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ABSTRACT

In science education, it is well understood that teachers' scientific conceptions can influence students' learning, but the extent to which students' knowledge influences teachers' ideas is not known. This paper describes a study of the mutual interaction of ideas between two second grade teachers, one teacher intern, and their classrooms during the course of an astronomy unit. In this case study, the teacher with the most content knowledge and the greatest ease in addressing student ideas was most influenced by the students. (Contains 16 references.) (WRM)

STUDENT AND TEACHER CONCEPTIONS ABOUT ASTRONOMY: INFLUENCES ON CHANGES IN THEIR IDEAS

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Introduction

It is common knowledge that students bring their own ideas and understandings about science to the classroom (Driver, Guesne, & Tiberghien, 1985; Osborne & Freyburg, 1985; Scott & Driver, 1997). Children's ideas influence what students gain from instruction. Additionally, teachers have their own ideas of science content that may not always reflect accurate conceptions (Kruger & Summers, 1989; Lawrenz, 1986; Neale, Smith, & Johnson, 1990; Stoddart, Connell, Stofflett, & Peck, 1993). Thus, teacher conceptions can be related to what students learn. Teaching can be thought of as a way for a more knowledgeable person to transform understanding, skills, attitudes, or values, into representations or actions that allow a less experienced person to develop an understanding of a concept (Shulman, 1987). An awareness of the process of teaching begins with knowledge of teacher conceptions. What the teacher knows influences students' conceptions, but does what the students know influence teachers' ideas?

Purpose

The purpose of this study was to compare the content knowledge of two second grade teachers, one intern teacher, and their students during the course of instruction in an astronomy unit. The current study looked at the similarities and differences of children's and teachers' ideas about astronomy, and how those ideas changed during the course of an 8-week unit. Influences of the teachers' ideas on the students, and students' ideas on the teachers were sought and described.

Research Methodology, Design, and Procedures

As part of a larger project, two second grade teachers, one teacher intern, and their classrooms were selected to participate in a study tracking content knowledge of astronomy. The teachers who participated in this study did not use a professional curriculum from which to teach their astronomy unit. Instead they pulled from a variety of sources to develop a unit they determined fit their own students.

Pre-instruction content knowledge was determined by pre-instruction interviews. A panel of expert science educators and research scientists validated interview protocols (see Appendix A). Ten of twenty students in each classroom were selected by each teacher to participate in the interviews. Each teacher also participated in pre-instruction interviews. Students were interviewed individually at an undisturbed location between both teachers' classrooms. The teachers were interviewed in their own classrooms after school. The interview questions were divided into two sections: (a) questions that addressed teacher goals for the students, and (b) questions that addressed *Benchmarks* goals for students to know about astronomy by the end of second grade (See Appendix B). All interviews were audio and video-taped and later transcribed. The transcriptions were coded to find patterns among conceptions. These conceptions were used to describe the content knowledge held by the students in both classrooms.

Teacher and student ideas were compared at the beginning of the study. As would be expected, the teachers held a more sophisticated level of knowledge than did the students. The students' views were compared to earlier studies conducted by Nussbaum and Novak (1976) and Mali and Howe (1979) (See Table 1). The ideas held by students in the current study were similar to the students' knowledge described in the earlier studies (Nussbaum & Novak, 1976; Mali & Howe, 1979).

Table 1
Second grade student post-instruction knowledge comparison of notions of the Earth compared to Nussbaum and Novak (1976) and Mali and Howe (1979)

	Notion 1	Notion 2	Notion 3	Notion 4	Notion 5
Current Study	T1[a]: 0	T1: 1	T1: 4	T1: 4	T1: 1
(1997)	T2[b]: 1	T2: 2	T2: 2	T2: 4	T2: 1
Nussbaum &	I[c]: 3	I: 7	I: 3	I: 7	I: 6
Novak (1976)	U[d]: 3	U: 7	U: 6	U: 6	U: 4
Mali & Rowe	K[e]: 36	K: 2	K:1	K: 1	K: 0
(1979)	P[f]: 39	P: 4	P: 4	P: 1	P: 0

Note. Numbers indicate the total students who fit into each notion category. [a]Response of students from Teacher One's classroom. [b]Responses of students from Teacher Two's classroom. [c]Responses of instructed students. [d]Responses of uninstructed students. [e]Response of students from Kathmandu, Nepali. [f]Response of students from Pokhara, Nepali

All science lessons during the 8-week units were observed and videotaped for transcription. The transcripts were coded to find instances of student expression of ideas, teacher recognition of student ideas, teacher action on student ideas, the effect of teacher action on student conceptions, and the influence of students on teacher conceptions.

At the conclusion of the unit teachers and students were again interviewed for their conceptions of astronomy. Interview protocols contained questions from the pre-instruction interviews as well as new questions developed from the astronomy unit. The post-instruction interviews proceeded in the same locations and fashion as the pre-instruction interviews. Transcripts were analyzed to find patterns of conceptions within the classrooms and the teachers. Comparisons were made of teacher and student knowledge, and the change in their conceptions over time.

Results

Change in Conceptions—Students from Classroom One

There was no difference in how students defined astronomy at the pre and post instruction interviews. Students all defined astronomy as a study of space. At the post-instruction interview all students could name, illustrate, and label the planets in order from the sun. Students were unable to do this at the pre-instruction interview.

All students believed the Earth was round. This belief represented no change from pre-instruction knowledge. However, at the post-instruction interview all students responded that gravity holds things to the Earth, where at the pre-instruction interview only seven students held that belief. Students seemed to have a more accurate understanding of gravity after instruction given responses like "the amount of gravity depends on the mass of the planet—bigger mass has more gravity." However, it was evident that most students did not have a scientifically accurate understanding of gravity, but simply that it was the force that held us on the planet, either by pushing or pulling on us. All students believed a dropped ball would land at your feet, and that gravity would let a ball roll, but not fall off the planet. Seven of the ten students drew pictures and described gravity as pulling toward the center of the Earth. The other three students believed gravity pulled things toward the "bottom" of the Earth.

Invariably, all students interpreted the question that asked for a response to what can be seen in the sky at night and during the day, as asking what creates day and night at the pre-instruction interview. Students generally had inaccurate conceptions of day and night. Three students believed the sun would move to the other side of the Earth so it would be night on one side. Three additional students believed the moon made night, and the sun made day. One child personified the sun, stating it would be night when the "sun went to bed." The moon and the clouds blocking the sun was a response given by one student as a description of why it became night. At the post-instruction interview students did not misinterpret the question. This time students responded with different celestial bodies they could see at day and night. Most conceptions were accurate, with most students in both classrooms responding they could see the sun in the day, but not other stars because the brightness of the sun makes it difficult to see other stars. One student believed she would be able to see other stars during the day if she looked carefully enough. All students noted they could see the stars and moon at night. All students in believed they would never see the sun at night, and three believed they could sometimes see the moon during the day.

Students were asked to select balls to represent the Earth, moon, and sun, and show the interviewer how they moved in space. At the pre-instruction interview nine students accurately selected the balls according to relative sizes. The other student used color as a selection criterion. At the post-instruction interview all students selected the balls according to relative sizes and most believed the Earth rotates around its axis and revolves in an orbit around the sun, with the moon rotating around its axis, revolving in an orbit around the Earth. Most students knew the length of time it takes for the Earth to rotate and make a day, and for it to revolve around the sun and make a year.

None of the students believed the moon looked the same in the sky each night at either the pre or post instruction interview. At the pre-instruction interviews seven students agreed that the moon does not really change shapes, it just looks different in the sky. One seemed to have a fairly conventional viewpoint of why the moon looks different in the sky, believing it was light from the sun shining on the moon in differing amounts, causing parts of the moon to show up in the sky. About half the students (4) believed something such as clouds, other planets, the darkness, or the sun covers the moon, causing parts of it not to be seen on the Earth. In Classroom One there was no formal instruction regarding the moon. There were no activities and students were not asked to watch the moon in the sky. Only one student at the post-instruction interview continued to believe parts of the moon broke off and go away and come back to create changes in how the moon looks. Eight students believed the moon looked different because of shadows from the Earth or other planets, or from clouds blocking the moon, which represents no change from pre-instruction interviews. Only one student mentioned an order in which the moon looked like it got "skinnier and then thicker."

All students thought there were more stars than could be counted. One student gave a definite answer of '100.' At the post-instruction interview there was no change in ideas, except the student now gave the response of '500.' Students often believed that the stars could not be counted because there were stars on the other side of the Earth that could not be seen from their side. Also, there was a general belief that there were so many stars that it would be hard to keep your place if you were counting them, and you could not count them in one night and would not know where to start counting again the next day. Nine students, at the pre, and all at the post-interview, believed that stars were balls of gas and fire. At the pre instruction interview eight students believed stars were actually circular, but that people draw them with points because it makes it look like they are sparkling, not how they really are shaped. Nine students believed stars were circular rather than five-pointed at the post-instruction interview.

When students were allowed to tell anything they wanted about astronomy, only three students responded at the pre-instruction interview. Seven responded at the post-instruction interview. At both interviews students generally responded with factual information they had heard or learned, though one student at the pre-instruction interview explained his theory about why we changed the clock back in relation to the spinning of the Earth and daylight savings time.

In general, student knowledge improved from their experiences in their astronomy unit. At both settings most students had ideas they could share and discuss. All students could talk intelligibly about what they knew. What they knew was not always in line with current scientific ideas. However, students had more accurate conceptions to most questions than prior to instruction. The area at which they had their most difficulty was regarding why the moon does not look the same each night.

Changes in Conceptions—Students from Classroom Two

Knowledge change in Classroom Two was dependent on both Teacher Two and the Intern Teacher actions. Teacher Two orchestrated most of the class discussions, including debriefs of the activities presented by the Intern Teacher. The Intern Teacher presented all the hands-on activities in the class. Teacher Two gave the topics to the Intern, but the Intern developed and presented them independently.

Prior to studying the unit only six students in Classroom Two had a conception of what "astronomy" meant. Students continued to lack a definition until the Intern Teacher presented a lesson on the final day of the unit during which students were asked to define and apply the definition. All students understood that astronomy was the study of "stuff in space" at the conclusion of the unit. Each student was able to draw and name all the planets in order from the sun at the post-instruction interview.

Students improved in their understandings of gravity, though four students believed gravity "pushed on you" from the air above. The Intern Teacher told students this idea several times during her instruction. Teacher Two did not address the concept of gravity with the class, but a guest speaker presented an activity designed to help students understand that air resistance affected how things fell to the Earth, not the mass. Only three students understood that gravity pulled toward the center of the Earth at the conclusion of the unit. The other seven interviewed believed that things were pulled toward the bottom of the Earth.

Students had better understandings of the relationship of the Earth, moon, and sun at the post-instruction interview. All students used relative size as the criterion for selecting balls to represent the bodies. Only seven students used this criterion at the pre-instruction interview. Students understood that the Earth spins and revolves around the sun, with the moon spinning and revolving around the Earth.

Students had a better understanding at the post-instruction interview of why the moon looks differently in the sky. Seven students understood it had something to do with the reflection of light from the sun and the "way the moon and Earth were in the sky." Teacher Two assigned homework to the students to track the way the moon looked in the sky each night, and held discussions nearly every day to allow students to describe the differences they saw. Thus, the idea of the apparent changes in the moon was revisited many times during the unit. Students recognized the changes occurred in a certain order. In addition, the Intern Teacher delivered a lesson during which students participated as the Earth and parts of the moon's orbit so they could see how where the moon was receiving light from the sun affected what they part they could see "lit up" on the Earth. The conceptions represent a significant change from the pre-instruction responses where five students believed something like clouds, other planets, or even the sun, covered the moon, causing it to look different.

At the post-instruction interview only three students responded to the final question asking them to tell anything more about astronomy they wanted. These students responded with factual information they had gathered from studying their individual topics. Student knowledge seemed to improve, but to a lesser degree than students in Classroom One. The greatest areas of improvement were the conceptions of what caused the moon to look different.

Changes in Conceptions—Teachers

Teacher One

Teacher One holds a master's degree in early childhood education. She has 24 years of teaching experience, sixteen of which at the first or second grade levels. She has experience teaching high school and college mathematics courses. She also has experience teaching special education. She considers her specialty reading, and enjoys teaching the primary grades in particular because her skills in reading are used to their best advantage. She has taught at her current school for sixteen years.

Teacher One's knowledge was fairly substantial and scientifically accurate. When she was unsure of a content question she felt comfortable stating her uncertainty. Her content knowledge did not change substantially over the course of the study as evidenced by her post-instruction interview responses. However, she researched other content areas not measured by the protocol in response to students' queries. Thus, her knowledge of astronomy also grew.

Teacher One defined astronomy as a study of "all heavenly bodies," by which she meant all naturally occurring things in space. Teacher One accurately named and drew the nine planets using relative size in order from the sun.

Teacher One agreed that the Earth is spherical, and related the pull of gravity to the mass of objects. She believed that objects with greater masses had a greater pull of gravity, but did not further explain her ideas. She understood that a ball dropped on the Earth would fall toward the center of the Earth.

When selecting balls to represent the sun, moon, and Earth, Teacher One chose relative size as the criterion. She held the conventional idea about what causes day and night, stating that the side of the Earth that is rotated to face the sun is at day, while the other side is night. Regarding the movement of the Earth, sun, and moon in space, she talked about everything in space moving, with the universe expanding, claiming this knowledge by red light tests conducted by scientists. She discussed the orbiting of the Earth around the sun and moon around the Earth, along with spinning on their axes.

Teacher One believed the moon does not always look the same in the sky. She described the changes in terms of phases of the moon. She discussed the moon phases in terms of the moon 'waxing and waning' in a cyclical way. She described the apparent change in the shape of the moon in terms of the Earth blocking some of the sunlight, and the moon getting only some of the reflected light.

Teacher One believed there is a countless number of stars. She stated that at the current level of knowledge it is impossible to know whether the universe is really infinite, or whether it is finite, and if it is finite perhaps we could someday count the stars. She responded to the final question that allowed her to express her own ideas about astronomy in relationship to teaching astronomy to children. She discussed the importance of elementary teachers feeling confident in their abilities to teach a wide variety of science concepts, and to continue fostering in children interest in knowing about the world.

Teacher Two

Teacher Two has a master's degree in early childhood education and has taught for ten years at grades one and two. She most enjoys teaching mathematics and language arts, and searches for ways to combine both subjects. She was a 1994 nominee for the Presidential Awards for Excellence in Mathematics Teaching. All of her ten years of experience teaching has been at the school she is now teaching. She is the lead instructor with Teacher One at math inservices they conduct for primary teachers, and is the lead author for the mathematics activity book both teachers wrote in 1994.

Teacher Two was concerned that she did not appear knowledgeable. She had difficulty responding to several of the questions. She had more accurate responses at the post-instruction interview. She said she remembered information as she delivered lessons each time that she taught the unit. It is also the case that she reviewed and studied astronomy books prior to teaching each portion of the unit.

Teacher Two called astronomy a study of things in space. Her view of astronomy included the study of space travel and rocketry as she discussed helping her students to learn about what it might be like to live in space. She had some difficulty naming all the planets accurately in order from the sun. She began to sing a song as a mnemonic, and still could not recall the 9th planet until her Intern Teacher stated from across the room "It begins with an 'N'." The teacher then remembered the planet Neptune. She did not discuss any of the orbits, and did not list all planets in the correct order. She was able to accurately name all the planets at the conclusion of the unit.

Teacher Two agreed the Earth was spherical, and that gravity keeps us on the Earth. Teacher Two was unsure how gravity worked, and tried to explain gravity using many science terms, such as 'pressure,' 'weight,' and 'force.' She talked a bit about what it would be like to be on a planet with less gravity, but did not discuss her ideas about gravity. She was visibly flustered at explaining her ideas about gravity, stating she knew this was the "gravity question," but was unable to explain her ideas. She understood that a ball dropped anywhere around the surface of the Earth would fall toward the center, but attributed it to pressure from outside. At the post instruction interview she spoke of gravity as "a force with the ability to keep things in place."

Teacher Two held conventional ideas about what causes day and night, stating that the side of the Earth that is rotated to face the sun is at day, while the other side would be night. She extrapolated to explain what might happen if the sun exploded, that pieces of the sun would go into space and "envelope other areas." She thought children might also talk about the sun exploding. However, no child discussed the sun exploding in response to this question.

When selecting balls to represent the sun, moon, and Earth, Teacher Two chose relative size as the criterion. She discussed the movement of the three in a traditional fashion, stating that the Earth and the moon spin on their axes, and that the Earth orbits the sun with the moon orbiting it. She was unsure whether the sun rotated on an axis. She was unsure in which direction the moon and sun revolved. At this point Teacher Two mentioned being concerned she would look inadequate with her responses, showing lack of confidence in her knowledge.

Teacher Two agreed the moon does not always look the same in the sky. She described the changes in terms of phases of the moon. She viewed the apparent changes in the moon in terms of changing toward one direction, increasing in size. She did not mention a cyclical attribute to the phases. She also held an unscientific idea about the phases of the moon, stating that the part of the moon that cannot be seen is in the shadow of the Earth. At the post-instruction interview she recognized that the apparent changes were from the sun's reflection on the moon from different positions.

Teacher Two thought it was impossible to count all the stars because some stars are being formed, and others are dying out. Because of the continual change in numbers it would not be possible to count them. She stated stars were made of debris pulled in with gas. She agreed that stars were circular, and thought it interesting that people do not draw them that way. She thought people probably draw the points on stars to represent solar flares coming off the balls of gas.

Teacher Two chose to respond to the final question, which allowed her to share what she wanted to add about astronomy. She responded by relating her ideas to teaching astronomy to children. She talked about wanting children to know more about astronomy than looking about in the sky. She wanted children to know about all the advantages research in space has given to people on Earth. She discussed ideas such as dehydrated foods, new materials that can create comfortable mattresses for use on Earth, and medicines that can help the sick.

Intern Teacher

The Intern Teacher was working toward a Master of Arts in elementary Teaching (M. A. T.) degree. Her internship in Classroom Two played a major role in obtaining her degree. She holds a Bachelor of Arts (B. A.) degree in liberal studies. The only teaching she has ever done has been as an intern, and the only science she has ever taught was in this second grade classroom. She recently took and received an 'A' in a college astronomy course at the same university at which she was earning her master's degree. She was amazed that she had received an "A" in astronomy because she did not believe she learned very much. At the post-instruction interview her content knowledge seemed much stronger than at her pre-instruction interview. It appeared she was reminded of information that she had previously learned through her own delivery of content. She grew quite excited about astronomy, even intending to teach it in her own classroom.

True to the Intern Teacher's perception of her knowledge, her pre-instruction content knowledge was not very strong. She was hesitant about her responses, and concerned that she appeared not to know very much. She was present during Teacher Two's pre-instruction interview and may have been influenced in her responses by knowledge of questions that were asked. Some of her responses below seemed stronger than they would have been had she not studied the topic in preparation shortly before her interview.

The Intern Teacher defined astronomy as a study of space and everything in space. She included in her definition "everything involved with space." She correctly named all the planets in order of distance from the sun.

The Intern Teacher believed the Earth was spherical, and that gravity keeps us on the Earth. She believed that gravity pushed from above us in the atmosphere to hold all things on the Earth. This conception was apparent in her lessons when she taught students that gravity pushed down from above us.

When selecting balls to represent the sun, moon, and Earth, the Intern Teacher chose relative size as the criterion. She discussed the movement of the three in a traditional fashion, stating that the Earth and the moon spin on their axes, and that the Earth orbits the sun with the moon orbiting it. She was certain the sun did not spin, but was positive the Earth and moon rotated in a counterclockwise clockwise direction because she had seen it on *Bill Nye the Science Guy*.

The Intern Teacher believed the moon does not always look the same in the sky. She studied this topic prior to the interview in preparation for the lesson she was to teach. She described the perceived changes in terms of phases of the moon. She stated the moon looked different because the sun reflects only on part of the moon, and depending on where the Earth is in relation to the sun and moon we see only part of the reflected portion. She recognized that it took about a month for the moon to proceed through a cycle of first appearing to grow larger, and then appearing to become smaller.

The Intern Teacher believed there is a countless number of stars. She believed that stars are made of gas, explicitly stating it was hydrogen gas that caused explosions on the sun. She agreed that stars were circular. She agreed that people probably draw the points to represent solar flares coming off the balls of gas.

The Intern Teacher chose to respond to the final question and share whatever she wanted about astronomy. It is interesting to note that like Teachers One and Two, the Intern Teacher responded in relation to teaching about astronomy to children. She stated that astronomy was "hard to teach!" but that it is important to teach about astronomers and what they do.

Influences in Change in Conceptions

Students

From this study it was found that student ideas about astronomy did change over the course of the unit. Their ideas became more conventional. Student ideas became more in line with their teacher's ideas, which would be expected considering it is the teacher who is providing the instruction. Some of the students' comments were very similar to expressions teachers used when describing their own ideas.

Classroom One

Teacher One influenced her students' ideas in many ways. She elicited students' ideas at the start of each lesson by using an Idea Invitation question that encouraged them to share their own thoughts about the science content that they were to study. She planned to address specific ideas through development of lessons following the elicitation of ideas. One such example is that of recognizing that students believed that Neptune and Pluto physically switched places in their orbits. Teacher One planned a demonstration and modeling activity specifically to help students understand that it was the oddity of Pluto's orbit that made it seem like Pluto and Neptune switched places, but that it did not mean they were trading orbits. Once she gained an understanding of their ideas she used several strategies to help students develop more accurate ideas, such as reading non-fiction tradebooks to give students new content ideas, explaining the content to the students, and scaffolding new ideas onto old understandings.

Another manner in which Teacher One influenced children's ideas was through cycling the ideas by eliciting and addressing the same ideas repeatedly during the course of the unit. Her pattern consisted of eliciting ideas in a whole group setting, addressing ideas shared by a majority of students, eliciting the ideas again within small groups to check for individual understandings, addressing ideas in small groups, and raising the question again in a large group setting. The cyclical revisiting of science content and confrontation of ideas seemed to influence students in Classroom One in developing their more accurate understandings of astronomy content.

Classroom Two

Teacher knowledge of astronomy influenced the learning of students in Classroom Two. Both the Intern and Teacher Two had lower levels of astronomy knowledge than did Teacher One. Students in Classroom Two had lower levels of astronomy knowledge than did students in Classroom One at the end of the unit.

Students were influenced to share ideas by the Intern Teacher, but when they did share their ideas it surprised the Intern Teacher and she was not able to effectively address them. The Intern Teacher claimed to be aware of the importance of prior knowledge and did use an Idea Invitation question to elicit student ideas. However, she was very surprised by their ideas, and believed if she could just phrase her questions better she would obtain the types of responses she believed she should receive. She did not attempt to address student ideas in instruction, but instead ignored or only partially acknowledged their ideas by picking up on portions of their statements that helped support her instruction.

Teacher Two, on the other hand, did attempt to influence student ideas using several strategies. She elicited children's ideas through a question that invited them to share their thoughts. This Idea Invitation question was raised at the beginning of each lesson. When she collected student ideas she chose to respond to them in several ways to help improve their knowledge of astronomy. She read a non-fiction tradebook, provided an explanation, or debriefed the Intern's activity lesson. These strategies were used in the arenas in which ideas were elicited. When ideas were raised in small groups, they were addressed in small groups. When elicited in large groups, they were addressed in large group settings. Occasionally while raising questions and conducting discussions with students Teacher Two did not have sufficient knowledge to respond to their statements, and thus, the conversation surrounding the content was dropped.

The students in Classroom Two were thus influenced in two different ways: (1) encouraged by Teacher Two to share ideas which were addressed in instruction by

Teacher Two, and (2) verbally encouraged to share ideas by the Intern Teacher, but also inhibited from sharing ideas by the responses given them by the Intern.

Teachers

The teachers' ideas about astronomy also changed during the course of the unit. The teachers' conceptions became more in-depth and scientifically accurate. It was found that not only did student expression of ideas influence how the teachers presented future lessons, but also influenced teacher thinking about science content. Teachers noted that questions and ideas raised by students caused them to reconsider their own thinking about scientific ideas. In this study it was found that not only did teachers influence student conceptions, but students also influenced teacher conceptions.

Teacher One was influenced by students' ideas to increase her knowledge of certain astronomy concepts. Several times during the course of instruction students raised questions for which Teacher One had no answer. Instead of dropping the ideas, she chose to research the information and bring it back to the students. One such example is when she studied the definition of 'galaxy' to share with students, and what it meant to be a 'spiral galaxy.' She claimed that each time she taught this astronomy unit she learned more, simply because of the research students conducted and the questions they raised.

Teacher Two was influenced by her students enough to elicit their ideas about astronomy. Though she was weaker in her astronomy content knowledge than Teacher One, she was not influenced by her students' questions to go beyond a moderate level of knowledge. She was, however, influenced to learn more about the content that she was going to teach to address their ideas. She had a much stronger level of knowledge at the end of the unit than at the beginning. She had a more accurate idea of why the moon seems to change shape, which was a concept that was addressed several times during instruction. She had no greater understanding of gravity, which was a concept she did not teach to her students. She had a better understanding of the planets and their relationship to the sun at the end of the unit, largely because she taught the students a song about the planets. Thus, the concepts she taught to the class influenced her own understandings, and those she did not teach did not impact her knowledge at the end of the unit.

The Intern Teacher was also influenced to learn more content, but not specifically by what the students raised. She was influenced to learn more about astronomy by the curriculum she was given by Teacher Two. Because she was required to teach certain subjects she endeavored to learn more about them to be able to present them to the students. She was able to effectively increase her own knowledge of astronomy. However, her presentation of information to students was not as effective. She did not have a good idea of the developmental appropriateness of certain activities she chose to present to the students, nor of the importance of listening to and addressing their own theories about the astronomy content. She was influenced by the students in the manner that she was surprised about what they said, and indeed, believed if she could only improve her questioning technique she would get better and more accurate responses from the students.

It is apparent that the act of teaching enabled all three teachers to improve in their own knowledge of subject matter. Teacher One, who already held a substantial knowledge of astronomy, increased her knowledge beyond that addressed in the interview protocols by questions raised by her students. Teacher Two improved in her knowledge based on what topics she taught in her unit and ideas raised by the students.

The Intern Teacher also improved her knowledge based on the curriculum she was to cover in her activities. She was not influenced to know more about astronomy by questions or ideas raised by the students.

Implications

From this study it can be stated that not only do teachers influence students in developing their knowledge, but also students influence teachers in their knowledge. The teacher with the greatest level of content knowledge, and with the greatest ease in addressing student ideas, was influenced most by her students. The Intern Teacher and Teacher Two were also influenced in their knowledge by students, or at least by the curriculum in the case of the Intern Teacher. One of the complaints about elementary science teachers is that they lack content knowledge (Perkes, 1975; Tobin, Briscoe, & Holman,1990). By helping elementary teachers become more aware of student ideas and their importance in student learning it is possible we can help elementary teachers become more knowledgeable themselves because they will seek to address student questions and ideas. Another way to improve content knowledge may be to have interns practice teaching the content. At the conclusion of the current study the Intern Teacher held more accurate content knowledge of astronomy, and planned to teach it again when she had her own classroom. Scholz (1996) found that the act of teaching influences subject matter knowledge. Having teachers practice lessons in content areas could improve their knowledge in those areas. This finding implies that providing time for preservice teachers to practice lessons can improve not only their pedagogical knowledge, but also their subject matter knowledge.

Children's ideas influenced teacher planning. All three teachers planned to elicit student ideas, and the experienced teachers intended to address those ideas. Teacher One was so influenced by student ideas that she even developed lessons to address specific ideas. Student ideas influenced instruction in Classroom One such that their ideas about different astronomy concepts were revisited throughout the unit. Teacher One cycled the ideas several times through her instruction, in both large and small group settings. This revisiting of ideas seemed to help students improve in their knowledge of astronomy. Students in Classroom One had the highest level of knowledge. The continual checking for change in ideas allowed Teacher One to continue addressing the ideas with a variety of strategies. Indeed, the one idea revisited in Classroom Two that was not revisited in Classroom One, that of moon phases, was the one concept understood better by students in Classroom Two than those in Classroom One.

Related to planning to elicit student ideas, inservice and preservice teachers can learn strategies for eliciting student ideas. Both teachers in this study elicited students' ideas as a starting point to every lesson by asking them to share their ideas. Strategies that appeared to be useful were initial Idea Invitation and Probing Question strategies that required students to discuss ideas and negotiate meanings and understandings of content and experiences in their classrooms. The strategies used by the teachers were specifically directed to knowing student ideas. A further recommendation about eliciting student ideas from this study is that it is not necessary to elicit all ideas in the classroom, but to find out which ideas are shared by the most students and use those ideas in planning ways for addressing student ideas. It is important that teachers recognize the influence student ideas have on student learning, and to develop strategies for identifying conceptions that are held by the majority of students, followed by strategies for dealing with those conceptions (Berliner, 1987; Bromme, 1987).

Secondly, teachers in the current study provided many paths for students to change their ideas toward more accurate conceptions. The experienced teachers in this study used several strategies for helping students change their ideas, such as developing specific lessons, providing demonstrations, reading children's non-fiction literature books, explaining the content, and scaffolding new ideas on old understandings. Both preservice and inservice teachers can be introduced to different methods of addressing student ideas based on the success of these experienced teachers, particularly Teacher One. Teacher One cycled ideas through her classroom, addressing them several times in many different ways, while Teacher Two and the Intern Teacher's strategies did not include cycling the ideas. Teacher One's manner of listening and reacting to ideas in the classroom guided her delivery of content. She depended on creating an atmosphere, in which students would share and discuss ideas, so she could address them in instruction. Her cyclical method of eliciting and addressing student ideas can inform the use of the Learning Cycle (Karplus & Thier, 1967) in the primary grades. An implication from this study is that an additional component of the learning cycle should contain a revisiting of ideas over time. Student ideas can be elicited, addressed, and checked again for more accurate conceptions that develop over time. It is appropriate to educate the teachers to recognize the importance of student ideas as persistent alternative conceptions, and to use them as springboards for developing lessons. Revisiting ideas was an important component as a springboard in the most Teacher One's classroom. Previous research has shown that primary aged students hold surprisingly similar conceptions about a variety of science content. Even students in the current study held ideas that were similar to ideas found in previous studies of children's ideas of astronomy (Mali & Howe, 1979; Nussbaum & Novick, 1976). Teachers must have sufficient knowledge to help students confront their ideas, and that knowledge can take more forms than simple content knowledge.

It must be remembered that not all interns can handle the sophistication of responding to children's ideas. There are differences between novices and expert teachers, and responding to student ideas may be a skill that develops with experience. Because of these differences and the process of becoming a teacher is difficult, interns are concerned with many other factors (Hollingsworth, 1989). For instance, the Intern Teacher did not expect nor anticipate the types of responses she received from the students. Thus, though she was influenced by the curriculum to increase her knowledge of astronomy, her students did not influence her to increase her knowledge. A future study could explore how preservice teachers who are given thorough background and a reason to anticipate student ideas would approach instruction. Perhaps it may be found that student ideas influence teachers who expect students to have such prior knowledge of science concepts.

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Appendix A

Pre and Post-Instruction Interview Protocols for Students and Teachers

Teacher goals:

1. Your teacher has told me and has talked to you about studying astronomy. What is astronomy? What kinds of things do you think you will be learning about?

2. When you grow up, what kinds of jobs might you have if you studied astronomy?

3. Can you tell me the names of the planets? Which do you think is the largest? The smallest? Which is the hottest? The coldest?

4. Can you draw me a picture of how the planets are in the sky? (provide paper, pencils, crayons.) Can you put the sun in your picture? Where would it go in relation to the planets you have drawn (probe for names of planets the student has drawn).

Benchmarks objectives:

5. Provide a new sheet of paper.) What shape is the earth? Can you please draw a picture of the earth? On your drawing, please point to where you stand on the earth. (Using the child's drawing) What if you dropped a ball—which way would it fall?

6. What kinds of things do you see in the sky during the day? (Do you ever see the moon in the sky during the day? When?) What kinds of things do you see in the sky at night? (Do you ever see the sun in the sky at night?)

7. (Provide a variety of sizes of balls) Please choose one of these balls to be the sun, one to be the earth, and one to be the moon. Does the sun, earth, and moon move in space? Can you show me how they move using the balls? (Provide a new sheet of paper) Can you please draw a picture of how you think they move in space?

8. Does the moon always look the same in the sky? Why does it sometimes look different? What different shapes have you seen? Can you please draw some of those shapes? How often does the moon change shapes?

9. Tell me what you know about stars. How many stars are there? What colors can they be? What are stars? How bright are they? Are they all the same brightness? Why or why not?

10. Is there anything else you want to tell me about astronomy?

Appendix B
Teacher and *Benchmarks* Goals for Instruction

Teacher goals for instruction:

〈 Students should know various vocations in astronomy.

〈 Students should know the names of the planets, the smallest planet, the largest planet, and the coldest and hottest planets. They should know the make-up of the planets.

〈 Students will understand the order of the planets and their relationship to the sun.

〈 Students will know lots of information about planet earth.

〈 Students will know the sun is the center of the solar system and the earth revolves around it, and the moon revolves around the earth.

〈 Students will know the earth spins

〈 Students will learn how to pick a topic within astronomy to study independently, and how to find out information about that topic.

From Benchmarks and Standards:

〈 The moon looks a little different every day, but looks the same again about every four weeks.

〈 The sun can be seen only in the daytime, but the moon can be seen sometimes at night and sometimes during the day.

〈 The sun, moon, and stars appear to move slowly across the sky

〈 There are more stars in the sky than anyone can easily count, but they are not scattered evenly, nor are they all the same in brightness and color.

〈 The sun, moon, stars, clouds, birds, and airplanes all have properties, locations, and movements that can be observed and described.

〈 The sun provides the light and heat necessary to maintain the temperature of the earth.

〈 Objects in the sky have patterns of movement. The sun, for example, appears to move across the sky in the same way every day, but its path changes slowly over the seasons. The moon moves across the sky on a daily basis much like the sun. The observable shape of the moon changes from day to day in a cycle that lasts about a month.

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