The Ramifications of Teachers Lack of PCK while Uncovering Student Misconceptions

Kimberly E. Saccardi
St. John Fisher College
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Students come to our science classrooms with a diverse set of ideas of how the world works, as do teachers. When these ideas are incorrect, they are sometimes referred to as misconceptions and can come from a variety of sources. Misconceptions can come from books, television, and simple life experiences. It is imperative that teachers uncover these misconceptions in order to properly teach scientific concepts. What happens however when teachers do not know enough content to be able to uncover these misconceptions? How does the pedagogy suffer? This research explored the intersection of pedagogical knowledge and content knowledge (PCK) and showed that many teachers are unable to uncover basic science misconceptions via a true/false science beliefs quiz.
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The Ramifications of Teachers Lack of PCK while Uncovering Student Misconceptions

In the science classroom, both students and teachers have a definite idea of how the world works. These ideas can have a major impact on both teaching and learning. When these ideas or notions are incorrect they are often referred to as misconceptions. When these misconceptions go unchecked, the student is unable to properly understand scientific concepts and inevitably have misunderstanding about the world in which they live. A critical component to teaching in the science classroom is a teacher’s ability to uncover misconceptions, acknowledge them and teach the content accordingly. Teachers need to recognize and interpret student response if they are to properly teach the subject at hand (Akerson, Flick, & Lederman, 2000). This ability falls under the umbrella of pedagogical content knowledge, (PCK). In short, with respect to science, PCK can be explained as the difference between a scientist and a science teacher (Cochran, 1997). It is how a teacher transforms content into meaningful, teachable lessons.

It must be asked however, what happens when the teacher does not have the content knowledge that allows her to recognize these misconceptions? What happens when the teacher does not have the content knowledge to answer a student’s question? How is a teacher supposed to be able to differentiate a lesson if he does not understand how a food chain works? How can a teacher be expected to excite a classroom about energy if she does not even understand it? The following research will attempt to uncover that many teachers and prospective teachers do not understand many, basic scientific concepts that ultimately will interfere with their ability to create meaningful, enduring understandings in the classroom. Without the correct and accurate content knowledge, teachers tend to fall back on superficial assignments and projects. This research intends
to show that there needs to be a major examination of both undergraduate and graduate teacher preparation. There needs to be an overlapping of both content knowledge and pedagogical content knowledge. Teachers need to be equipped with a solid foundation in basic scientific principals and processes in order to properly apply the current and effective teaching methods.
Literature Review

It is generally accepted that teachers know that students do not come to the classroom with a blank slate. Students come to class with very strong ideas on how the world works (Nelson, 1999). They come to class with a diverse set of ideas and alternate conceptions concerning the objects and the world around them (Wandersee, Mintzes, & Novak, 1994). There has been a large body of research conducted regarding these ideas as to where they come from, how to uncover them and the implications for teachers, especially the importance of acknowledging them and tailoring lessons accordingly. Often the ideas that students hold regarding science concepts are incorrect or inaccurate (Gang, 1993). When these ideas are incorrect, they are often referred to as alternative conceptions, pre-conceptions or misconceptions (Abimbola, 1988). For the purpose of this literature review the term misconceptions will be used with respect to scientific concepts that are incorrect based on current and accepted scientific research.

In addition to this research, there is also research on how teachers acquire content knowledge and then transform it to teach students. This field of research is generally referred to as pedagogical content knowledge (PCK). This literature review will explore the intersection of student misconceptions with respect to teachers PCK, and specifically, a teachers' content knowledge of their specific subject matter.

A Brief Overview of PCK

There have been many ideas and concepts researched in the field of PCK. Research has been conducted to find out how teachers acquire this knowledge, how they conceptualize it, how they transform their knowledge into teaching material and what
happens when teachers lack subject specific content knowledge. Despite all of the research, there is no universally accepted, comprehensive definition of PCK (van Driel, Verloop & de Vos, 1997).

Cochran (1997) explained that PCK is the knowledge used by teachers to teach students what they know about a particular subject. She stated that PCK is the organization of subject matter and content from a teaching perspective. She described this as the difference between a scientist and science teacher.

Teachers differ from scientists, not necessarily in the quality or quantity of their subject matter, but in how that knowledge is organized and used. In other words, an experienced teacher's knowledge of science is organized from a teaching perspective and is used as a basis for helping students to understand scientific concepts. (1997, ¶ 6)

The basis for most of the research on PCK centers on the acquisition and content of a teacher's knowledge base. Basically, the researchers were concerned with the sources of teacher knowledge and what a teacher does with said knowledge in a teaching capacity.

Shulman (1986) organized his concepts of teacher knowledge by starting with the knowledge base of teachers. This includes a teachers content knowledge, general pedagogical knowledge to include classroom management strategies and organization, knowledge of curricular resources (media and materials available to teachers), and PCK, "...that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (p. 8). Shulman went on to include in his description of teachers knowledge base, the knowledge of learners and
their characteristics, knowledge of educational contexts (governance, financing, community and culture) and the knowledge of...educational ends, purposes and values, and their philosophical and historical grounds” (p. 8).

In their research on assessing beginning science teachers’ PCK, Lee, Brown, Luft, and Roehrig (2007), organized PCK into knowledge of the science content, goals, students, curriculum organization, assessment strategies, teaching strategies and knowledge of teaching resources. “We define PCK as: The knowledge that science teachers use to facilitate students’ understanding of scientific concepts and to encourage their scientific inquiries. This knowledge includes an understanding of effective instructional strategies, representations in diverse teaching situations” (p. 52).

To be more consistent with the constructivist perspective on teaching, Cochran, DeRuiter & King (1993) added to and modified the definition of PCK. It should be noted here that because they believed the term knowledge is too static to described a teachers state of PCK, they prefer the term knowing in place of knowledge for PCK and thus refer to PCK as PCKg in their research. They define PCKg as, “...a teacher’s integrated understanding of four components of pedagogy, subject matter content, student characteristics and the environmental context of learning” (p.256). They also added developmental levels, learning abilities, ages, attitudes, motivations and students’ prior and misconceptions to be included in the definition of PCK. In addition, they included that PCKg must include a teachers understanding of cultural, political, environmental, social physical setting in which a student is asked to learn.

At this point, the idea of student misconceptions needs to be revisited with respect to a teacher’s lack of PCK, specifically the lack of content knowledge and what happens
when a teacher does not know the content he is required to teach. Shulman, along with other researchers, were concerned with the fact that content, the actual subject matter, had somewhere, somehow, lost focus. In 1986, Shulman worried that the research and policy makers were so concerned with how teachers organize and manage their classrooms, divvy out praise and blame, formulate their questions, assessments and lesson plans that they had allowed the pendulum too swing too far away from the importance of content. Shulman referred to this as the missing paradigm. He asked where teacher explanations come from, how teachers decide what to teach and how to represent it. He asked how teachers know how and what questions to ask a student to check for understanding. He stated that most of the research focuses on how children learn but not how teachers learn. Shulman went on to ask several questions regarding teacher knowledge such as what happens when a teacher does not know that a textbook is flawed or how to clarify a concept to a confused student. He asked, “What pedagogical prices are being paid when a teacher’s subject matter competence is itself compromised by deficiencies of prior education or ability” (p. 8). This question has plagued researchers and prompted deeper analysis of what happens when a teacher lacks content knowledge.

It was also noted in the research that PCK should include the teachers’ awareness of common misconceptions students hold in science (Hashweh, 2005; Lee et al. 2007). To help understand the pervasiveness of misconceptions, it needs to be noted that there are many sources in which students acquire ideas about the world.
Sources of Misconceptions

Many researchers have identified and studied these sources in hopes to help teachers become more aware and help create more meaningful lessons for their students. One source of misconceptions is simple life experiences (Adams & Hamm 1999; Crockett, 2004; Edens & Potter, 2003; Liggitt-Fox, 1996; Yip, 1998). Cynthia Crockett (2004) wrote of an experience with her five year old niece regarding why socks and mittens are warm. Her niece knew that socks were not inherently warm and knew that mittens were inherently warm. When Crockett asked her why, her niece stated that mittens were warmer because they were thicker. Crockett went on to explain in her research that children may simply imagine the way things work and apply those ideas to their everyday experience. Until challenged, those ideas serve as a constant source of explanation for them. These ideas are very powerful as they come to the child before any formal science instruction. They are most resistant to change and may only be changed if a teacher first acknowledges that these misconceptions exist (Yip, 1998).

Misconceptions can be found in a wide variety of mass media as well. Although these sources are not technically teaching resources, they still offer up plenty of incorrect ideas that students bring with them to the classroom. Cartoons and comics showed man and dinosaurs living together when in actuality, humanoids have only been on earth for a few million years and dinosaurs have been extinct for over 65 million years (Adams & Hamm, 1999). In addition, the media has a tendency to portray science as dangerous, boring and tedious. It also portrays aliens landing on earth and glorifies sorcerers and mystics thus perpetuating pseudoscience and along with it, misconceptions (Adams & Hamm, 1999).
Another, more troubling, source of scientific misconceptions were found in science text and trade books. Researchers discovered both dramatic and subtle inaccuracies in many texts used by classroom teachers. This problem was compounded by that fact that teachers tend to fall back on errant textbooks when teachers lack subject specific content knowledge (Tamir, 1988).

Research showed that teachers relied heavily on the teacher’s manual for support but the manuals host problems as well. Diagrams were often improperly captioned; questions were evasive and did not offer enough information to solve the problem and many texts defined or described scientific principals incorrectly (Raloff, 2001). One pervasive problem was that texts and manuals omit important information regarding student misconceptions and did not provide the correct explanation or corrective activities to contradict these misconceptions (Eaton, Anderson & Smith, 1983). While Eaton, Anderson and Smith were researching how teachers teach the concept of light, they noticed that many of the children believed that light helps us see things by simply brightening the object. At this point, the teachers needed to not only provide a correct explanation of the role of light in seeing, but they needed to contrast it and compare it to the students’ misconceptions. The textbook did not alert the teachers to this very common misconception and did not offer any ways in which the teachers could help the students grasp the idea that light bouncing off an object is what allows us to see it.

“Consequently, the teachers gave the concept little attention, and few children learned it” (p.8).

George D. Nelson, director of Project 2061, a childhood education program of the American Association for the Advancement of Science in Washington, D.C., stressed that
the problem of teachers having too little time is compounded by the seriousness of errant
textbooks. His studies along with the findings from the TIMSS analysis of textbooks
found that, “US textbooks lack focus and coherence and rarely provide teachers with
effective instructional strategies to help students learn specific content” (Nelson, 1999, p. 56). As part of a solution to this problem, project 2061 has developed a comprehensive
set of questions to help evaluate a textbook thus providing teachers a better set of
classroom resources.

Misconceptions also came from trade books in the classroom. Teachers tended to
use these books because they are so easy to integrate as part of a whole language
curriculum (Mayer 1995). Both teachers and children gravitate towards these books
because they are visually stimulating, easier to acquire in stores and libraries, more fun to
read than science textbooks. They can spark curiosity creating a more positive and
motivating science experience (Kralina, 1993; Yopp & Yopp, 2006). Teachers also used
trade books to help connect material that may seem isolated in textbooks and worksheets.
And furthermore, it allowed teachers to reach a variety of reading levels while
maintaining consistency in the content (Butzow & Butzow, 2000).

In 1995, associate professor in the department of education at Indiana University-
Perdue University, Deborah A. Mayer, conducted extensive research to see how trade
books can affect the development of scientific concepts in elementary students. Mayer
read a science trade book, which specifically dealt with children’s misconceptions
regarding whales, to students ranging in age from 5-9. She read, Dear Mr. Blueberry, by
Simon James. Mayer found that not only did the book have inaccuracies regarding
marine life but children also acquired new misconceptions. The students also
remembered the stated misconceptions and they recounted them as new facts. Clearly, in
efforts to alleviate misconceptions, the author actually planted new ones. She also found
that illustrations and fanciful text were very misleading. In his book, *The Nature Fakers*,
author Ralph H. Lutts warned against using books that impose human values on wildlife,
showing humans controlling nature, incorrectly representing death in nature and
portraying animals as people think they should be. Lutts believed that this created a
distorted view of nature thus creating misconceptions (Eggerton, 1996).

In addition to the above mentioned sources, misconceptions can inadvertently
come directly from the teachers themselves (Yip, 1999, Schoon & Boone 1998). Many
teachers feel inadequate about their understanding of science (Lederman, Gess-Newsome
& Latz, 1994; Stepans, 1996). Research showed that many elementary school teachers
did not fully understand the content that they teach (Kruger & Summers, 1990). There
was also evidence to support that notion that when teachers do not feel comfortable
teaching a topic they tend to confuse terminology and do not encourages exploration of a
topic (Eaton, Anderson & Smith, 1983). As noted earlier, misconceptions can be very
resistant to change and this is true for teachers as well. Robert Barrass, (1984) asked why
teachers continue to teach things that are incorrect. He answered in part, “...teachers
(including the authors of textbooks for introductory courses) are influenced by the books
that they used themselves when they were at school and college. In this way, unless it is
recognized, dogma will be perpetuated” (p. 204).
Methods of Uncovering Misconceptions

Clearly, the research supported the notion of the importance of uncovering misconceptions. There has been considerable research in different methods for teachers to uncover misconceptions. One of the most common methods discussed in the literature was the use of a pretest to help uncover student misconceptions. By using well designed questionnaires and examining the results of carefully selected questions, a teacher may uncover pervasive misconceptions that need to be addressed in class (Buck, 2001). In Gang’s (1993) research, he notes that ironically, the worse the results of a pretest are the better for the teacher. Gang explained that by sharing the poor test results with the students, the misconceptions will lose power and become more resistant to change allowing the correct concept to remain. Also, a pretest may reveal a surprise to the teacher. While conducting research on student misconceptions regarding concepts of light, Eaton, Anderson and Smith (1984) reveal through a pretest that none of the students were aware of the role that light that bounces off an object allowing us to see it. By using this item on a pretest, the teachers knew they had a responsibility to correct this misconception.

Another efficient method to uncovering misconceptions was web-based, authentic scenarios such as internet multimedia exercises or IMMEX (Cox, Jordan, Cooper & Stevens, 2006). Developed at UCLA and initially developed to improve the capabilities of medical students, this free software allows teachers to see the problem solving process in action and allows them to pinpoint exactly where a student might have a misconception. IMMEX has several science based scenarios such as participating on a hazmat team, being a secret agent in charge of an unknown chemical and determining
what it is, genealogy projects based on Mendelian genetics and epidemiological cases. The scenarios have many different clones of each other and allows for students to keep participating on one topic. This software, in part, helped with a teachers lack of scientific background by providing a detailed report and description of the though process and were neatly displayed in a chart for each scenario and each student. This allowed teachers to pinpoint potential trouble spots, uncover misconceptions and possibly identify class-wide discrepancies on a particular topic. When teachers know what particular misconceptions a student holds is allows them to more effectively develop lessons and better prepares students for mandated testing (Cox et al., 2006).

Research also has shown that simply talking with your students before planning a lesson can add tremendous insight into student misconceptions (Buck, 2003; Crockett, 2004; Eaton, Anderson & Smith, 1983; Thompson, 2007; Yop & Yop, 2006). Active classroom conversation allowed for students to verbally explore an idea and reason though them with guidance from the teacher. These discussions allowed teachers to hear specific misconceptions early on in the planning phase (Crockett, 2004). In addition to teacher guided discussions, the research showed that small group discussions were effective as well. When students discuss and debate a concept, a clearer picture of student misconception may be emerge. Discussions centered on a KWL (what a student knows, wants to know and what they learned) can help bring out misconceptions and see how prevalent some ideas may be in the classroom (Lindgren, 2003).

Although there are several ways to uncover misconceptions, the research failed to point out that the teacher must possess a great deal of content knowledge to even begin to attempt to uncover the students’ misconceptions. Shulman’s research (1987) supported
this idea. He wrote of a teacher being so uncomfortable with the content at hand that she actively ignored a very bright student's ideas and would not make eye contact with the student. She confessed that she knew this student always had good questions and wanted to avoid being asked a question in which she was uncertain about the answer.

One group of researchers was concerned with the uncovering of both teacher and student misconceptions though. Mary Stein, Charles R. Barman and Timothy Larrabee, (2007), developed a very powerful tool to help both teachers and students uncover common misconceptions in general science. They developed a 47 item, true/false, online test that provides instant feedback to the test taker. They found that by taking this test, students were made more aware of their misconceptions allowing room for change. Just as important, it revealed that teachers as well as students held many misconceptions and that by taking this test themselves, the misconceptions were halted, revised and thus not perpetuated in the classroom.

**Implications for Teachers Regarding PCK**

The review of the literature showed that students hold many misconceptions in science. And research also supported that it is imperative that teachers acknowledge and correct these misconceptions for the learner to acquire a deep understanding of a concept. Because we know that children bring many ideas to the classroom and they are often incorrect, teachers need to work to change them but need to first have the pedagogy to recognize misconceptions and then teach for understanding (Bracey, 1998). What happens though when the teacher does not know enough science to recognize his students' misconceptions? What happens when a teacher does not know enough science
content to even write a meaningful questionnaire? What happens when a teacher's professional course work centers around best classroom practices and not science content with respect to those practices? Here is where the research lacks in volume compared to the amount of research on student misconceptions. Most research on misconceptions simply ends with telling teachers that they need to acknowledge them to enhance student learning.

Shulman reminded us that learners have many ideas about their world before entering the classroom and stressed the importance of a teacher's ability to recognize of misconceptions. He went on to state that teachers need the research based, content knowledge that allows them to recognize these misconceptions in order to transform them into the correct concepts (1986). Many pre-service teachers have been told how important it is to uncover misconceptions before beginning a lesson. Researchers have discovered what happens when children are confronted with new information and what happens when a child's misconception goes unchecked. When students encounter new information, if it conforms to their expectations, the ideas are reinforced. Sometimes however, an idea goes against what they know and children respond in one of two ways, they ignore, distort or deny the idea, or they correctly modify it allowing for correct conceptions (Minstrell & Smith, 1983). By simply introducing a lesson and conducting experiments, and ignoring the fact that children come to the classroom with misconceptions about science, teachers run the risk of losing the students interest and forgoing a lasting, correct science concept. Students that do not understand the topics end up feeling helpless and resort to simply memorizing definitions and formulas (Stepans, 1996). Research showed that a different approach to teaching is needed.
It is no longer sufficient to merely present scientific information and allow students to develop or discover knowledge on their own. Teachers need to directly confront student misconceptions and use correct scientific concepts to properly explain scientific phenomenon (Eaton, Anderson & Smith, 1983).

*When Misconception Go Unchecked*

Su Gang (1993), a retired physics researcher and educator at Liaoning Normal University in China, conducted a very revealing study on what happens when teachers ignore or do not acknowledge student misconceptions. When beginning a lesson, teachers may use students' correct conceptions to their advantage but tend to ignore the negative role that misconceptions play. Gang tested what would happen if teachers used the misconceptions as the actual starting point for a lesson. He tested three groups of middle school children, groups A, B & C. The teachers for group A and B gave the children a pretest on buoyancy. They revealed the results to the class in which many of the class responded incorrectly to several test items. The pretest was designed to uncover misconceptions and to shake and discredit students' ideas. The teacher for group C was to teach with engaging activities and take the usual measures to ensure a positive learning environment but was not to uncover or acknowledge student misconceptions. The students in groups A and B were both surprised and intrigued by the amount of incorrect responses. This surprise and intrigue led students to a fierce inquiry as to why they were wrong. The teachers then provided experiences and activities that challenged their misconceptions. The results were students paid more attention and seriously thought about their own ideas and replaced them with the correct conceptions. These teachers
taught by a method of comparisons of misconceptions to accurate conceptions. The students in group C scored well on rote and formula based questions but did not do well on conceptual questions and did not show anywhere near the excitement for learning that was seen in groups A and B. Su Gang's research showed why it is so important that teachers confront student misconceptions and use them to their advantage.

*Lack of Content Knowledge in the Classroom*

While researching Malaysian science teachers' PCK and its influence on physics teaching, Lilia Halim and Subahan Mohd Meerah (2002) were able to show what happens when a teacher does not have the content knowledge she needs to conduct a meaningful lesson. They interviewed several teachers on the basic concepts in physics and found that trainee teachers' PCK for prompting conceptual understanding is limited. They discovered that teachers that gave incorrect answers on a questionnaire were less likely to be able to uncover student misconceptions and worse, they also discovered that due to a lack of understanding they created more misconceptions due to poor analogies and misused terminology. When teaching outside of their specialty areas, teachers could not transform ideas due to lack of and poor content knowledge.

Also concerned with the role of a teacher's content knowledge, Tobin and Garnett (1988) researched exemplary practice in science classrooms. They studied two primary and two secondary science classroom teachers. "The comparison was made as a result of dramatic differences observed in the content knowledge of the secondary and primary teachers and possible implications of such discrepancies for science teacher education" (p. 199). They found that there were many problems in the primary classrooms. Tobin
and Garnett did acknowledge that developmental differences between primary and secondary students could be a factor in the gravity of their results but they were confident in their interpretations of the major differences in the classroom.

Both primary teachers were certified to teach primary school but were not specialized in any one particular science content area. Their undergraduate and graduate work primarily focused on teaching science with respect to curriculum resources and appropriate activities for the age of the learner. They were both enthusiastic teachers and knew that a hands-on approach to teaching science was the best way to teach their students. The problems arose when it came to the actual content of the lesson. The teachers were not able to effectively lead a lesson because in essence, they did not know what they were talking about. Because of this, the classroom management strategies that they had learned were called upon and the class was managed rather than taught. Tobin and Garnett (1988) concluded that neither of these two teachers possessed the science content knowledge that they need to successfully conduct a hands-on lesson. They were misusing the supplies and unable to direct student learning or ask critical questions to keep the students focused. It was even evident that the teachers themselves were not even sure what the students were supposed to learn from the activity.

In contrast, the two secondary teachers were specialists in their content area, chemistry. They were able to use their deep knowledge and understanding to stimulate student learning and engage students in high level cognitive objectives. They knew how to sustain student engagement by using real world examples that the students could relate to and understand. Because of their extensive content knowledge in chemistry, they were able to link prior lessons and introduce new concepts in a way that made sense to the
students. Classroom management in terms of group size or method of instruction was not as important because the teacher knew how to, through content, keep their students engaged.

Teacher Preparation

Most, if not all, educators and policy makers agreed that teachers need both adequate subject matter preparation and adequate pedagogical training to be effective teachers (Ball & McDiarmid, 1990; Bracey, 1998; Cochran, DeRuiter & King, 1993; Halim & Meerah, 2002; Lederman, 2003). The research also supported that teachers need to be able to recognize and misconceptions in order to tailor the lesson to help the students adjust their framework to allow a deeper, correct understanding of a concept. The problem however is that according to the research, there is no universal set of criteria that defined what it is a teacher should know and be able to do in the classroom (Lederman & Flick, 2003; Shulman, 1987; Stotsky, 2006; Yip, 1998). “There is little, if any empirical evidence on how much more in-depth knowledge of a concept a teacher must possess to teach a concept successfully” (Lederman, 2003). Shulman (1987) was also concerned with the ramifications of such loose standards.

The rhetoric regarding the knowledge base however, rarely specifies the characteristics of such knowledge. It does not say what teachers should know and be able to do, understand or profess that will render teaching more than a form of individual labor, let alone it be considered among the learned professions. (p. 4) While researching who should be accountable for what beginning teachers need to know, Sandra Stotsky commented on policies she helped write.
Just about every standard in the five categories of professional standards for teachers in the regulations could have been suggested by anyone with even a remote understanding of what teachers should be able to do in their own classroom, regardless of subject matter and grade level. I helped write all of them, but they could have been generated almost entirely on the basis of common sense alone. (p. 259)

While Din-Yan Yip (1998) was researching novice teachers’ ability to identify misconceptions in biology teachers, he concluded that many teachers lack the content knowledge to effectively uncover biology misconceptions. He attributes this to the lack of pre-service training.

The incompetent subject matter knowledge of teachers suggests that the undergraduate courses taken by potential biology teachers may not be able to equip them with a strong foundation in the discipline for teaching the secondary biology curriculum. This problem can be attributed to the large variety of optional courses open for selection in undergraduate studies. (p. 474)

Unfortunately, due to lack of pre-service training, teachers often learn the content while teaching it and may never acquire the deeper understanding of a topic required to challenge students misconceptions and create meaningful connections (Ball & McDiarmid, 1990). Shulman (1987) realized the complexity of teaching and the many facets of the demands placed on teachers to effectively teach students so much so that he challenged teacher education preparation and claims that teacher’s exams should, in several ways, parallel exams given to doctors. He went on to argue that through the design and content assessment of teachers exams, “...teaching is trivialized, its
complexities ignored and its demands diminished. Teachers themselves have difficulty articulating what they know and how they know it” (p.6).

The research showed that one problem in teacher preparation is that the content courses for undergraduate and graduate students are not designed from a teaching perspective (van Driell, et al., 1996). While they researched preservice science teachers conceptions, Lederman, Gess-Newsome and Latz (1994) concluded that, “…if we desire highly interconnected subject matter structures in our preservice teachers, subject specific pedagogy courses must be integrated as well as subject matter courses” (p. 143).

Shulman (1987) recognized this as well.

“…the key to distinguishing the knowledge base of teaching lies at the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students”. (p.15)

Shulman (1986) also stated that the research does not intend to discredit the importance of one or the other, pedagogy or content knowledge but rather to blend the two aspects. “Mere content knowledge is likely to be as useless pedagogically as content-free skill” (p.8). He also noted that as equal time should be devoted to the elements of the teaching process and the content aspects as well.

Lee, Brown, Luft & Roehrig (2007) agreed that a strong background in science alone does not guarantee proficient level of pedagogical content knowledge but rather the combination of content classes within the framework of classroom experience. They found that, “...most beginning teachers, even those with advanced science degrees, bad
difficulties tailoring activities and materials to the needs of their students and monitoring student learning" (p. 57).

Summary

The research clearly showed that PCK is a special amalgam of many facets of the classroom and teacher education. Those components have been classified and categorized many ways but generally include teachers' knowledge of the subject, knowledge of different teaching styles, knowledge of classroom management and the ability to call on and combine any of those to teach meaningful lessons. Within the components of PCK is the teachers' knowledge of common misconceptions and the ability to correct and replace them with the correct conceptions. The research also clearly supported that there are a tremendous amount of sources through which a student can acquire misconceptions. When these misconceptions are overlooked and not acknowledged by the teacher the result is either a superficial or incorrect understanding of a scientific concept. The research also drew attention to the fact that there is not universal set of teacher preparation guidelines. This allowed for an unequal level of preparation for teachers thus creating a myriad of ineffective teaching strategies taking place in many schools at many grade levels.
Methodology

Many teachers lack the pedagogical content knowledge (PCK) to be able to uncover misconceptions because they themselves do not understand the content. Teachers, as well as students, hold many misconceptions. Without the proper undergraduate and graduate training, teachers, specifically in science content courses, inadvertently perpetuate misconceptions and also run the risk of creating new ones due to lack of content knowledge. The purpose of this research was to uncover teachers’ current state of science content and to see if they can recognize simple but pervasive misconceptions in science concepts and drawings.

The participants of this research were graduate students enrolled in the Math/Science/Technology graduate program at St. John Fisher College in New York. It was assumed that students enrolled in an MST program are proficient in science but initial research showed otherwise. By selecting students enrolled in this program, a broad sample of teachers was available. The program includes both in-service and pre-service teachers ranging in grade level from pre-kindergarten through high school. The participants range in age but all are over the age of 18. The participants also vary greatly in their experience in the classroom. Some of the participants changed careers and have not yet taught in a classroom, some have just begun their careers and have some classroom experience and some have been teaching for many years. Regardless of the level of experience, many of the participants had the potential of teaching in a science classroom. The participants were enrolled in one or more of the following classes from...
the MST program; Assessment, Classroom Dynamics, Problem Based Learning and Integrating Math, Science & Technology.

The participants in this study were given a 44 item true/false test based on current pervasive misconceptions and current science beliefs. The test was developed by Mary Stein and Timothy Larrabee from Oakland University and Charles Barman from Purdue in 2006. They developed the online instrument to help identify commonly held misconceptions from a variety of subjects within science curricula. They designed the test to be taken online and immediate feedback is provided with detailed descriptions of the correct explanations of the misconception. The test has been scrutinized and revised by both teachers and scientists and has been found to both valid and reliable. Their goal was to help both students and teachers identify misconceptions which may create barriers to learning. The students at St. John Fisher took the same test that was developed by Stein, Larrabee and Barman. For the purpose of this research however, the test was typed and distributed in a hard copy format. In addition to taking the test in the hard copy version, the participants were encouraged to take the online version to get immediate feedback and possibly uncover their own misconceptions.

There were some additions to the online version of the test. In hopes to better analyze the results, participants were asked to answer a few questions regarding their current professional status. Participants were asked if they are currently teaching or substitute teaching and if so, what grade level and subject and for how many years. They were also asked if they have ever taught any science classes or have the potential to someday be teaching any science classes. After completing the 44 item true/false section,
the participants looked at three diagrams found in science texts. The diagrams contain common misconceptions and the participants were asked to circle or somehow identify the possible source of misconceptions. One diagram shows the circulatory system with both blue and red blood, a mushroom activity included in a plant activity book and a flyer from a science camp that shows a cave man walking a dinosaur on a leash. The last contained a passage from a bird identification guide describing how some birds are actually black but the sunlight is refracted within the structure of the feathers making them appear blue. The participants were asked if they could explain this phenomenon to a student and could they use additional real world examples to help illustrate this concept.

The participants were provided with an introduction letter and a consent form. The test was taken in an anonymous format and collected by the researcher. The data collected for the research was considered quantitative based on either a true/false or yes/no answer. The tests were analyzed and the data was recorded based on the results of the 44 true/false items. The diagrams were analyzed and the data was collected as to whether or not the participant could identify the misconception. For the purposes of this research, the researcher was looking for the identification that blood is not blue, mushrooms are not plants, and man and dinosaur did not live together. All other responses were considered and discussed as point of interest and unintended results. The bird passage was analyzed as a simple yes/no response to the question. The results of this research will be used to highlight deficiencies in teacher education and will be used as an implement to change in both undergraduate and graduate teacher education courses.
Results

The quizzes were divided into four categories based on a pre-quiz survey as to the current professional status; those that are currently teaching in a science classroom, those that are seeking out a science position in the future, and those that do not teach science and are unlikely to seek out a science position (this category has both pre/in-service teachers). In addition to the professional status, the participants were asked how long and what grade level they had been teaching. The content of the questions could be loosely categorized into the living world (biology, botany, and ecology), the physical world (physics and chemistry) and earth science (ecology, geology and astronomy). Because the questions were based on commonly held science misconceptions, there were many questions that overlapped in those categories.

Of the 38 participants, 17 were currently teaching (or substitute teaching) science ranging in levels from elementary to high school. The average score of correct answers for those currently teaching was 64%. The highest score for this category was 90%. At the time of this study, the participant has been substitute teaching in high school for 3 years. The participant missed three earth science questions and left one diagram blank. The lowest score for this category was 54%. Both participants that scored 54% had been substitute teaching for less than one year in a variety of subjects and grade levels. These two participants had the potential to sub or teach science but had very little experience with science content thus far.

One particularly noteworthy result however was from a high school chemistry teacher of 11 years. This participant answered only 28 of 48 questions correctly for an average score of 58%. Further analysis of this quiz revealed incorrect answers in all
disciplines of science. Of 13 chemistry related questions, eight of them were answered incorrectly. For example, when presented with question # 22, “A ball made of solid steel will not float on water. However, when the steel is used to make a boat it floats because the steel is made less dense”, the participant responded that this is true; the steel is made less dense. Of the 12 earth science questions, some of which were based in chemistry, eight were answered incorrectly.

The next category analyzed were those participants that were not teaching in any capacity and were currently seeking a science teaching position at various levels. This category consisted of 8 of 38 participants and the average score was 56%. The highest score for this category was 75%. This participant had once taught physics and eighth grade science but did not disclose the length of time taught. With respect to the question content, there appeared to be an even distribution of both correct and incorrect answers. The lowest score for this category was 33%. When asked if they had the potential to be in a science classroom, this participant wrote, “HOPE SO!!”. Of the 48 questions, there was no consistency as to the question content of the correct or incorrect answers.

Ten of the 38 participants fall into the category of those that do not teach science and are unlikely to seek out a science position. The average for this category was 60%. This category consists of math and special education teachers. These participants are unlikely to have extensive science content courses. The highest score for this category was an 83% and this participant was not currently teaching but hopes to be teaching math. The lowest score was a 48% for a participant that was not currently teaching and does not have the potential to be teaching science.
The overall analysis of the data collected for the 38 participants revealed a 60% average of correct answers to the science beliefs quiz. Three of the 38 participants did not answer any of the pre-quiz questions as to professional status. The results of those quizzes were one participant at 56% and two at 73%.

There were several interesting observations made during the quiz. The quiz was given as an individual assignment; participants were not asked to work on this in groups or share ideas. In two of the three classes, it was observed that students were looking at others' quizzes. One participant was very secretive about her wandering eyes. She seemed to be very uncomfortable with her own answers and looked onto the papers of three of her tablemates throughout the entire quiz. When she turned in the quiz she smiled and sarcastically said, “Thanks” and rolled her eyes. Another participant was very vocal about her unease with her answers. She and another participant were laughing at their lack of knowledge and one said, “Who ever even knew this stuff?” They continued with the quiz on their own once they were reminded that this was an individual test.

In one class, the participants were very eager to hear the correct answers. One interesting comment came from a self-proclaimed math teacher. He was commenting on a blood-flow diagram in which the blood was shaded both red and blue. When it was revealed that the common misconception was that blood is blue, he asked, “What do you mean? How is that misleading?” Another student quickly asked, “You don’t really think blood is blue do you?” He sheepishly laughed and said he misunderstood. He then stated how thankful he was to be a math teacher.

Several general comments were made after the quiz and answer session. Many students were surprised at their lack of knowledge. Some said they felt stupid. One said,
"Glad they didn't ask me that in my interview". Another student wished he could have been quizzed on his methodology because that he was, "... really good at that". Some argued points, and one said it was stupid to even argue about science because it is all facts. The result seemed to be that the majority of the participants gained a sense of awareness regarding their science content knowledge. And some even saw a perceived division of PCK.
Past research revealed that many teachers feel inadequate about their understanding of science (Lederman, Gess-Newsome & Latz, 1994; Stepans, 1996) and showed that many elementary school teachers did not fully understand the content that they teach (Kruger & Summers, 1990). That research was confirmed by many of the participants of this study who verbally acknowledged that they were not comfortable with their current level of science experience. This inadequacy and lack of understanding does not allow for teachers to even attempt uncovering misconceptions. Past research showed that by using well designed questionnaires and examining the results of carefully selected questions, a teacher may uncover pervasive misconceptions that need to be addressed in class (Buck, 2001). However, it is likely that many of the participants in this study could not even create a meaningful, well designed questionnaire in attempt to uncover misconceptions. Several researchers have shown that by simply having content rich conversations with students, or doing KWL’s, teachers can dramatically improve a lesson by uncovering prior knowledge and misconceptions (Buck, 2003; Crockett, 2004; Eaton, Anderson & Smith, 1983; Thompson, 2007; Yop & Yop, 2006). It is unlikely that several of the participants would feel comfortable with, and be successful at this, based on their content knowledge.
Conclusion

Shulman (1986) posed the question, “What pedagogical prices are being paid when a teacher’s subject matter competence is itself compromised by deficiencies of prior education or ability” (p. 8). Based on several informal conversations during this research, one of the ramifications of lack of content knowledge is that the pedagogical knowledge and methodology suffers. While discussing what teachers do when they are confronted with unfamiliar content, many answered that they go online and come up with something for the next day. One teacher commented that she was so embarrassed at her lack of content knowledge that she would not go to her mentor teacher for help. She figured if the door was closed, no one would know they were playing science vocabulary BINGO. Another teacher asked how could he possibly differentiate a lesson that he himself had learned last night? It had also been revealed that when unfamiliar with a topic, it was generally considered safe to go with fill-in-the-blank, multiple choice, true/false and superficial yet fun projects. Many teachers felt more comfortable with their text books and the activities provided rather than venturing out on their own to create a lesson tailored to their own class needs. This was confirmed by Tamir’s research in 1988. And, as previous research has shown, text books have a host of problems and perpetuate misconceptions as well (Raloff, 2001). The general consensus was that it is impossible to develop inquiry based, meaningful lessons with unfamiliar content. It needs to be reiterated here that when the classroom is not engaged and challenged, they, feel helpless, resort to memorization become bored and uninvolved and ultimately, the classroom becomes managed rather than taught (Gang, 1993; Tobin & Garnett, 1988).
The solution here is not to simply add generic content classed for teacher preparation. There needs to be comprehensive research devoted to the development of PCK. Teachers need to be taught science within the framework of teaching it to other students. Teacher preparation courses need to have an integration of both content and pedagogy. A well designed class would allow the prospective teacher to participate in an inquiry-based, hands-on lab and in which the student is allowed to discuss the thought process along with the scientific process. Pitfalls and misconceptions must be addressed so the teacher will be able to challenge and excite his students. Many teachers are unable to apply teaching strategies because they are overwhelmed with learning the content. It is unacceptable that many colleges and universities are allowing teachers to graduate without basic science content firmly established. Shulman (1986) referred to this as the missing paradigm; he reminded us that we need to study not just how children learn but how teachers learn as well.
References


Rice, D. C. (2002). Using trade books in teaching elementary science: Facts and


Appendix A

Informed Consent

Informed Consent Form

St. John Fisher College
INFORMED CONSENT FORM

Title of study: Teachers lack of PCK and how it interferes with uncovering student’s misconceptions in science

Name(s) of researcher(s): Kimberly Saccardi

Faculty Supervisor: Dr. Diane Barrett
Phone for further information: 585-385-8366

Purpose of study: The purpose of this research is to uncover teacher’s current state of science content and to see if they can recognize simple but pervasive misconceptions in science concepts and drawings. It is my hope that this research will reveal that many of our current science teachers do not fully understand the content that they are teaching. In addition, I hope to use this research as a catalyst to help change undergraduate and graduate course work for elementary and secondary science teachers.

Approval of study: This study has been reviewed and approved by the St. John Fisher College Institutional Review Board (IRB).

Place of study: SJF College classroom
Length of participation: 30-40 minutes

Risks and benefits: The expected risks and benefits of participation in this study are explained below: Participants may be made aware of possible science content difficulties. There will be no physical risks associated with this research.

Method for protecting confidentiality/privacy: This is an anonymous quiz. Quizzes will be destroyed after research is completed.

continued on back
Your rights: As a research participant, you have the right to:

1. Have the purpose of the study, and the expected risks and benefits fully explained to you before you choose to participate.
2. Withdraw from participation at any time without penalty.
3. Refuse to answer a particular question without penalty.
4. Be informed of appropriate alternative procedures or courses of treatment, if any, that might be advantageous to you.
5. Be informed of the results of the study.

I have read the above, received a copy of this form, and I agree to participate in the above-named study.

_________________________  ___________________________  _____________
Print name (Participant)    Signature                      Date

_________________________  ___________________________  _____________
Print name (Investigator)    Signature                      Date

If you have any further questions regarding this study, please contact the researcher listed above. If you experience emotional or physical discomfort due to participation in this study, please contact the Office of Academic Affairs at 385-8034 or the Wellness Center at 385-8280 for appropriate referrals.
Appendix B

Letter of Introduction

St. John Fisher Graduate Students,

Have you ever been in a position to teach a concept that was unclear to you? Have you ever heard how important it is to create enduring understandings of deep meaningful science concepts and realized that you don’t have a deep enduring understanding? And finally, have you ever been told how important it is uncover student’s misconceptions only to find out that you don’t know if what the student is thinking is right or wrong? You are not alone. I have heard and seen many of my classmates stumble on science topics you'd think a teacher would know – myself included!

Tonight you will be asked to take an anonymous quiz regarding science beliefs. This quiz was developed by Mary Stein of Oakland University. With her permission, I am asking that you take this quiz in a totally anonymous format to help me understand the current state of teacher’s content knowledge in the areas of general science. This research is a component of my thesis project. Your rights are protected in this research; the Institutional Review Board has reviewed and approved this research. There is an informed consent form that will accompany this research.

Also, I am asking that you look at a few science drawings to see if you can uncover some misleading information and explain some text. These are not trick questions! These come directly from science related material designed to TEACH kids in a science context.

I strongly encourage you to take the online version of the science quiz. You will receive instant feedback on your results. See where you may have science content weaknesses. By taking the online quiz you are contributing to research that will help make changes in teacher education.

https://www2.oakland.edu/secure/sbquiz/index.cfm

Thank you for your time, you are making a difference!

Kim Saccardi
kendle@rochester.rr.com

Please let me know if you are interested in further information or have any questions or comments

For more info on Mary Stein:
Appendix C

The Science Beliefs Quiz

This is an anonymous quiz. I would like to know however, a bit about where you are in your teaching career. I will not share any of this information with anyone. Do not put your name anywhere on this quiz.

Do you currently teach or sub? If you are currently teaching or subbing, please indicate approximate number of years.

What grade level/subject(s) do you teach?

Have you ever taught any science classes or have the potential to someday be teaching any science classes?

Below is a set of 44 TRUE/FALSE science questions. Please circle either TRUE or FALSE based on your science beliefs. Feel free to write comments in the space provided below the question.

1. The only essential constituents that plants need in order to grow are: water, light, and nutrients from the soil or medium in which they exist.

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<th>TRUE</th>
<th>FALSE</th>
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2. Plants use oxygen.

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<td>3. Most animal species depend on plants.</td>
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<td>4. Typically, the arrows of a food chain symbolize what each organism is eating (e.g., grass -&gt; mouse -&gt; snake -&gt; hawk).</td>
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<td>5. If the producers (plants) disappeared from Earth, organisms that prey on other organisms for food (carnivores) would only be slightly affected.</td>
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<td>6. Humans, dogs, fish, worms, and insects are all considered to be animals.</td>
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<td>7. Any organism that possesses locomotive structures (e.g., movement capabilities) and is able to reproduce is correctly classified as an animal.</td>
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<td>8. An organism is composed of one or more cells.</td>
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<td>9. Reproduction is a characteristic of all living systems.</td>
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<td>10. Sexually produced offspring can be identical to either of their parents.</td>
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<td>11. Extinction of species of organisms is common.</td>
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12. When a book is at rest on a table (not moving), other than the force of gravity, there are no other forces acting on it. | TRUE | FALSE |

13. An astronaut is standing on the moon with a baseball in her/his hand. When the baseball is released, it will fall to the moon’s surface. | TRUE | FALSE |

14. When two spheres that are the same size, have similar surfaces, but have unequal masses are dropped in a vacuum, the more massive sphere will fall faster. For example, assume one sphere is made of wood and one sphere is made of lead (greater mass). | TRUE | FALSE |

15. A force is needed to change the motion of an object. | TRUE | FALSE |

16. It is possible to light a flashlight bulb with just one wire and one battery and no other equipment. | TRUE | FALSE |

17. We need light in order to see | TRUE | FALSE |

18. If you see your head and shoulders in a mirror, with the mirror mounted securely and flat against the wall, and you wanted to see more of yourself (for example, your belt), you should back straight away from the mirror. | TRUE | FALSE |

19. The velocity of a radio wave and a visible light wave in a vacuum are the same. | TRUE | FALSE |

20. The total mass+energy in the universe is constantly changing. | TRUE | FALSE |
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<tbody>
<tr>
<td>21. Heat flows from warmer objects to cooler ones until both reach the same temperature.</td>
<td>TRUE</td>
</tr>
<tr>
<td>22. A ball made of solid steel will not float on water. However, when steel is used to make a boat it floats because the steel is made less dense.</td>
<td>TRUE</td>
</tr>
<tr>
<td>23. Under normal temperature and pressure conditions, all particles, such as atoms or molecules, are in constant motion.</td>
<td>TRUE</td>
</tr>
<tr>
<td>24. An increase in temperature corresponds to an increase in the motion of particles.</td>
<td>TRUE</td>
</tr>
<tr>
<td>25. If a small amount of sugar is added to a closed container of water and allowed to sit for a long period of time (e.g., a week or longer) without stirring, the sugar molecules will be more concentrated at the bottom of the container.</td>
<td>TRUE</td>
</tr>
<tr>
<td>26. The bubbles in boiling water consist primarily of air.</td>
<td>TRUE</td>
</tr>
<tr>
<td>27. Two containers with equal amounts of clear water are at two different temperatures. Equal amounts of green dye are added to each container. The dye will mix with the warmer water faster.</td>
<td>TRUE</td>
</tr>
<tr>
<td>28. When a chemical reaction occurs, the total number of atoms in the resulting products can be less than or greater than the original number of atoms that comprised the reactants depending on the type of chemical reaction that took place.</td>
<td>TRUE</td>
</tr>
<tr>
<td>29. On a hot, humid day you place a cold glass of lemonade on the table. The droplets of water you notice forming on the outside of the glass are due primarily to condensation of water vapor from the surrounding air.</td>
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<tr>
<td><strong>30.</strong> As one goes higher into the atmosphere (for example, climbing a mountain), the atmospheric pressure decreases.</td>
<td>TRUE</td>
</tr>
<tr>
<td><strong>31.</strong> A baseball hit with the same force will travel farther on a humid day as opposed to a dry day, assuming the baseball maintains its properties of elasticity and mass independent of the weather conditions.</td>
<td>TRUE</td>
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<tr>
<td><strong>32.</strong> A visible cloud in the sky consists primarily of water vapor.</td>
<td>TRUE</td>
</tr>
<tr>
<td><strong>33.</strong> Approximately 97% of the earth’s water is found in the oceans.</td>
<td>TRUE</td>
</tr>
<tr>
<td><strong>34.</strong> Molten earth material (magma) that produces such features as volcanoes comes from the middle mantle (about half way between the Earth’s center and surface).</td>
<td>TRUE</td>
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<td><strong>35.</strong> Moderate earthquakes (5.0 - 5.9 on the Richter Scale) happen approximately twice a day.</td>
<td>TRUE</td>
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<tr>
<td><strong>36.</strong> There is a 10% chance that Chicago will experience a powerful earthquake (greater than 5.0 on the Richter scale) in the next 50 years.</td>
<td>TRUE</td>
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<td><strong>37.</strong> One type of rock, such as a igneous rock, can be transformed into another type of rock, such as a sedimentary rock.</td>
<td>TRUE</td>
</tr>
<tr>
<td><strong>38.</strong> From homes in the continental United States, there is no date or time when the sun is directly overhead.</td>
<td>TRUE</td>
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<tr>
<td><strong>39.</strong> Day and night are caused because the earth spins on its axis.</td>
<td>TRUE</td>
</tr>
<tr>
<td><strong>40.</strong> We see phases of the moon because the moon moves into the earth's shadow.</td>
<td>TRUE</td>
</tr>
<tr>
<td><strong>41.</strong> In the northern hemisphere, the earth is closer to the sun in the summer.</td>
<td>TRUE</td>
</tr>
<tr>
<td><strong>42.</strong> When people in North America view a full moon, people who live in Australia would see a different phase.</td>
<td>TRUE</td>
</tr>
<tr>
<td><strong>43.</strong> The reason we experience seasons is because the distance between the earth and sun changes.</td>
<td>TRUE</td>
</tr>
<tr>
<td><strong>44.</strong> The longest daylight period in Australia occurs in December.</td>
<td>TRUE</td>
</tr>
</tbody>
</table>
Do you see any possible misconceptions a student might acquire by looking at this flyer? Please describe.
Do you see any possible misconceptions a student might acquire by looking at these diagrams? Please describe.
Do you see any possible misconceptions a student might acquire by looking at this activity from a book about plant activities? Please describe.
After reading the section highlighted, would you be able to explain this to a student that didn’t understand this concept? Would you be able to compare/contrast using real objects as to why some things really are blue and some “are not”?

**Indigo Bunting**

- **Size:** 9/" (23 cm)
- **Male:** Vibrant blue finch-like bird. Scattered dark markings on wings and tail.
- **Female:** Light brown bird with faint markings
- **Juvenile:** Similar to female
- **Nest:** Cup; female builds; 2 broods per year
- **Eggs:** 3-4, pale blue without markings
- **Incubation:** 12-13 days, female incubates
- **Fledging:** 10-11 days, female feeds young
- **Migration:** Complete to southern Florida, Mexico and Central and South America
- **Food:** Insects, seeds, fruit; will visit seed feeders
- **Compare:** Male Eastern Bluebird (pg. 63) is larger and has a rusty red breast.

**Stan's Notes:** Usually only the males are noticed. Actually a black bird, as it does not have any blue pigment in its feathers. As with the Blue Jay, sunlight is reflected within the structure of the bunting feathers, making them appear blue. Appears indescent in direct sun. Molts to acquire body feathers with gray tips, which quickly wear off to reveal bright blue plumage in spring. Molts in full to appear like females during winter. Males often sing from treetops to attract mates. Will come to feeders in spring before insects are plentiful. Mostly seen along woodland edges, feeding on insects. Migrates at night in flocks of 5-10 individuals. A late migrant, males return before females and juveniles, usually returning to previous years’ nest site. Juveniles move to within a mile from birth site.