Countering Astronomy Misconceptions in High School Students

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Abstract:

What exactly are misconceptions? Why do they persist, and what can we do to overcome them? Thus the purpose: To discover common astronomy misconceptions held by high school students and to determine appropriate intervention for these misconceptions so that the students graduate with correct knowledge of this topic. The results from a review of literature show that misconceptions occur for many reasons, from misunderstanding of vocabulary to combining several ideas into one. The best way to counteract misconceptions is to challenge students to think objectively. One good way of challenging the students is through guided inquiry investigations where the students discover the correct ideas for themselves. If teachers were able to do more than just get through the prescribed material, but could also eradicate incorrect information through inquiry, students would leave school better equipped with the tools needed for life, such as self-initiative and critical thinking.

Literature Review:

What exactly are misconceptions? They are also known as: preconceived notions, nonscientific beliefs, naÏve theories, mixed conceptions or conceptual misunderstandings. Misconceptions are defined as something a person knows and believes but does not match what is known to be scientifically correct (Misconceptions in Science, n.d.). There are five major classifications defined by how they occur: preconceived notions, nonscientific beliefs, conceptual misunderstandings, vernacular misconceptions, and factual misconceptions. They can also occur from not knowing where or how to look to find the correct answer.

Preconceived notions are ideas formed from what we see everyday. For example, young children think the Earth is the center of the galaxy or universe because people describe the sun as setting and rising. Nonscientific beliefs are views learned from sources other than scientific education, such as religious or mythical teachings that do not have supporting scientific evidence. Conceptual misunderstandings can occur when scientific information is presented in a way that does not challenge their preconceived notions, and as a result, conflicting information results. Vernacular misconceptions, or vocabulary problems, occur when a scientific term means one thing in science, and something else in everyday life. The best example of this is “work”. In science the word "work" means exerting a force over a distance, while in everyday terms this word means getting up early and going to a job. This double meaning often confuses students. Factual misconceptions are false information usually learned early in life that goes unchallenged (Simanek, n.d.). An example is the belief that there are no earthquakes in Texas. Though they do not occur often as in California, we do get small ones occasionally.

From reviewing the literature, most of the methods countering misconceptions are aimed at junior-high to high school aged students. University level students tend to have fewer misconceptions overall, probably because by this age they have been exposed to science for quite some time. The most likely age group to hold misconceptions tends to be elementary students, because they have the least experience (Trumper, 2001).

There are numerous ways that misconceptions can occur. Scientific data is constantly changing. No one person can stay current on all of the new research findings. As teachers, we are supposed to be teaching the newest and best of scientific information, but by the time textbooks are written and published, much of the information is old. This inability to stay on top of constant change causes misinformation. We also deal with conflicting information because of opposing viewpoints. This conflict of information causes much confusion, and can lead to combining information into a completely new concept (adapted from Misconceptions in Science, n.d.). Parents and teachers relay their misconceptions to the children they teach with little to no challenge of the ideas. Often, adults have no idea that what they "know" is actually a misconception (Greenhouse Effect Misconceptions, n.d.).

Another way misconceptions occur is by oversimplification of scientific information, either by the media, who are not trained in science (Public Misconceptions in Science, n.d.), or by teachers and parents. In trying to make scientific material understandable, many times the information is overly simplified, causing an inaccurate view. The media also tend to have an agenda that slants scientific information to their point of view. One of the worst causes of misconceptions is cognitive overload. This occurs when too much information is presented at one time causing people to shut down all processing because they are overwhelmed with information (University of Massachusetts, 2000). This is detrimental because it can cause children to loose interest in science as a result of the "fear of failure" or "fear of peer ridicule". The loss of interest in science during school years can also eliminate the possibility of pursuing a science related career because of the way it is taught (McComas, W., 1996).

The persistence of misconceptions gives us clues to counter them. Teachers and parents often are not aware of children's incorrect scientific ideas. As a result, adults are unable to challenge student's thinking. Misconceptions also persist in children because they are not taught critical thinking skills in school. Instead, children are taught to memorize facts and to take multiple-choice tests. As a result, when presented with incomplete or new information, many students do not ask questions or otherwise challenge the new information, causing misconceptions to take root and flourish.

So what can we do to prevent misconceptions and challenge misconceptions held by our students? The first step is to attempt to discover what misconceptions the students already have. To do this we need to ask open-ended questions and truly LISTEN to the students' ideas (Misconceptions in Science, n.d.). This can be done in small groups, as a class, or in a journal. The students should commit to an outcome before an activity begins. Their ideas should be written on the board or on an overhead for later comparison (Podolner, 2000).

Once we know where the students stand, student thinking can be challenged by structuring experiences and the learning environment so that there are opportunities for students' to "test out" their ideas and prove the correct concepts to themselves (Simanek, n.d.). While students are testing their ideas, they also need to resolve any conflicts between their preconceived ideas and observations that may arise within their team during the testing (Podolner, 2000). When finished with the activity, the teacher must debrief the class, checking for student questions and for understanding of the new concepts learned (Podolner, 2000).

Another good method to counter misconceptions is to use concept mapping during the lessons. With concept mapping, students learn to visualize a group of concepts and their interrelationships (Committee on Undergraduate Science Education, 1997). A good way to utilize concept mapping is to do a "before lesson concept map" and an "after lesson" map, so that the learners can see what they have accomplished.

There are several things to keep in mind as we work to correct misconceptions. One method is to remind students that experiments are a means of testing ideas, not of arriving at an expected result. In other words, remind them that just because an activity doesn't turn out the way they expect, it does not mean that the experiment failed (Committee on Undergraduate Science Education, 1997). Students must also be encouraged to think more like problem-solvers and to practice critical thinking skills (Beaty, W. J., 2000).

Through reviewing the literature, it is apparent that there are several fairly common astronomy- specific misconceptions. The most common is about the cause of the seasons (Trumper, 2001; Henriques, 2000). Others include the formation of clouds, rain, thunder and lightning (Henriques, 2000), the nature of vacuum (Henriques, 2000; Oberg, J., 1993), lunar phases, revolution and rotation of the moon, and the size of the universe and distance between the planets (Trumper, 2001).

From the literature research, it appears that misconceptions are much more complex and prevalent than simple misunderstandings or receiving incomplete information. There are multiple methods for arriving at misconceptions. They can occur as a result of a misunderstood vocabulary or they can occur because of combining several ideas into one. Some are caused by deeply held beliefs, while others are caused because the recipient was overwhelmed with information causing a shutdown of all processing. Misconceptions can also occur from not knowing where or how to look to find the correct answer. The next thing needing investigation is how teachers can help students to confront and overcome their misconceptions (Riche, R.D., 2000).

Method:

The participants in this study were junior and senior level high-school students taking Geology, Meteorology & Oceanography (GMO) at a suburban high school in North Central Texas. There were 73 students in 3 classes during the 2002-2003 school year. There were 70 students who participated in the pre-survey and 48 who participated in the post-instructional survey. The population of the GMO classes was predominantly Caucasian, with about 8% African-American and Hispanic students. Of these students, 17% were concurrently taking chemistry, physics, or anatomy and physiology, while the other 83% were only taking the GMO science class.

A questionnaire developed by Dr. Marc Hairston at the University of Texas at Dallas to research astronomy misconceptions in grade school students was used to assess the students' knowledge of astronomy before studying it in class (See Appendix A). Questionnaires were distributed to the GMO students to be answered with the best of their ability for a daily grade (an attempt to increase validity of the questionnaire) without using any books or outside resources. The idea was to assess the student's ideas about astronomy before formal education on the topic. The same questionnaire was given to these students after completion of the astronomy and meteorology units to assess their understanding of the material. Students were allowed to use their textbook and notes as resources for the post-surveys, which was given as an optional assignment, again an attempt to increase the validity of the responses.

The two sets of questionnaires were then tabulated and compared for the following information: what were the most common misconceptions (ten questions were chosen), were these misconceptions corrected with instruction, and if not corrected with instruction - find out why. Assessment was also done to see if there was a difference between male and female responses to the questionnaires. Limitations of this study were that some of the students did not even try to answer the questions, and other questionnaires were illegible, reducing the number of valid surveys received.

Data were evaluated by recording the answers given for ten specific questions, and then tabulating the answers with the number of times a specific answer was given. The data were further divided into responses made by each gender. This was done for both the pre and post instruction questionnaires. The results were graphed for some of the questions to better evaluate the data. Once data were collected and tabulated into correct and incorrect responses for each question, then the t-test for independent samples was used on those results to determine significance (Gay & Airasian, 2003).

Results:

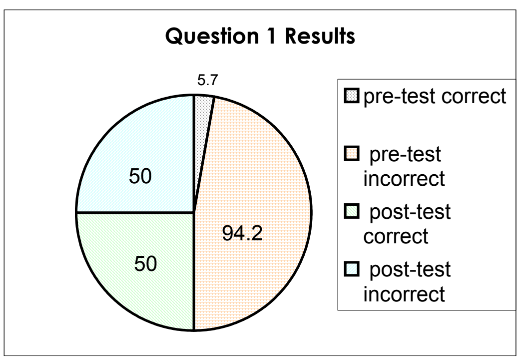
The final analysis focused on ten questions from the survey that were covered in the astronomy and meteorology units during the first semester. The questionnaires were analyzed, finding that female high school students had more "I don't know" answers than the males on the pre-instruction surveys. On the post-instruction surveys, the females still had more "I don't know" answers than males, though the differences were smaller than on the pre-instructional surveys. No less than seven different answers were found for each of the questions on the pre-test, many had ten to twelve different responses to the same question. The expectation was to find more misconceptions or "I have no idea" type answers than correct answers on the pre-instruction questionnaires.

Pre Survey			
Question	Female correct	Male correct	Who had More correct
1	2	2	Equal
2	6	4	Female
3	1	3	Male
4	12	11	Female
5	7	8	Male
6	0	0	Equal
7	0	0	Equal
8	0	1	Male
9	20	11	Female
10	1	11	Male
Post Survey			
Question	Female correct	Male correct	Who had More correct
1	19	5	Female
2	14	13	Female
3	6	5	Female
4	21	9	Female
5	6	9	Male
6	10	3	Female
7	6	1	Female
8	17	4	Female
9	10	6	Female
10	2	2	Equal

Table 1: Comparison of male and female correct responses.

Further analysis was done to determine if females had more or less correct answers per question than males. Table 1, above, shows the number of female and male correct and incorrect answers for each question on both the pre and post surveys. The column labeled "more correct" signifies if the females or males had more correct answers on the given question, or if they were equal. For the pre-survey, males answered more questions with correct answers than females, with three ties. However, on the post instructional survey, females answered more questions correctly than males. A conclusion that can be drawn from this information and observations is that females tend to be more willing than males to look up the correct answers if they have resources available.

Previous research showed common misconceptions in areas such as: the cause of the seasons; the formation of clouds, rain, thunder and lightning; the nature of vacuum; lunar phases; revolution and rotation of the moon; and the size of the universe and distance between the planets. This research found that high school students also have misconceptions about where weather occurs, ions and the ionosphere, the details of aurora borealis and the sun's corona, and the how and why satellites are able to stay in orbit or come back to earth. Most of these misconceptions were corrected with instruction and lab activities. Some were not corrected with the instruction given, possibly because the issue was not specifically addressed, or not sufficiently explained. The two questions regarding why a satellite stays in orbit or returns to Earth were not specifically addressed in class, and the structure of the sun was briefly visited, but not thoroughly discussed. Further studies should be done to see if these concepts are corrected with instruction.



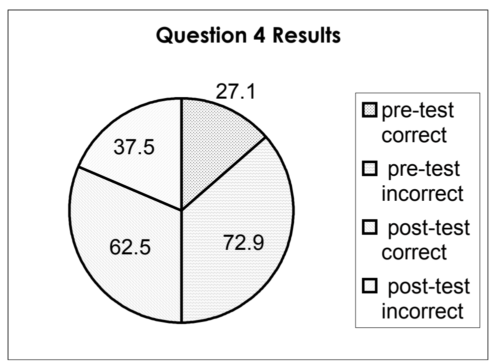


Figure 1

Figure 2

Comparison of the data in graph form helps to show which items improved with instruction. The graphs in Figures 1 and 2 below show two questions the students improved on after instruction. Question one asked where weather occurs. On the pre-test, only 5.7%of the students knew the correct answer. After instruction 50% of the students knew the correct answer. Question four asked what ions are. On the pre-test, correct answers were recorded for 27.1% of the students. This increased to 62.5% on the post-test. This shows that for some of the questions, instruction and inquiry activities aided in countering misconceptions.

Statistical analysis of the data in Table 2 shows that the results obtained were valid. The t-test for independent samples was used to determine if there was a significant statistical difference between the pre- and posttests (Gay & Airasian, 2003). Table 2 below breaks down the correct and incorrect answers to each of the ten questions. This is done for both the pre and post instructional surveys. The t-test for independent samples was calculated for both sets of surveys. The two t-test values were then compared to the t-test table value. Using a probability (α) of 0.05 and a calculated degree of freedom (df) of 116, the t-value required for the rejection of a null hypothesis was 1.980 (Gay and Airasian, 2003). The calculated t-value for the pre-survey was 8.418, and the value for the post-survey was 2.675. These were both larger than the requirement, indicating that the results of this analysis were statistically valid.

Question	Pre- correct	Pre-incorrect		Post-correct	Post-incorrect
1	4	66		24	24
2	10	63		27	21
3	4	66		10	38
4	19	51		30	18
5	15	54		15	35
6	0	70		13	33
7	0	70		7	41
8	5	65		21	27
9	31	40		16	32
10	12	68		4	44
	t calculated	8.418		t calculated	2.675
	t table value	1.980		t table value	1.980

Table 2: Astronomy Survey Results with t test for independent sample calculations.

Conclusion:

The most important result of this research was discovering good ideas about how to teach science more effectively, and hopefully how to prevent misconceptions. As a teacher, it was surprising to find out how common science misconceptions are, especially among those who teach science. This revelation encouraged examination of teaching styles in the science classroom. In previous years, science was usually taught in a traditional style classroom, with only tangents into the world of inquiry because of time and standardized test limitations. Recently, science instruction has leaned more toward the inquiry style of teaching, emphasizing critical thinking and problem solving skills, with mixed results. Those students who were already interested in the sciences have greatly enjoyed this type of challenge. Some of the students who took GMO because they thought it would be easy have decided that science is fun, while others decided that science is not easy. However, the overall result was an increase in critical thinking and problem solving skills in the students, and a reduction of misconceptions on the topics discussed in this research.

The most exciting method to test in the classroom is the total inquiry activity. The activity starts with the students committing to what they think will happen in the experiment by writing their hypotheses on the board or in their notebook. From there the students complete the activity, or a demonstration is done. The students will discuss and problem solve in their groups in order to come to a consensus on what actually happened compared to what they thought would happen. Finally we will discuss the results, any questions they have, and what they learned from the activity (Poldolner, 2000; Simanek, n.d.). From the literature researched and other experiences this year, this method is an excellent tool to allow the students freedom to find the answers themselves and to get involved in their learning. It also reinforces the students to use both critical thinking and self-initiative to discover the correct answers, helping to reduce misconceptions.

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Appendix A

Astronomy Survey (Numbered questions indicate questions used for research)

Atmosphere

1) Where in the atmosphere does weather occur?

2) What happens to the air as you go higher up (temperature, pressure, density, etc.)?

Where does the atmosphere stop?

Where does outer space begin?

Is there any air (no matter how little) in outer space where, say, the space shuttle orbits?

Ionosphere

3) What is the ionosphere?

4) What are ions?

5) What are neutral atoms and/or molecules and what does that mean?

What "ionizes" the atmosphere?

How do we use the ionosphere for communication?

Aurora and space science phenomenon

6) What is the aurora?

7) Where does the aurora occur?

Does the aurora occur in the southern hemisphere?

Can we ever see the aurora in Texas?

The sun, solar wind, and solar cycle

8) What is the corona?

Does material come off the sun and go into space?

What is the solar wind, where does it come from and what is it made of?

How does the solar wind affect the Earth (or does it affect the Earth at all)?

What is the solar cycle and how does it relate to the solar wind, sunspots, and the Earth?

Spacecraft and orbits

9) Why do satellites stay up in orbit?

10) What makes some satellites come back to Earth?

What happens to satellites which do come back to Earth? Why?

What is the shape of a satellite orbit?

How does the speed vary with the location of a satellite in its orbit?