items were chosen due to their alignment with the NSTA core knowledge standards (Appendix A) and because they are used as the benchmarks for domain specific knowledge of grade 8 students nationally and internationally. Table 1 illustrates a matrix of the NSTA Core competencies and how they align with the items within the instrument.

Life science items aligned with 7 of 12 core knowledge standards for biology. The physical science items aligned with 11 of 12 physics core knowledge standards and 2 of the 13 chemistry standards. Finally, the earth science items aligned with 8 of 12 core knowledge standards. Appendix A illustrates specific standards addressed by each question in the instrument.

Students were given this instrument in class and the results were used to inform future instruction. The multiple choice items were selected based on the responses students provided as to their belief of their knowledge in these areas. Anecdotal evidence prior to administering the test suggested students did not feel as confident with their knowledge of earth science as opposed to their knowledge in life and physical science. As earth science is becoming a required and tested course in middle and high schools, the results of the instrument would shed light on the areas where preservice science instruction needs to be redirected so future teachers are better prepared to teach a wide variety of science topics; most specifically earth science.

### *Data analysis*

Student responses to the instrument were collapsed into life, physical and earth science based on the content description provided by the NAEP and TIMSS test. Items were collapsed by calculating the mean of individual responses to each item that aligned with 1 of the 3 domain

Table 1: Matrix of NSTA Core Competencies and their match to instrument domain items

NSTA Competency	Question														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C.2.a. Core Competencies. All teachers of biology should be prepared to lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand:															
1. Life processes in living systems including organization of matter and energy.	x							x	x						
2. Similarities and differences among animals, plants, fungi, microorganisms, and viruses.	x														
4. Scientific theory and principles of biological evolution.												x			
5. Ecological systems including the interrelationships and dependencies of organisms with	x								x						
7. General concepts of genetics and heredity.												x			
10. Regulation of biological systems including homeostatic mechanisms.								x							
11. Fundamental processes of modeling and investigating in the biological sciences.								x	x						
12. Applications of biology in environmental quality and in personal and community health.	x							x	x			x			
C.3.a. Core Competencies. All teachers of chemistry should be prepared lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand:															
11. Environmental and atmospheric chemistry.		x													
13. Applications of chemistry in personal and community health and environmental quality.		x													
C.4.a. Core Competencies. All teachers of the Earth and space sciences should be prepared lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand:															
1. Characteristics of land, atmosphere, and ocean systems on Earth.		x	x												
3. Changes in the Earth including land formation and erosion.			x												
5. Energy flow and transformation in Earth systems.													x		
6. Hydrological features of the Earth.			x										x		
7. Patterns and changes in the atmosphere, weather, and climate.		x						x					x		
8. Origin, evolution, and planetary behaviors of Earth.							x	x							
10. Fundamental processes of investigating in the Earth and space sciences.							x	x					x		
12. Applications of Earth and space sciences to environmental quality and to personal and community health and welfare.		x													
C.5.a. Core Competencies. All teachers of physics should be prepared lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand:															
1. Energy, work, and power.										x	x				x
2. Motion, major forces, and momentum.										x					x
3. Newtonian principles and laws including engineering applications.										x					x
4. Conservation of mass, momentum, energy, and charge.										x					x
5. Physical properties of matter.					x	x				x					
7. Radioactivity, nuclear reactors, fission, and fusion.											x				
8. Wave theory, sound, light, the electromagnetic spectrum and optics.				x	x										
9. Electricity and magnetism															x
10. Fundamental processes of investigating in physics.														x	
11. Applications of physics in environmental quality and to personal and community health.		x		x	x						x				x

areas of life, physical and earth science. Frequency of responses based on academic year (grouped as freshman, sophomore, junior, senior, and alternative licensure) was calculated and a Kruskal-Wallis test was conducted. Differences in mean rankings were analyzed to gain insight as to which, if any, academic subgroup had more knowledge of these 3 areas of science content than another.

## RESULTS

Table 2 shows the descriptive statistics of the academic subgroups and the results of the instrumental responses. From this table it is interesting to note that the percent of questions in the physical science domain that all students answered correctly is the lowest (0.725) of the 3 content domains. However, the standard deviation in responses is considerably higher for earth science (2.395). A mean rank was calculated for each content domain based on the academic year of the respondents (see table 3).

Table 2: Descriptive statistics of sample by academic year and test results by content domain

	N	Mean	Std. Deviation	Minimum	Maximum
LIFE	24	.8917	.16659	.40	1.00
PHYSICAL	24	.7254	.20173	.29	1.00
EARTH	24	.8613	.23959	.33	1.00
YEAR	24	3.2500	1.18872	1.00	5.00

Table 3: Mean ranks of content domain by academic year of sample

	YEAR	N	Mean Rank
LIFE	freshman	1	6.50
	sophomore	6	15.25
	junior	8	13.88
	senior	4	11.75
	licensure only	5	8.80
	Total	24	
PHYSICAL	freshman	1	2.50
	sophomore	6	10.08
	junior	8	15.00
	senior	4	13.25
	licensure only	5	12.80
	Total	24	
EARTH	freshman	1	2.00
	sophomore	6	12.50
	junior	8	16.00
	senior	4	9.88
	licensure only	5	11.10
	Total	24	

Sophomores had a higher rank on life science (15.25) and juniors had the highest rank in physical (15.0) and earth science (16.0) respectively. Although Chi square results show life (4.514), physical (3.938) and earth (7.686) sciences are considerably different in terms of responses from this sample, the Kruskal-Wallis test suggest no differences in student scores for any of the 3 domains tested (see table 4).

Table 4: Kruskal-Wallis test for significance on academic year and domain specific knowledge

	LIFE	PHYSICAL	EARTH
Chi-Square	4.514	3.938	7.686
df	4	4	4
Asymp. Sig.	.341	.414	.104

## CONCLUSIONS

The null hypothesis of no differences in accurate knowledge of earth science phenomena between preservice science teachers and alternative licensure students is not accepted. It is important to note that only 1 freshman was a participant of the study and thus does not provide a true reading of content knowledge differences between these groups. The university in which the study took place has recently made accommodations to the science teacher licensure program to encompass more required earth science courses to better prepare the graduates with a broader knowledge base in the sciences. However, what is intriguing are the mean ranks illustrated in table 2. These students take most of the biological sciences in the freshman year and physical sciences in the sophomore and early junior years. Most of the participants take the required earth science content courses during the junior year and juniors performed better on earth science questions than the other academic levels. The basic knowledge of earth science is more than likely fresher to these students and thus it might explain why they performed better on the earth science items in the instrument.

These results suggest the potential impact of graduating teachers with lacking Domain-specific knowledge; specifically in earth science. In North Carolina for example, the majority of first year teachers with a comprehensive teaching license are generally asked to teach earth science. With recent science education reform movements advocating for a greater development of PCK for preservice teachers (Doster, 1997) it is crucial teacher educators develop an understanding of what their prospective teachers have assimilated in their science content courses.

The National Science Education Standards call for teachers to acknowledge and redirect student preconceptions about incorrect scientific phenomena (National Research Council, 1996). It can be argued that teachers who themselves have misconceptions about basic scientific phenomena will not likely be able to redirect students with naive conceptions. As Standard 1 of the National Science Teachers Association (1998, section 1.3 Recommendations of the National Science Teachers Association) stated,

---

*The content knowledge of the prospective science teacher is developed primarily in science courses taught by science faculty. Assigning the development of the skills and knowledge required by this standard to one or even several science method courses is unlikely to produce the depth of understanding needed for effective teaching practice. All science teacher candidates should be provided with a carefully designed, balanced content curriculum leading to a demonstrated knowledge of the concepts and relationships they are preparing to teach.*

Moreover, INTASC I calls for teachers to be able to articulate the major concepts within the science domain in which they teach. Certainly, one could argue that grade 8 test items are not complex enough to be considered anything other than “Big Ideas” in that domain. These standards need to be taken seriously and teacher educators need to acquire information that assures their students are prepared to teach a wide variety of science topics. Hewson and Hewson (1983) defined conceptual change as allowing learners to examine their own experiences and confront naive conceptions. It is critical that teacher educators challenge preservice teachers to confront expert views and to reflect upon their current views and how that might impact teaching and learning; specifically in earth science (Dahl et. al., 2004). As Lynch (2003) suggested, with increased understanding of content, teachers may change their beliefs on how science should be taught. "Unless we make some effort to explore students personal theories we will continue to graduate college students with their childhood misconceptions virtually untouched" (Woods, 1994). In science education if this phenomenon is perpetuated, the NSTA Core Knowledge Standards and INTASC Standard I will likely never be met.

## REFERENCES

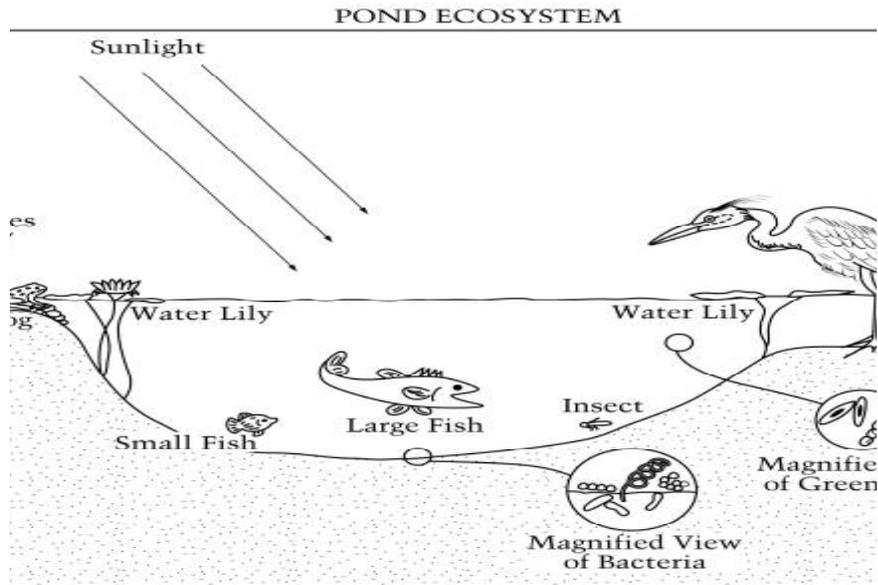
- Ausubel, D. P. (1968). *Educational Psychology: A cognitive view*. New York: Holt, Rinehart & Winston.
- Ball, D., & McDiarmid, G. (1990). The subject matter preparation of teachers. In M. H. W. Houston, & Sikula (Ed.), *Handbook of Research on Teacher Education*. New York: Macmillan.
- Barba, R. H., & Rubba, P.A. (1992). A comparison of preservice and inservice earth and space science teachers' general mental abilities, content knowledge, and problem-solving skills. *Journal of Research in Science Teaching*, 29(8), 188-192.
- Barba, R. H. and Rubba, P.A. (1993). Expert and novice earth and space science teachers' declarative, procedural and structural knowledge. *International Journal of Science Education*, 15(3), 273-282.
- Borko, H., & Putnam, R.T. (1996). Learning to teach. In R. C. C. D.C. Berliner (Ed.), *Handbook of Educational Psychology* (pp. 673-708). New York: Simon & Schuster Macmillan.
- Boyes, E., Chamber, W., & Stanisstreet, M. (1995). Trainee primary teachers' ideas about the ozone layer. *Environmental Educational Research*, 1(2), 133-145.
- Butler, S. (2003, March). *Process vs. science content knowledge of middle school students constructing contour maps: A spatial, inquiry-based task*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Philadelphia, PA.
- Dahl, J., Anderson, S.W., & Libarkin, J.C. (2004). *Digging into Earth Science: Alternative conceptions held by K-12 teachers*. Retrieved August 8, 2005, from <http://newton.bhsu.edu/eps/dahletal2004v2.pdf>
- Doster, E. C., Jackson, D.F., & Smith, D.W. (1997). Modeling pedagogical content knowledge in physical science for prospective middle school teachers: Problems and possibilities. *Education Quarterly*, 24(4), 51-65.
- Driver, R., Guesne, E., & Tiberghien, A. (1985). *Children's ideas and the learning of science*. In *Children's Ideas in Science*. Philadelphia, PA: Open University Press.
- Enfield, M. (2000). Content and pedagogy: *Intersection in the NSTA standards for science teacher education*. Retrieved May 3, 2002, from <http://www.msu.edu/~dugganha/PCK.htm>
- Gruber, K. J., Wiley, S.D., Broughman, S.P., Strizek G.A., & Burian-Fitzgerald, M. (1999-2000). *Schools and Staffing Survey, 1999-2000: Overview of the Data for Public, Private, Public Charter, and Bureau of Indian Affairs Elementary and Secondary Schools*. Washington, D.C.: National Center for Educational Statistics.
- Harcombe, E. S. (2001). *Science teaching, science learning*. New York: Teachers College Press.
- Hewson, M. G., & Hewson, P.W. (1983). Effect of instruction using students' prior knowledge and conceptual change strategies on science learning. *Journal of Research in Science Teaching*, 20, 731-743.
- Khalid, T. (2003). Pre-service high school teachers' perceptions of three environmental phenomena. *Environmental Educational Research*, 9(1).

- Lynch, S. (2003). Deepening understanding of science and mathematics education reform principles: Novice teachers design web-based units using Project 2061's curriculum analysis. *Journal of Science Teacher Education*, 14(3), 193-216.
- National Assessment of Educational Progress. (2000). The Nation's Report Card. Washington, D.C.: National Center for Educational Statistics.
- National Research Council. (1996). National Science Education Standards. Washington, D.C.: National Academy Press.
- National Science Teachers Association. (1998). CASE draft standards. Washington, D.C.
- Reynolds, A. (1995). The knowledge base for beginning teachers: Education professionals' expectations versus research findings on learning to teach. *Elementary School Journal*, 95(3), 199-221.
- Schoon, K. J. (1995). The origin and extent of alternative conceptions in the earth and space sciences: A survey of pre-service elementary teachers. *Journal of Elementary Science Education*, 7(2), 27-46.
- Shulman, L. S. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher*, 15(2), 4-14.
- Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1), 1-22.
- Shymansky, J. A. (2000). The role of student outcome data in teacher certification. Paper presented at the *National Science Council ROC(D)*, Taipei, TW.
- Smith, D. C. (2000). Content and pedagogical content knowledge for elementary science teacher educators: Knowing our students. *Journal of Science Teacher Education*, 11(1), 27-46.
- Stofflett, R. T. (1993). Preservice elementary teachers' knowledge of rocks and their formation. *Journal of Geological Education*, 41, 226-230.
- The National Commission on Teaching and America's Future. (1996). *What Matters Most: teaching for America's Future*.
- Trend, R. (2000). Conceptions of geological time among primary teacher trainees, with reference to their engagement with geoscience, history and science. *International Journal of Science Education*, 22(5), 539-555.
- Trend, R. (2001). Deep time framework: A preliminary study of UK primary teachers' conceptions of geological time and perceptions of geoscience. *Journal of Research in Science Teaching*, 38(2), 191-221.
- Veal, W. R., & Makinster, J.G. (1999). Pedagogical content knowledge taxonomies. *Electronic Journal of Science Education*, 3(4).
- Westbrook, S. L., & Marek, E.A. (1992). A cross-age study of student understanding of the concept of homeostasis. *Journal of Research in Science Teaching*, 29, 51-61.
- Woods, N. C. (1994). A close-up look at how children learn science. *Science Education*, 41, 33-34.

## Appendix A

Figure 1

The picture below shows a pond ecosystem. Use this picture and what you know about the things in it to answer the questions in this section.



1. If air pollution causes the rain that falls on this pond to become much more acidic, after two years how will this acidity affect the living things in this pond?

- A) There will be more plants and animals because the acid is a source of food.
- B) There will be fewer plants and animals because the acid will dissolve many of them.
- C) There will be fewer plants and animals because many of them cannot survive in water with high acidity.
- D) There will be more plants and animals because the acid will kill most of the disease-causing microorganisms.

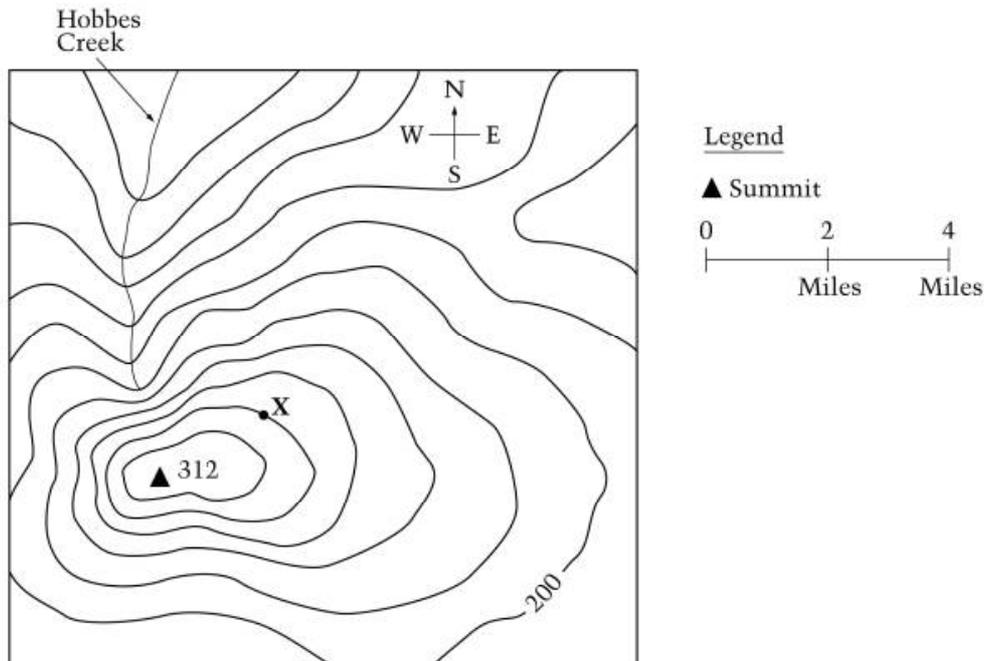
STANDARDS C.2.A. 1,2,5,12

2. Which of the following best explains why the pressure inside a high-flying airplane must be controlled?

- A) At high altitudes there is greater atmospheric pressure than on the surface of the Earth.
- B) At high altitudes there is lower atmospheric pressure than on the surface of the Earth.
- C) If the cabin is not pressurized, ozone and other upper atmospheric gases will enter the airplane.
- D) If the cabin is not pressurized, carbon dioxide will escape from the airplane.

STANDARDS C.3.A. 11, 13; C4.A. 1,7,12; C.5.A. 11

The following question refers to the topographic map below, which shows Willow Hill (elevation 312 feet) and Hobbes Creek. On the map, each contour line represents 20 feet of elevation.



3. In which general direction does Hobbes Creek flow?

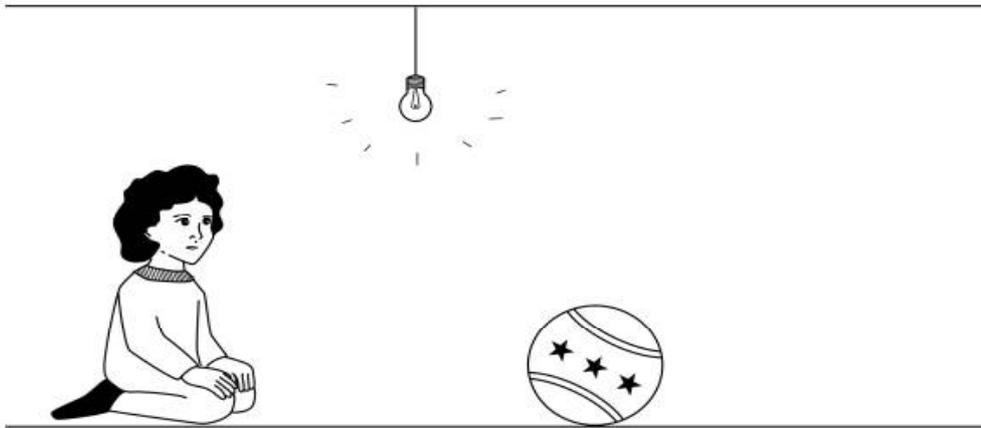
- A) To the north
- B) To the east
- C) To the south
- D) To the west

STANDARDS C.4.A. 1,3,6

4. If you were looking at an apple in a completely dark room (absolutely no light source present), what would you see after being in the room for more than 5 minutes?

- a. The shape of the apple, but not the color.
- b. The color of the apple but not the shape
- c. Nothing at all
- d. Everything with some difficulty

STANDARDS C.5.A. 5,8,11



5. In the figure above, which of the following is the pathway of light that allows the child to see the ball?

- A) Light bulb \* child's eyes \* ball
- B) Child's eyes \* light bulb \* ball
- C) Ball \* light bulb \* child's eyes
- D) Light bulb \* ball \* child's eyes

STANDARDS C.5.A. 5,8,11

6. The Earth's Moon is

- A) always much closer to the Sun than it is to the Earth
- B) always much closer to the Earth than it is to the Sun
- C) about the same distance from the Sun as it is from the Earth
- D) sometimes closer to the Sun than it is to the Earth and sometimes closer to the Earth than it is to the Sun

STANDARDS C.4.A. 8,10

7. What causes North Carolina to experience different seasons throughout the year?

- a. It is warm (summer) when earth is closer to the sun in its orbit and cold (winter) when earth is further away from the sun?
- b. Earth is always equidistant to the sun
- c. Earth is tilted on its axis and North Carolina is never tilted toward the sun
- d. Earth is tilted on its axis and tilts toward the sun at one point and tilts away from the sun in the opposite point of its orbit.

STANDARDS C.4.A. 7,8,10

8. In the human body the digestion of proteins takes place primarily in which two organs?

- A) Mouth and stomach
- B) Stomach and small intestine
- C) Liver and gall bladder
- D) Pancreas and large intestine

STANDARDS C.2.A. 1,10,11,12

9. What property of water is most important for living organisms?

- A) It is odorless.
- B) It does not conduct electricity.
- C) It is tasteless.
- D) It is liquid at most temperatures on Earth.

STANDARDS C.2.A. 1,5,12

10. To keep a heavy box sliding across a carpeted floor at constant speed, a person must continually exert a force on the box. This force is used primarily to overcome which of the following forces?

- A) Air resistance
- B) The weight of the box
- C) The frictional force exerted by the floor on the box
- D) The gravitational force exerted by the Earth on the box

STANDARDS C.5.A 1,2,3,4,5

11. Which of the following is designed to convert energy into mechanical work?

- A) Electric fan
- B) Kerosene heater
- C) Flashlight
- D) Baking oven

STANDARDS C.5.A. 1,7,11

12. Which of the following is most consistent with the modern theory of evolution?

A) Parents pass their physical traits to their offspring; those offspring with traits that help them survive in the environment are able to reproduce.

B) Parents change their physical traits in order to survive in the environment, then those parental traits are passed to their offspring.

C) Life on this planet came from another planet far out in space.

D) Living organisms have not changed for hundreds of millions of years.

STANDARDS C.2.A. 4,7,12

13. Which of the following would be the best model to show the interactions between water and the Sun's heat energy in cycles of precipitation?

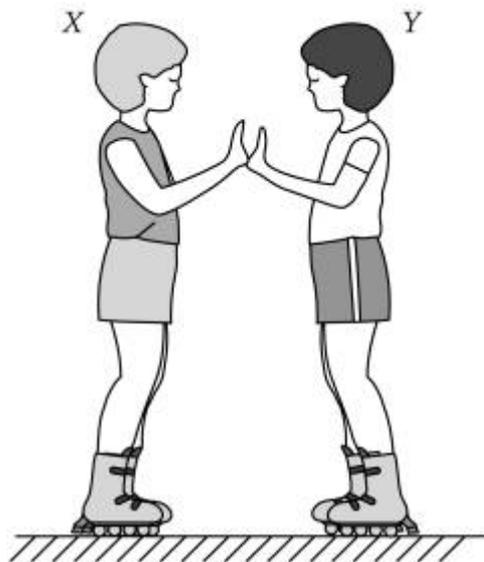
A) A light shines on an aquarium covered with glass, and water droplets form on the inside of the glass.

B) A light shines on a closed cardboard box containing a plant.

C) A light shines on a man's face. Droplets of sweat form on his face as he exercises.

D) A light shines on a glass of iced tea. Water droplets form on the outside of the glass.

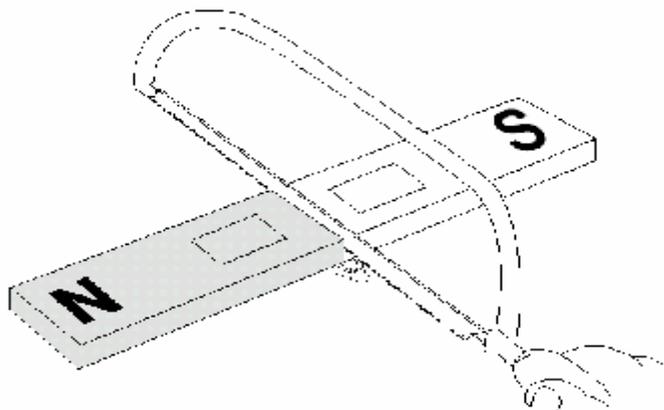
STANDARDS C.4.A. 5,6,7,10



14. Two boys wearing in-line skates are standing on a smooth surface with the palms of their hands touching and their arms bent, as shown above. If Boy X pushes by straightening his arms out while Boy Y holds his arms in the original position, what is the motion of the two boys?

- A) Boy X does not move and Boy Y moves backward.
- B) Boy Y does not move and Boy X moves backward.
- C) Boy X and Boy Y both move backward.
- D) The motion depends on how hard Boy X pushes.

STANDARDS C.5.A. 1,2,3,4,10



15. A bar magnet is cut in two with a hacksaw. Write an “N” or an “S” in each box on the diagram to show the polarity of the cut ends.

STANDARDS C.5.A. 9,11

**Leonard A. Annetta**

College of Education, North Carolina State University

Poe Hall 326-H Box 7801

Department of Mathematics, Science and Technology Education

Raleigh, NC 27695-7801

Tel: (919) 513-1286 (919) 515-1063 Fax

E-mail: [len\\_Annetta@ncsu.edu](mailto:len_Annetta@ncsu.edu)

**Sharon Dotger**

Syracuse University