Front-end Evaluation for

ADVANCING CONTENT THROUGH INTERACTIVE VIRTUAL ENVIRONMENTS

Institute for Scientific Research

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EXECUTIVE SUMMARY

The purpose of this front-end evaluation study is to inform design decisions about the development of an interactive learning system focusing on Earth and planetary science. The design team is led by the Institute for Scientific Research (ISR), and the project is funded by the National Science Foundation (NSF). The aim of the Advancing Content Through Interactive Virtual Environments (ACTIVE) Project is to create an interactive learning environment that allows exploration of the solar system through several senses including touch, sound, and sight. Developers will incorporate NASA Earth and Space Science data into a virtual reality system including haptics, an innovative touch technology. The program will be designed for middle school students (grades 5-8) who are blind or visually impaired. A mobile unit will be available through loan to schools for classroom use or for an exhibit setting. Carey Tisdal of Tisdal Consulting in St. Louis, Missouri designed and conducted this front-end evaluation study to provide information to project developers during the conceptual and content development stages of their work. The overarching methodology of the study was naturalistic inquiry. Two primary methods were used, a literature review and in-depth interviews. Respondents were 8 middle school students with visual impairments and 3 teachers at the West Virginia Schools for the Deaf and Blind. Interviews were conducted January 11, 12, and 13, 2006 in the Learning Resource Center of the school.

The ACTIVE interactive learning system has the potential to provide a rich, exciting learning experience for both middle school students with visual impairments and their sighted peers. The most likely educational environmental for students with visual impairment to use this system is a regular classroom along side their sighted peers. About 74% of students with visual impairments are served in regular schools in West Virginia and 87.5% in the U.S. as a whole. Our respondents shared some of the challenges of that environment. The literature cites others. Several of these environmental factors point to important design features for the system.

Based on this study, several overarching factors should be considered in the design. Technological design elements that ensure accessibility (audio narration, audio cues, high contrast graphics, sound cues) should be integrated into the overall design of the system so that students with visual impairments and their sighted peers can use them together without calling attention to the differences in visual ability. Sequencing of both content and haptic experiences is important.

The lesson design should begin with activities to elicit students' existing knowledge and misconceptions so teachers can make good decisions about adaptation. Content should be carefully sequenced so students encounter familiar and less challenging topics early the program. These topics included Earth's structure and landforms. Respondents were also familiar with some planetary surface feature forming processes such as plate tectonics and impact cratering. Many of the target audience (both sighted and with visual impairments) are still concrete thinkers. Current scientific theories in planetary and Earth sciences use the underlying construct of complex system. Scientists best explain these systems with models involving multiple causes and multiple effects on different levels of system operation. For the younger members of the target population (5th and 6th graders), most have not reached a level of cognitive development that allows them to learn and process this type of information. Many older students may also have difficulty. The concept of a system should be carefully defined and supported with familiar examples. Goals for in-depth understand of these concepts should be modest should be at a factual and recognition level rather than expecting students to develop deep understandings.

Haptics technology has the capacity to assist students with visual impairments in developing spatial mental models of the solar system. This, however, should not be an initial or introductory activity. Students with visual impairments need to be given addition time to explore the haptic environments to orient themselves spatially. Some activities should be included that require them to organize this information in an integrated way.

Inquiry or problem-based scenarios appear to be a good teaching/learning strategy for this population and for the content. The social design of the small task groups should be carefully constructed to assure that students with visual impairments have the opportunity to display expertise and leadership. Approaching this content through the context of space travel appears to be a motivating factor for males, and provides a link to considering their own futures and identity. Disaster and catastrophic scenarios were also appealing but these may overpower scientific accuracy. Other strategies such as narrative structure with character and plot and reinforcing sound effects appear fruitful.

ACKNOWLEDGMENTS

First and foremost, we want to acknowledge the contribution of the students and teachers at the West Virginia Schools for the Deaf and Blind (WVSDB) who agreed to share their knowledge, perspective, and expertise. No evaluator could ask for a more cooperative, patient, and courteous group of young people. Their parents and teachers should be very proud of them. Teachers at the school provided insights and opened doors for exploration—doors that would have been missed without their experience and willingness to share.

A most sincere thank you goes to Dan Oates, Educational Outreach Specialist at the West Virginia Schools for the Deaf and Blind and national coordinator for the Space Camp for Interested Visually Impaired Students (SCIVIS). Mr. Oates arranged access to respondents; handled scheduling and logistics; sent out letters for permission; and then provided gracious hospitality during data collection. The evaluator offers a special thank you to WVSDB's Learning Resource Center staff for making the evaluator welcome and sharing access to materials and their own insights and expertise.

We also want to thank Marjorie Darrah, Ph.D., Principal Scientist, Visualization and Informatics Branch Supervisor Institute for Scientific Research, Inc. (ISR) and ACTIVE Project Principal Investigator (PI). Marjorie provided content information; hospitality and a tour of ISR; knowledgeable access to respondents, and aplomb and support in dealing with unexpected challenges. Amy M. Jacquez, Senior Member Research Staff at ISR, provided references to ongoing projects and guidance in focusing a literature review into specific areas where it counted most. Patricia Harris, Professor of Education, Alderson Broaddus College provided a useful listing of West Virginia content standards and objectives that was very useful in identifying important content.

Finally, we wish to thank the National Science Foundation (NSF) for its support of this project and its commitment to the science education. NSF's long-term commitment has contributed to the development of a community of learners among science educators in diverse settings and for diverse audiences.

INTRODUCTION

The purpose of this front-end evaluation study is to inform design decisions about the development of a learning environment on Earth and planetary science. The design team is led by the Institute for Scientific Research (ISR), and the project is funded by the National Science Foundation (NSF). The aim of the Advancing Content Through Interactive Virtual Environments (ACTIVE) Project is to create an interactive learning environment that allows exploration of the solar system through several senses including touch, sound, and sight. Developers will incorporate NASA Earth and Space Science data into a virtual reality system including haptics, an innovative touch technology. The program will be designed for middle school students (grades 5-8) who are blind or visually impaired. A mobile unit will be available through loan to schools for classroom use or for an exhibit setting. Carey Tisdal of Tisdal Consulting in St. Louis, Missouri designed and conducted this front-end evaluation study to provide information to project developers during the conceptual and content development stages of their work.

The overarching methodology of this evaluation is naturalistic inquiry (Lincoln & Guba, 1985). Methods included literature review and in-depth interviews with eight students in grades 5 through 8 who were blind and with low vision at the West Virginia Schools for the Deaf and Blind (WVSDB) and three of their teachers. The ACTIVE team will use the findings from this study to make informed decisions to ensure the materials meet the needs of this target population. The evaluator conducted interviews on January 11, 12, and 13 at the campus of WVSDB in Romney, West Virginia.

This front-end study had three overarching questions:

1. What is the range of knowledge, attitudes, skills among the target audience in relation to the West Virginia content standards in Earth and planetary science?
2. What attitudes, skills, access, and experience do target audience members have with computer technology and assistive devices?
3. To what extent and in what ways are the current teaching/learning strategies and materials in Earth and planetary science adequate to meet the needs of the target audience?

A Topical Framework of specific questions the study would address was developed collaboratively with the ACTIVE project team at ISR. This topical framework is included in Appendix A.

DESCRIPTION OF THE PROGRAM

The ACTIVE project will create an interactive learning environment that allows "exploration of the solar system through sight touch and sound." (Institute for Scientific Research, 2005) The project will utilize an emerging technology called haptics. The target audience of these learning materials is middle students who are blind or visually impaired. These learning materials may be used in schools, out-of-school programs, or museum settings. The interactive learning experience is being designed based on national and state content standards and objectives by a team from ISR, Alderson Broaddus College, and Davis & Elkins College in association with the West Virginia Schools for the Deaf and Blind (WVSDB).

Haptics is an emerging technology that provides force-feedback and tactile sensations to user as they interact with an object in virtual space. The materials will also provide auditory cues "such as narrative instructions, and verbal help, as well as 3-D auditory cues to guide students within the virtual environment [and] high contract visual objects within the environment for low vision learners." (Institution for Scientific Research, 2005) The virtual experiences will be based on NASA and other space science data.

The specific content focus of this system falls into the area of comparative planetology. As part of the development of the evaluation, the ISR team provided initial statements of learning objectives for the materials.

1. ***List the celestial bodies in the solar system: the Sun, planets, and moons.***
2. ***Describe the relative sizes of solar system bodies and the dynamic nature of the solar system.***
3. ***Demonstrate the role of gravity in holding our solar system together.***
4. ***Describe the relationship between mass, weight, and gravity.***
5. ***Describe how planets' surfaces change over time.***
6. ***Recognize that the surface of the Earth is covered with different kinds of features.***
7. ***Recognize that each type of feature is made by a different process: volcanism, impact cratering, tectonics, gradation.***
8. ***Infer that the same types of features made by the processes on Earth are found on other planets. (Institute for Scientific Research, 2005b)***

This system will include DVD-based software, accompany hardware and lesson to accompany the materials. Teacher lesson plans and a technical guide are also being developed to make implementation easier for teachers. The system will be disseminated through the NASA Enterprise-based program including the Educational Resource Center and the Aerospace Education Services. Developers anticipate uses of the materials in classrooms, traveling exhibits, museums or the NASA visitor centers.

METHODOLOGY AND METHODS

Methodology

The purpose of front-end evaluation is to assess the entering knowledge, interests, and attitudes of the target audience during the concept development phase of exhibition design. This is one of four phases (front-end, formative, remedial, and summative) as defined by Screven (1990), which all differ by purpose, audience, and timing. They are now the commonly accepted frameworks in museum exhibition development (Bitgood & Shettel, 1994), but the front-end and remedial stages may be less familiar to those working in formal education. While evaluation shares theoretical frameworks and methods with education research, it is different in its obligation to be practical and useful to these stakeholding groups (Patton, 1997). The purpose of evaluation is to inform decisions by very particular sets of people in particular situations.

We used naturalistic inquiry (Lincoln and Guba, 1985) as the overarching methodology to frame this study. Naturalistic inquiry aims to provide a holistic understanding of a phenomenon by looking at it from several angles in a real-life setting. This type of inquiry uses a systematic approach for collecting and analyzing data in the context in which it occurs. The researcher captures processes and activities through a variety of sources and from multiple perspectives of various stakeholder groups. These are then presented through in-depth descriptions. In this way, findings provide meaningful and relevant input to program decisions made by the various stakeholder groups.

Methods

To organize the study, we worked collaboratively with staff of ISR to develop a framework of specific questions the study would address. This Topical Framework is included in Appendix A. The collection and analysis of data addressed the questions in the topical framework though two methods: a review of relevant literature and in-depth interviews with target audience members and their teachers.

Literature Review

Literature review is a method that plays a distinctly different role in evaluation than in traditional educational research. In research, the purpose of the study is to add to generalizable knowledge. In evaluation, the purpose is to answer questions about the value of alternative decisions for a group of stakeholders. In research, one specific area is deeply reviewed. In evaluation, a wide range of "literatures" may be useful to answer questions. In naturalistic inquiry, Guba & Lincoln (1989) recommend that analects from the literature are simply another form of data. In contrast, McCraken (1988) recommends qualitative inquirers use the literature to develop conceptual categories through which to view their data. This study reflects both approaches. A wide variety of literature was sampled that was relevant to the questions, and it used to develop conceptual categories that would be useful in interpreting interview data. We used information to triangulate findings. These ranged from statistical frequency of visual impairment in the general population to theoretically based empirical studies from both psychology and education.

In-Depth Interviews

Sampling

In naturalistic inquiry, respondents are selected purposively (Miles & Huberman, 1994) based on various characteristic of importance to the questions of the study. In this study, our range of respondents was somewhat limited by our access students in diverse educational environments and the relative small student population in this residential school. Thus, it did not include a full range of characteristics of interest. Among the students, there were 7 male respondents, and only 1 female respondent. Only 1 of the students was congenitally blind. However, respondents varied from rather long-term visual impairment to those who had only recently become visually impaired. The sample also included a preponderance of respondents near the upper grade levels of the target audience.

Student Interviews

Student in-depth interviews were designed to take about 45 minutes and were conducted in Learning Resource Center office area (one interview) and conference room (7 interviews). A script of the student interview protocol is included in Appendix B. The interviewer used tactile graphics used as part of the interview process. At various points in the interview, respondents were guided to or handed objects from a solar system kit, an Earth model, and a flat topographical map with a raised land features. This allowed the interviewer to asked questions about spatial relations and movement among elements of the solar system. None of these devices was specifically designed for the use by people with visual impairments. Some planet models, the Earth model, and the topographical map had visual feature apparent to respondents with low vision.

Teacher Interviews

Teacher interviews were designed to take about 1 hour. This interview protocol is included in Appendix C. Teachers were interviewed during their planning periods in a conference room of the Learning Resource Center of the WVSDB. Samples of tactile graphics used were available for review by the teachers to obtain information on their assessment of student familiarity with these types of learning materials that are similar to haptics, the technology used in the proposed learning system.

Analysis of Data

In naturalistic inquiry, data collection and analysis are iterative processes. In this study, we analyzed data using a modified inductive constant comparison approach (Lincoln & Guba, 1985), whereby each set of data is compared with previous data sets to direct the focus of subsequent data collection. All interviews were audio recorded, and transcribed. Immediately after the data collection trip, the evaluator wrote a debriefing document including preliminary findings and patterns. Codes developed from debriefs and literature categories were used to analyze transcripts in a qualitative software package, *Atlas.ti*.

Ethical Treatment of Respondents

Several steps were taken to insure that respondents in this study are treated fairly and ethically. Written informed consent was obtained from parents or guardians before data collection began. A package including a cover letter explaining the research, Consent Forms, and a list of depth-interview questions and were mailed to a parent or guardian of students through Mr. Dan Oates at the WVSDB. Parents or guardians were asked to consult with students about their willingness to be scheduled for the interviews with the understanding that they will have the opportunity to withdraw after hearing a complete explanation of the purpose and procedures with no negative impact. Consent and Assent forms were return to Mr. Oates by mail or with the student before scheduling of the interviews began. When students arrived for the interview, they received a complete explanation of purpose and procedures from the interviewer, a large font consent form was available, and again they were given the option to withdraw if they wished. Respondents received a $10 gift certificate to compensate them for their time.

For teachers, consent forms were mailed to them prior to the interviews with a cover letter assuring them that there were no negative consequences to their employment should they choose not to attend. Dan Oates returned these forms to Tisdal Consulting. Teachers were also given a $10 gift certificate to thank them for their time.

Evaluator

In qualitative research, the human being is the instrument for data collection and analysis. For that reason, it is important for the evaluator to clearly describe factors that will affect his or her understanding of the situation under study. This section provides a brief overview of experiences and perspectives that I believed influenced the nature and direction of the study.

My educational background includes an undergraduate degree in English and M.S. in Educational Technology, specializing in instructional development and design. I have spent half of my professional life in formal education (high schools and community colleges) and half in informal education (museums and cultural institutions).

My interests in educational technology and learning systems are based on two years teaching 9th through 11th grade students. The primary features of this interest were technology's capacity to elicit deep engagement, address individual needs, and provide access to diverse settings and ideas. I also have a long-term interest in adolescent development and research. This fascinating phase of life is filled with interesting contradictions. Adolescents long for independence and crave dependence. They experience increased power of and capacity for abstract thinking. It is difficult not to have empathy with human beings sorting so many things at once and amazingly, and quite often, landing on their feet in unexpected and surprising ways.

Another strong influence is my experience in museums and other free-choice learning environments. In museum environments, people learn based on their own motivation and interests, often in social groups, and deeply engaged in a topic individually or with friends and family. In my experience, this is often what successful learning engagements look like—in the classroom or outside of it. Deep engagement, humor, creativity, and hard work are all part of the equation. Human beings are built to learn things that help them survive and thrive in an environment. While coercion may be a necessary in some short-term solution situations, when educational strategies, in the long-term, work against internal motivation, choice, and individual human dignity, they fail. Creating successful learning environments is what education is all about and one place where there is an opportunity to make that happen quite often is in museums.

Quite recently, I became involved in evaluation studies about how to make museums more accessible and welcoming to people with disabilities. I found that visiting exhibitions with people with disabilities opened my eyes to new ways of thinking about and designing learning environments—ones better and richer for everyone.

Limitations of the Study

While this study benefits greatly from the cooperation and access provided by the WVSDB, our range of respondents, as previously noted, was somewhat restricted. Of the 8 student respondents, 7 were male. Clearly, findings in this study are limited by this lack of female perspectives. We also had only one respondent who was blind. Teachers talked about the differences between students with some useable vision and blind students. Yet, even within this group, we found diverse sets of knowledge, skills, and attitudes. In addition, special attention was given to find research studies, which focused on this target population both in terms of age and levels of visual ability. These are included to triangulate the findings. While the study would have benefited from some students currently enrolled in mainstreamed classrooms, several of the student respondents we interview had only recently transferred to the residential school.

CHARACTERISTICS OF RESPONDENTS

Interviews were conducted at the WVSDB on November 11, 12, and 13, 2005. Dan Oates, Outreach Coordinator at the school, arranged these interviews. In preparing the interviews, the evaluator asked our contact at the school comparison as to the content knowledge understandings between this group of students and other students their age who do not have visual impairments. He repeated several times that it depended on the individual student, some were on grade level and some were not. He stressed that it would be hard to generalize. Mr. Oates was, of course, right on target. Several factors related to each individual's situation appeared to affect their understanding of the content. As one of the teachers we interviewed explained,

> ***And every visual impairment is different. But you know, what one kid that is totally blind is going to understand, maybe the next one won't understand because they're not necessarily a tactile learner. You may have — you might have a — a totally blind kid who is — who learns by hearing best. And so they don't explore their environment. And giving them a model and saying well this is the surface features of — of West Virginia — that's not a very good example. It's really — it's really hard because every kid is different. And that — and that's a struggle that I deal with is trying to — trying to get an understanding of how they learn best and — it's hard to explain. It really is. (Case B)***

This wide range of differences in knowledge, skills, and attitudes are instructive of the issues that some visually impaired students face in any educational environment. The following Case Introductions provide brief overview of some of the factors that appeared to influence these individual's understandings about Earth and planetary science topics.

Case 1. This respondent was a male in grade 8. The staff described him as a student with low vision, and he had been at the residential school for four years. He reported enjoying sports and video games. During the interview, he characterized himself as a good student. Another respondent cited him as a kind and good friend. Before entering the residential school, he had attended public schools for four years. He recalled being teased in that setting. Overall, he appeared to have one of the higher levels of content knowledge among this group of respondents.

Case 2. This respondent was a male 7th grader with low vision. He reported enjoying basketball, wrestling, and goal ball (a sport played at the school). During his interview, he was the only respondent who mentioned a career goal. He said he wanted to be an astronaut. From his interview, it appeared he had been at the residential school about two years. He mentioned being bullied and being involved in fights as part of his public school experience. This was one reason cited for attending the residential school. During the interview, he was polite, helpful, showed enthusiasm, and was very friendly. He had a relatively high level of content knowledge.

Case 3. This 8th grade male reported that his visual impairment had occurred "just before coming to the school" about two years ago (Case 3, Transcript, p.1). He said he enjoyed riding his bike, watching TV, and talking to friends. His demeanor was reserved and quiet, and seemed to fit the less "team oriented" activities. His recollections of his public school experience were primarily before his vision loss. He recalled having more friends. He had a relatively higher level of content knowledge compared to the group as a whole.

Case 4. This 8th grade male with low vision also had some additional issues affecting his learning. During the interview, he mentioned that he had been diagnosed as autistic and had experienced seizures from an injury. He noted that he had had a "hard life" and that some violent behavior had been the cause of his leaving public school. This young man showed a great deal of friendly, pleasant affect in his conversation using his voice expressively and displaying a large vocabulary to make connections to questions. His speaking style was rather formal and his manner dramatic. He noted that he did not participate in sports because the coaches were "mean." He had one of the lower overall levels of content knowledge.

Case 5. This respondent was a 5th grade male with low vision. He was the only one of the respondents who lived at home and road the bus, daily, to school with his brother and sister. He reported enjoying playing football and watching it with his father. He had been at attending the residential school for 12 weeks, a period he described as a "long time." This young man's conversation was full of his enthusiasm for the U.S. Space program. While he had not yet been to space camp, he was looking forward to it. In general, he had more facts and vocabulary than some other respondents and more alternative conceptions. His content information, in Earth and planetary sciences as well as in other areas such as the space program, was broad and connected in interesting ways with the characteristics of pre-adolescents

Case 6. This 7th grade male with low vision initially presented himself as a tough guy explaining he liked video games especially those involving killing. His vision loss was quite recent, within about the last year, and he had transferred to the residential school half way through his 6th grade year. He recounted that the students in public school were "annoying" and it appeared that he had been the object of bullying. As the interview progressed, he became much more animated and friendly even becoming fascinated by the solar system models used in the interviews and asking to keep them. Overall, he had considerable content knowledge but also several striking misconceptions.

Case 7. This female 8th grade student with low vision had begun attending the residential school only very recently (less than two full weeks). She said she enjoyed country music and dancing, and appeared to still be in the first stages of missing her mother. She said they talked every day. She recounted some embarrassment in her public school experience by having large print books and a larger desk than the rest of her peers. In general, her interview showed a somewhat higher level of abstract thinking than some other students, but a very low overall level of understanding of the content areas. Several of her answers displayed considerable metacognition—a more mature ability to think about her own thinking and assess her own learning.

Case 8. This 8th grade male was the only one of the respondents who described himself as blind. He reported liking swimming and gym, in particular. He never relaxed in the interview, and rocked in a way characteristic of some blind individuals. This young man had begun his schooling at the residential school. Most of his connections to the content questions were context based, that is, related to a specific class in which it had been a topic discussed or a specific family vacation or experience. Of all the respondents, he appeared, as far as could be determined from the interview, to have most concrete and limited amount of content knowledge.

Case A. This female teacher taught combined 5^{th} and 6^{th} grade classes and offered Braille instruction to any students in those grades or higher who were in need of this skill. She became interested in teaching people with visual impairments through term paper she wrote in the 5^{th} grade, and continued her interest in specialized training in college. She had never taught in a regular public school, but her husband, who was also a teacher, taught in that environment. She taught the state 5^{th} and 6^{th} grade science curriculum as part of her classroom assignment.

Case B. Any advanced science subjects taught at the school were handled by this female teacher. She also taught 7^{th} and 8^{th} graders in a classroom setting. She had taught at the WVSDB for several years, and worked with some students who were interested in taking physics and anatomy courses. Currently, none of those courses was offered.

Case C. This female teacher taught all subjects, including science, to 3^{rd}, 4^{th}, and 5^{th} grade students. The previous year she taught kindergarten meaning she had just moved to these grade levels. She noted that she had taught landforms and Earth history as part of her science curriculum this year. Case C had taught fewer years than the other two teachers.

PERSPECTIVES FROM THE LITERATURE

In this section, we discuss research and theory from several disciplines that appear useful in framing and understanding the findings of this study. We have also included population statistics and patterns to assist readers in understanding the context and scope of patterns. This is not intended to be a complete review of current research in this area. Rather, it is an introduction to several concepts that we found useful and relevant to answering the questions of the study. Areas we explored provide different perspectives on the target audience, their lives, school, and conceptualization of the universe in which they live.

Developmental Psychology

Members of this target population face the same developmental tasks as their sight peers—moving from concrete to abstract levels of thought, learning to use their increased vocabulary, adjusting to dramatic physical changes, a pre-occupation with peer group approval, beginning to think about adult occupations, and finding adults to respect and admire outside their families. Young people in the 5th through 8th grades can be expected to be between 10 and 14 years old. These young people can be expected to fall into two developmental levels the Middle Years (generally ages 8 to 11) and Early Adolescence (Ages 12 to 14). However, transitions vary greatly from individual to individual. In addition, children in this target population may not have had the stimuli or experience to accomplish some developmental tasks.

While the purpose of this project is to influence the academic growth of the target audience in specific standards-based contents, the students themselves are dealing with many additional concerns. Research and theory from developmental psychology help us understand more about the lives of the students who will be using the ACTIVE system.

Two developmental stages are relevant for this target audience:

- Middle Years—ages 8 to 11
- Early Adolescence—ages 12 to 14

As children move through the Middle years (ages 8 to 11) they transition into more logical thinking, are able to accept more responsibility for organizing their own work, and are able to deal with more features of categories as internal representations. Yet, children at this age are not independent or abstract thinkers. They are very concerned about "being right" and often are rigid in their understanding of rule sets or definitions. They are resistant to ambiguities and complexities in definitions and in social situations. Children at this age insist that things be "clear" and "fair," but the still tend to focus on adults as the authority in their lives. Almost all of the children in the middle years are still, in Piagetian terms, concrete-operational thinkers (Kodat, 2002).

Children at the upper end of the target audience age range will tend to be in the pre-adolescent stage. As adolescents grow, they focus on different developmental tasks. Havidghurst (1972) conceptualized adolescents as moving through several normal developmental tasks that must be completed to accomplish adulthood. The number and precise nature of the tasks differ from scholar to scholar (Feldman, 2003; Fenwick & Smith, 1994; Ingersoll, 1989). Feldman (2003) defines five core developmental tasks that appear to encapsulate many of the others.

- Developing emotional and behavioral autonomy
- Dealing with emerging sexuality
- Acquiring interpersonal skills for dealing with the opposite sex and mate selection
- Acquiring education and other experiences needed for adult work
- Resolving issues of identity and values

Ingersoll (1989) describes early adolescence (ages 12 to 14) as time young people begin to focus on peer group acceptance and conform to these influences in interests and clothing style. This is a period of rule and limit testing with some tendency to revert to childish behavior. Adolescents may also become quite critical, finding fault with parents, and question adult authority in matters of both social and content knowledge. At the same time, they start looking for other adults, such as teachers and program leaders, with whom they can develop affectionate relationships. Early adolescents show a marked increase in the ability of expression and language use, but many are not yet capable of abstract thinking. This means that their abilities to abstract conclusions from concrete data in the scientific process may be developing, but limited. But, some research indicates that nearly 40 to 60 percent of college students and adults tend to be at the concrete operational level where complexity is rejected when assessing situations in favor of simple single cause-effect relationships (Gardiner, 1997). Theoretical concepts, even when presented with concrete examples, may be difficult for some. While early adolescents show an increased ability to perform some complex work, their interests are still in the present and near future.

As McCauley (2001) points out, the combined changes in adolescence may affect girls and boys differently. For numerous reasons (e.g., earlier physical maturation, the timing of school transitions, the timing of cognitive development, differing social expectations during family crises), girls are more vulnerable to low self-esteem and depression in adolescence. While boys' self-worth increases at puberty, girls' may tend to decrease. Some researchers have connected these findings to the decreased interest in and estimates of, competency in both science and mathematics among girls in early adolescence. Hartner & Whitsall (1996) found two clusters of self-perceived competency that played an important role in estimates of self-worth among both boys and girls. One cluster was related to physical appearance, peer likeability, and athletics. The other cluster was related to terms of scholarship and behavioral conduct. Secondary influences on self-worth were social support from parents and peers.

McCauley (2001) also points out that gender socialization has a different impact on boys and girls. While establishing a sense of identity separate from one's family is an important part of adolescence for all young people, girls place a greater value on connectedness, especially with their mothers, than do boys. Girls sometimes view their own independent behavior as a threat to relationships (with parents and with peers), and therefore have particular difficulties in establishing independence.

Population of Visually Impaired Americans

According to the American Federation of the Blind (2006), about 1.3 million Americans and 55,200 American children are legally blind. Legal blindness is defined as

> ***visual impairment that has been defined by law to determine eligibility for benefits. It refers to central visual acuity of 20/200 or less in the better eye with the best possible correction, as measured on a Snellen vision chart, or a visual field of 20 degrees or less. (American Federation of the Blind, 2006)***

Distinctions are made between functional limitations based on the ability to see words and letters in ordinary print. People with several functional limitations are "unable" to see words and letters. People with non-severe functional limitations have "difficulty" seeing words and letters (American Federation of the Blind, 2006). However, many legally blind people have some usable vision. Only 10% of those who are legally blind have no usable vision.

Bishop (2004, p. 59) points out that both the characteristics of the visual impairment itself and when it occurs affects a child's learning. She explains

> ***If the visual impairment is present at birth (congenital), it is more likely to affect development and learning that if it is acquired later (adventitious). Even a few years of vision can provide spatial orientation to the brain. . . .***

Some of the differences among individuals we interviewed can usefully be explained by when visual impairment occurred, and the characteristics (level) of impairment. These individual characteristics also appeared to have interacted with respondents' previous learning environments.

Learning Environment of Students with Visual Impairments

History and Legislation

While there have been substantial changes in public policy over the last 30 years…the history of residential schools for the visually impaired dates back to the 19th century.

> ***Schools for the blind were established in the United States during the first half of the 19th century not to segregate children who were blind, or to shelter them, or even to provide care for them. They were established with the belief that children who were blind and visually impaired were capable individuals who could become contributing members of society. (Ferrell, 2003)***

Ferrell (2003) notes that in the 1950's 88.4% percent of blind children were educated in separate or residential schools and "by 1999 the number of children with visual impairments being educated in separate school environments had dropped to 15 percent."

Major changes in public policy and educational placement were enacted with the passage of the Rehabilitation Act in 1973 with schools trying to bring all students into the same facilities to provide educational services. Then in 1975, with the passage of PL 94-142, Education for All Handicapped Children Act, children were given the right to education in the least restrictive environment (LRE). In 1990, the Education of the Handicapped Act Amendments of 1990, PL 100-476 changed the name of the law to Individuals with Disabilities Act (IDEA). This act provided programs for transitional services, assistive technology, and the development of an

Individual Educational Plans (IEP) for each child (Ferrell, 2003 and Bishop 2004). With the passage of the reauthorization of IDEA in came calls for greater access to instructional materials and the general curriculum (Smith, Geruchat, & Hueber, 2004)

Educational Placement of Students

The policy set by this legislation involves an assessment of student needs followed by the development of an IEP. Based on the IEP, a placement is made in a continuum of educational environments (Bishop, 2004).

> ***For school-aged children, this location is one of the following: regular school campus, in which the student may be removed from his or her non-disabled peers, for less than 21 percent of the day, 21 to 60 percent of the school day, or more than 61 percent of the school day; public separate school; private separate school; public residential facility; private residential facility; or homebound/hospital. (Westat, October 2005)***

As Bishop (2004) explains, this continuum includes placement in a regular classroom, a special vision class, or in a residential school for students who are blind or visually impaired. Instructional services are provided by various education staff members. A Teacher of the Visually Impaired (TVI) is a certified staff member with specialized training in working with the visually impaired. These individuals may staff a vision resource room in one school, teach in a specialized school, or work in a residential school. Itinerant TVIs are assigned case loads of students, many times in different school buildings, and travel from place to place to provide consultation with regular classroom teachers or direct instructional support to students. Itinerants TVIs may provide consultation to regular classroom teachers and direct instruction for students with needs beyond the regular classroom. These regulations require that placements be made (1) based on the individual needs of the child, (2) as close as possible to the child's home, and (3) in the school the child would attend were s/he not disabled. Bishop (2004, p. 186—187) also stresses that research has identified about 70 factors involved in successful placement. Only about half of these are related to students, and they other half are related to characteristics of the school, parents, family, and the community.

The majority of students with visual impairments are served in regular schools in both West Virginia and the U.S. as a whole. In West Virginia 74% of students with visual impairments are served in regular school and 87.5% are in the U.S. as a whole. The number of students in these two geographic areas served in various settings is shown in Table 1.

Table 1: Students ages 6 through 21 with visual impairments served under IDEA, Number of Students

Geographic Area	- Outside regular class - < 21%	21-60%	> 60%	Public separ facil	Private separ facil	Public resid facil	Private resid facil	Home hosp envir	All envir
West Virginia	151	31	x	18	x	40	x	x	246
U.S. and outlying areas	14,801	4,179	3,833	934	536	1,449	213	136	26,081
(U.S. Department of Education, Office of Special Education Programs, Data Analysis System, 2005). facil=facility; resid=residential; separ=separate; hosp=hospital; envir=environments.									

Policy into Practice

Like other education reforms, legal policy does not always translate directly, or easily, into effective practice. After 30 years of mainstreaming and inclusion (terms often used to describe the LRE provision of the laws), out comes are mixed and the implementation is still not complete (Smith, Geruschat, & Huebner, 2004). Designers of the ACTIVE system need to recognize that resources for reformed-based teaching and efforts toward mainstreaming children with visual impairments and blindness are partial and have also had unexpected consequences. Only by understanding the limitations of this policy implementation can the system be designed to work effectively in situations where students with low vision and blindness have fewer resources than their sighted peers, lack access to educational supports to allow them to function at or near grade level in the content areas, and are sometimes bullied and socially excluded. While the policy was intended to bring more of these individual into the labor force as they reached adulthood, it has been relatively more successful in allowing these student to perform academically and less successful in preparing them for the world of work and adult independence. Designers should be prepared to hand over the completed system into learning environment where young people with blindness and low vision still suffer from stigma based on their disability, and they are served only few trained specialist and classroom teachers with little training to meet their needs. Many members of the target population can also be expected not to have received mobility training, which would provide the experience base for understanding the spatial relationships involved in the program content.

The original intent of Rehabilitation Act in 1973 was to provided education and other opportunities to allow people with disabilities to enter the labor force. Several authors cite as a concern the relatively high rates of college completion among people with visual impairments, but the somewhat lower levels of employment. Similar trends are noted in Western Europe and Canada as well as the U.S (Ferrell, 2003). Despite a through search, we could not located statistics for educational levels and employment from the 2000 Census figures. The AFB provides estimates of based on a 1994-95 national survey conducted by the federal government's National Center for Health Statistics.

> ***Seventy-four percent of the sighted working-age public are employed, compared to approximately 46% of working-age adults who are blind or visually impaired. However, the sighted public, as a group, is both younger and in better health than are people who are visually impaired or legally blind, and these two factors have major effects on rates of employment. (American Federation of the Blind, 2005)***
>
> ***In 1992-93, approximately 55% of individuals with severe visual impairment or blindness did not have a high school diploma, compared to 20% among fully sighted individuals in the same age group. Much smaller differences between these two groups were found in rates of higher education. Among high school graduates, those with severe visual impairment or blindness are about as likely to have attended college without receiving a degree as those who were sighted (24% compared to 27%), but are less likely to have graduated from college (16% compared to 26%). (American Foundation for the Blind, 2005)***

In a 2004 study, Smith, Geruschat, & Huebner found that only 31% of teachers compared to 70% of administrators believed that policies related to access to low vision services, low vision devices and printed materials for students with visual impairments were being delivered (p. 626). They found a heavy reliance on large print materials over other assistive devices. This appeared due to several factors.

> ***Parents do not want the stigma that is attached to optical devices, which makes their children's visual impairments more obvious to others. Similarly, the teachers and administrators expressed common opinions about students. They noted that students do no want to stand out from their peers and resist wearing anything that makes them look different. They gave the same reason for students possible preference for working in large print, which, they thought minimizes the appearance of student' differences from their peers. (Smith, Geruschat, & Huebner, 2004, p. 621)***

But they also found that some administrators and teachers simply were not aware of other types of access, that systems were not in place to deliver materials, and that the itinerant model of service delivery was not perceived as meeting the needs of students or classroom teachers (p. 622). Both administrators and classroom teachers spoke of their lack of training and awareness of assistive devices and alternatives to large print materials. Administrators believed that teachers did not want assistive devices taking up space in their classrooms. These researchers found important differences between states and overall levels of access to curricular materials were substantially different between states that did and did not have systems to provide distribution of assistive devices and services. Interestingly, among the states with effective systems, teachers cited a need to design assistive devices with features that make them "cool" and socially acceptable. Other studies show that the size of the caseload of itinerant TVIs and lack of trained TVIs are issues in implementation (Correa-Torres & Howell, 2004).

Ferrell (2003) reflecting on the trends and issues in the field of blindness and low vision cites mixed results in the efforts for inclusion and education in the least restrictive environments. First, she notes a crumbling research base that leaves the field "with best practices that are more philosophical than proven, more descriptive than empirical, and more antiquated than modern. (p. 4). She also emphasizes that successful placement is more than "providing books and materials in tactual modalities" (p6). Tactile diagrams and cognitive mapping are used, with the best of intentions, but the skills to use these are not within the experience of many students. Another issue is that students also receive large print materials well after their classmates receive textbooks. Ferrell observes that the expanded core curriculum, which includes living skills for those with visual impairments, is often neglected because of the emphasis on standards-based education and focus on standardized testing and achievement. She points to the increasing lower rates of students using Braille as a reading medium—only about 10-12% of legally blind students. The problems with the lowering rates are that students may be left with no literacy skills, and assistive technology support assumed to replace these resources is often simply not provided. While there are some promising trends with personal computers, children with visual impairments are less likely to have home computers than those without disabilities.

Finally, and most importantly to this subject, Ferrell (2003) concludes that many mainstreamed students are not receiving orientation and mobility training. These types of experiences allow students to firmly establish spatial and environmental concepts that could be generalized to larger scales such as the solar system and universe—content of the ACTIVE program. Without this spatial experience on a geographic scale, low vision students may be left without the skills and familiarity to organize more abstract notions of space. In addition, these skills are closely related to success for adults in inclusions as full-members of society—going to work, visiting areas of their community, and enjoying leisure activities with friends.

School Reform

Since the late 1950's, educational systems have also been involved in changes in policy and practice. This general movement is often referred to as school reform. The most recent surge of reform began in 1983 with the publication of *A Nation at Risk* (National Commission of Excellence in Education, 1983). Specific reforms affecting the teaching of science and mathematics were marked by the publications of several important documents in the late 1980's and 1990's including Benchmarks for Scientific Literacy (American Association for the Advancement of Science, 1993) National Science Education Standards (National Research Council, 1995), and Curriculum and Evaluation Standards (National Council for the Teaching of Mathematics, 1989).

Adoption of these standards is reflected in Policy 2520.3 Science Content Standards and Objectives for West Virginia Schools.

> ***Content Standards are broad descriptions of what students should know and be able to do in a content area. Content standards describe what students' knowledge and skills should be at the end of a K-12 sequence of study.***
>
> ***Objectives are incremental steps toward accomplishment of content standards. Objectives are listed by grade level and are organized around the content standards. Objectives build across grade levels as students advance in their knowledge and skills. (West Virginia Department of Education, 2003)***

One convenient way to summarize the overall trends in these reform documents is by reference to the Reformed Teaching Observation Protocol (RTOP) (Pilburn, Sawada, Turley, Benford, Bloom, 2000). This protocol developed under an NSF grant at Arizona State University includes 25 rubrics in five categories to identify the level and extent of reform teaching practices in a specific teaching/learning interaction. The teaching/learning practices as based on constructivist, inquiry-based principles.

According to MacIssac & Falconer (2002), this instrument operationally defines and critiques a set of behaviors that can be collectively referred to as reformed teaching.

> ***The 25 items in the RTOP can be briefly summarized for physics teaching as follows:***
> **•Lesson Design and Implementation*. The creation of physics lessons that: (1) respect student preconceptions and knowledge, (2) foster learning communities, (3) explore before formal presentation, (4) seek and recognize alternative approaches, and (5) include student ideas in classroom direction.***
>
> **•Content (Propositional Knowledge). *Teachers knowing their physics and teaching lessons that: (6) involve fundamental concepts of physics, (7) promote coherent understanding across topics and situations, (8) demonstrate teacher content knowledge (e.g. apparently "unrelated" questions), (9) encourage appropriate abstraction, and (10) explore and value interdisciplinary contexts and real-world phenomena.***
>
> **•Content (Procedural Knowledge*). Physics lessons that use scientific reasoning and teachers' understanding of pedagogy to: (11) use a variety of representations to characterize phenomena; (12) make and test predictions, hypotheses, estimates, or conjectures; (13) include critical assessment and are actively engaging and thought provoking; (14) demonstrate metacognition (critical self-reflection); and (15) show intellectual dialogue, challenge, debate negotiation, interpretation, and discourse.***
>
> **•Classroom Culture (Communicative Interactions*). The use of student discourse to modify the locus of lesson control such that: (16) students communicate their own ideas in a variety of methods; (17) teachers' questions foster divergent modes of thinking; (18) lots of student, particularly inter-student, talk is present; (19) student questions and comments shape discourse — the "teachable moment" is pursued; and (20) there is a climate of respect and expectation for student contributions.***
>
> **•Classroom Culture (Student-Teacher Relationships*). Lesson interactions where: (21) students actively participate (minds-on, hands-on) and set agendas; (22) students take primary and active responsibility for their own learning; (23) the teacher is patient (plays out student initiatives and is silent when appropriate); (24) the teacher acts as a resource and students supply initiative; and (25) the teacher is a listener. (pp. 481-482)***

These authors stress that the RTOP scores "were also found to strongly correlate with student conceptual gains" showing that "reform teaching is also effective teaching." (MacIssac & Falconer, 2002, p. 16)

Learning Theory and Research

Most educational and psychological research today can be placed under the broad umbrella of constructivism. As Phillips (1997) clearly reminds us constructivism has two primary forms: (1) the construction of knowledge by individuals, and (2) construction of public disciplines such as physics, biology, or sociology. In both endeavors, the development of knowledge is affected by social interaction and is socially mediated through language and symbols systems including pictures, models, and diagrams.

Scientific explanations of this topic, comparative planetology, have been substantially affected by changes in scientific theory of the underlying disciplines. Comparative planetology as a scientific field of study reflects the merging of traditional astrophysics with traditional earth sciences such as geology and meteorology. Pushing this merger is the theoretical lens of complex, dynamic systems. While the foundational concepts of system theory go back to Kant, the development of general systems theory in the 1950's profoundly influenced the development of theory and research in astronomy and Earth sciences in the subsequent decades (Wikipedia, 2006b; Kaufman, Vosniadou, diSessa & Thagard, 2000).

> ***The term complex system formally refers to a system of many parts, which are coupled in a nonlinear fashion. Natural complex systems are modeled using the mathematical techniques of dynamical systems, which include differential equations, difference equations and maps. Because they are nonlinear, complex systems are more than the sum of their parts because a linear system is subject to the principle of superposition, and hence is literally the sum of its parts, while a nonlinear system is not. (Wikipedia, 2006a)***

The specific educational reforms, particularly in the physical science teaching, are closely tied with ongoing research generally referred to as conceptual change theory (Kaufman, Vosniadou, diSessa & Thagard, 2000).

> ***Conceptual change names a family of theories, methodological approaches, and research traditions concerned with the origins, ontogenis, and evolution of knowledge systems as a result of formal and informal learning. Conceptual change is a subject of considerable research across all of the cognitive sciences. In particular, it is central to investigations in the philosophy of science, cognitive development, and science education. (p. 1)***

These conceptual changes happen in children, students, lay adults, and practicing scientists. In this research, the novice conceptions of children are sometimes compared to the expert conceptions developed by scientists as explanations for physical phenomena. These types of knowledge changes "go well beyond mere knowledge accretion or belief revision. There is general agreement that conceptual change necessitates a substantial reorganization of knowledge (Kaufman, Vosniadou, diSessa & Thagard, 2000 p. 2). Astronomical and Earth science conceptions have been a primary topic of this type of research. As Supring (2003) points out, this type of constructed conceptual knowledge has two properties—it can be incorrect and these concepts can be resistant to change through traditional instruction even when it is supported by observation.

Processes and Things

One very important finding, particularly for the topic of this material, concerns the nature of the conceptual category. Concepts are categories. Categories are often hierarchically nested. For example, cats and humans are categories that are nested under the super-ordinate category of mammals. But science concepts are not just about naming things, they are also about processes, e.g. light transmission, conversion between states, mountain building. Specifically, in this project four processes that produce surface characteristics on each of the rocky planets are central elements of the learning objectives.

Making this distinction between things (matter) and processes has been identified as an essential element of science concept learning. When students have process concepts assigned under the thing category, conceptual change is more difficult. Chi, Slotta, and Leeuw (1994) explain this in the abstract to their groundbreaking theory.

> ***Conceptual change occurs when a concept is reassigned from one category to another. The theory of conceptual change in this article explains why some kinds of conceptual change, or category shifts, are more difficult than others. The theory assumes that entities in the world belong to different ontological categories, such as MATTER (things) and PROCESSES. Many scientific concepts, for example light, belong in a subcategory of PROCESSES, which we call constraint-based interactions. However, students' initial conceptions of these concepts are categorized as MATTER. The ontological status of the initial and scientific conceptions determines the difficulty of learning. If the two conceptions are ontologically compatible (e.g., both are MATTER), conceptual change is easy. If the two conceptions are ontologically distinct, learning is difficult. Evidence for these two cases is presented from studies of learning about the human circulatory system and about key physics concepts, such as heat and light. (p. 27)***

How Conceptual Change Occurs—Theories or Pieces

There are at least two understandings of how people's explanations of scientific and natural phenomena develop and change over time. One body of research is exemplified by the landmark work of Vosniadou & Brewer (1992) focused on children's mental models of the Earth. This type research is often referred to as "naïve notions" or "prior conceptions."

> ***children begin the knowledge acquisition process by organizing their sensory experiences under the influence of everyday culture and language into narrow, but coherent, explanatory frameworks that may not be the same as currently accepted science. (Suping, 2003)***

According to this theory, as children encounter scientific explanations their coherent, deeply held conceptions begin to fragment.

The contrasting theory has a different viewpoint on how people's explanations of scientific and natural phenomena change over time. This research is exemplified by the landmark work of diSessa (1989, 1993). While diSessa acknowledges naïve conceptions, he understands these as pieces of knowledge systems:

> ***The system as a whole is only weakly organized and student intuitive scientific understandings are often a fragmented, loosely connected collection of ideas, having none of the commitment or systematically attributable to theories. (Kaufman, Vosniadou, diSessa & Thagard, 2000)***

There continues to be conflicting evidence about how these two divergent perspectives relate to one another. Clark (2003) in a study of conceptual change in the understanding of students at the 8^{th} and 12^{th} grade levels found greater support for the idea of "theory in pieces" than the idea of "integrated knowledge." By "normative explanations," Clark means accepted scientific explanations. He also found that curriculum that did not support integration of knowledge had little impact in moving students up the scale from misconceptions to scientific understandings. We hypothesize that fragmented knowledge is characteristic of areas with little meaning for the learner where he or she has had little or no opportunity to apply that knowledge to a specific task or problem. We believe that closely held misconceptions might be more characteristic of knowledge that has been developed for everyday use without access to experience or specialized knowledge.

Understanding Complex Dynamic Systems

The development of systems theory since the 1950s has strongly affected the conceptual frameworks that scientist use to view geosciences and astronomical phenomena. The level of abstraction of systems theory has effected education. These are challenging concepts for college students, and some educational standards require they be learned at the elementary and middle school levels. Both internationally and in the U.S., science education reforms have moved towards including these concepts in science curricula (Raia, 2005). As Raia explains (2005, p. 297) complex, dynamic systems demands an understanding of the arrangement of and relation among the parts. Identifying causation in these systems often involves seeing patterns of effect between levels of the system, and effects are emergent that is, they are not single cause-effect relationships and may not appear at the same level in the system. She observed college students in her classes to understand their mental models.

> ***I probed how students address complex dynamics systems in a course I teach- System Analysis of the Earth. Their responses reveal two main attitudes: a landmark view, i.e., a static view which does not take into account temporal and spatial scales on our planet; and a linear non-causal approach to Earth processes. (Raia, 2004, p. 298)***

Raia conducted an experiment with 16 college students. Students were asked them to generate scientific explanations for effects in complex systems. In general, Raia found that students with advanced courses and levels of content knowledge were no better at generating explanations of dynamic systems phenomena than other students. Rather, this was a skill possessed by students, several with liberal arts majors, that allowed them to "think in a nonlinear way, approaching issues from different angles, weighing multiple criteria, and considering multiple aspects of a system." (p. 300). Particularly, important was the ability to distinguish between micro and macro levels of the system. She concluded that identifying a close connection between the "landmark" view of things within systems and the lack of accounting for temporal of special scales. This "landmark" view of things may have some close parallels to route-based information processing typical among individuals who are blind and with low vision. For students transitioning from concrete to abstract thinking and with visual impairments, this is very difficult content conceptually. Designers of the ACTIVE system may want to consider providing building blocks for this type of thinking such as defining a system and clearly identifying different levels of a complex system such as the Sun and planets. Expectations for sophisticated understandings of systems by students in the 5th to 8th grades may not be realistic.

Spatial Cognition among Visually Impaired Students

Understanding the development of spatial cognition among people with visual impairments is of particular importance to the development of the ACTIVE system. Most of the studies on this topic have been conducted on a micro scale (e.g. reading information from Opticon devices or tactile diagrams) or a geographic scale (e.g. organizing spatial information about their neighborhoods or building space). A great deal of this research is conducted to support the development or orientation and mobility training for people who are visually impaired and blind. We could find no studies on macro scale spatial concepts such as objects in the universe, but considerable research has been done among spatial development. Yet, several of the findings in this area provide guidance for the development of the ACTIVE materials.

In a review of the literature on this topic, Ungar, Blades, and Spenser (1996) found that "groups of children who lost their sight early in life perform less well on a variety of spatial tasks that sighted children or children who lost their sigh later in life. (p. 247)." Some researchers cite mental picture as sensory system that, far beyond other modalities, provide the widest scope and clarity of spatial information. They conclude:

> ***It is now generally believed that visually impaired people can acquire spatial concepts and representations through their intact senses, but there is still some debate about the level of representation which can be constructed on the basis of non-visual information. A number of authors suggest that visually impaired people are limited to a relatively fragmentary and inflexible representation of the environment. Others, however, believe the representations of visually impair people are limited only by their experience with the environment and that even totally congenitally blind people have the potential to form integrated representations of an environment if provided with sufficient appropriate experience. (Ungar, Blades, & Spenser, 1996)***

Two issues appear to be involved in organizing spatial data from senses other than vision. Both the haptic system and sound can provide spatial information. But, haptic information is encountered sequentially and has to be actively reconstructed into and overall spatial representation. People who are blind and visually impaired often rely on route-based information and do not form two or three-dimensional mental representations of geographic areas (Ungar, Blades, & Spenser, 1997). Sound generally is less useful as a way to precisely located specific objects (Ungar, Blades, & Spenser, 1996). However, these researchers found that tactile maps were very useful ways of helping blind and visually impaired people develop coherent and applicable representations of geographic space. Note that this involves the transfer of spatial information from one scale to another. Therefore, while this type of representation is quite possible, the researchers note that many blind and visually impaired people do not have experience and practice in making these mental representations.

Changing "perspective" is another important skill in mentally manipulating representations of spatial concepts. Juurmaa & Lehtinen-Railo (1994) found that blind and visually impaired people required a greater amount of time to identify the static placement of objects in a space when they approached it from a different position. Apparently, like developing two and three-dimensional representations of space, shifting perspective also requires addition active mental processing and additional time for people who are blind or with low vision. This too needs to be considered in the design of the ACTIVE haptics applications.

Learning Structures and Concept Learning

Davies (1973) describes learning structures that are useful in understanding the level at which many of the respondents in the study "know" some of the important content concepts in the study. By using these categories of learning, we can better explain the knowledge and understanding of respondents and make recommendations for materials design. The range of content within the West Virginia CSOs applicable to this project (Appendix D) is one type of Davies' learning structures.

Table 2: Classes of Learning Structures: Definitions, Examples, and Prerequisites —Davies (1973, p. 98)

LEARNING STRUCTURE	DEFINITION	EXAMPLES	PREREQUISITES
Signal	A signal involves a specific response to a specific stimulus	Learning definitions in science. Warning light in car dashboards.	——
Chain	A chain involves a fixed sequence of verbal or motor responses	Carrying out cockpit checks in a VC 10. Setting up a lathe or tying a shoelace.	Each of the links or signals making up the chain must already have been acquired by the student.
Multiple-discrimination	A multiple-discrimination involves distinguishing one category of phenomena from another.	Distinguishing between latitude and longitude. Distinguishing between different waveforms on an oscilloscope.	Each of the signals making up the set to be discriminated must already have been acquired by the student.
Concept	A concept involves making a generalization about a whole class of related phenomena.	Classifying or making generalizations about objects or events, e.g., resistance, evil, loyalty.	Each of the chains or signals making up the class or set to be generalized must already have been acquired by the student.
Principle	A principle involves a chain of concepts.	Fundamental truths or laws, e.g., Joule's law, theory of the conservation of energy.	Each of the concepts making up the principle must already have been acquired by the student.

Each of these structures implies some specific approaches to teaching and learning. Several of the important content pieces of the ACTIVE program can be classified as concepts. Davies provides this advice on teaching concepts:

> ***The tactic for teaching or learning a concept involves two processes, for the student must: (1.) Generalize with the class. The student should be presented with a set of related, but different stimuli, to each of which he makes the same response. Examples: shown triangles, squares, circles, and rectangles, the student could be expected to respond 'geometric figures.' (2.) Discriminate between classes. Once the generalization has been acquired, the student must learn to discriminate between the concept and all other concepts with which it is likely to become confused. (p. 102)***

We explored several questions in this study that involved concepts. As Davies points out, one way to "test" to see if a concept is acquired is to ask the learner to provide examples and non-examples of the concept. This definition of concept learning is useful as a tool to characterize the level of understanding of respondents and we will use it throughout the discussion of findings. It is also an important definition to use in building embedded assessments for the concepts presented in the learning materials.

Learning Theory and Standards-Based Education

There mounting evidence that the National Science Education Standards (National Research Council, 1996) sets standards in content areas for middle school science that is difficult for students of this age and development level to comprehend. The shift from concrete operation to abstract thinking levels occurs within the middle school years. Kavanaugh, Agan, & Schneider (2005) specifically focus on learning about phases of the Moon and eclipses, they indicate up to half of middle school children are not ready and will have difficulty with these concepts. They strongly recommend constructivist methods (e.g., inquiry based strategies, problem based strategies) if "students are to build adequate mental models of these bodies relate to each other."

Yet many of the specific curriculum strategies and learning activities they recommend build on visual observation of the night sky and assumed everyday experience and conception based on the visual inspection of the properties of light. For elementary and middle school students with visual impairments, this experience and these everyday conceptions may be lacking or even absent. Even among their sighted peers, when constructivist methods have been used, Kavanaugh, Agan, & Schneider (2005) note that "To our knowledge, no studies have been conducted to determine if students who observe lunar cycle in K-4 are any better at developing modern mental models of the Earth-Moon-Sun in grades five through eight."

Some promising problem based curricula deserve exploration. For example, Salinerno, Edelson, & Sherin (2005) cite a problem-based curriculum called Planetary Forecaster.

> ***The premise of the curriculum unit is that students have been asked by a fictitious space agency to identify the portions of a newly discovered planet that are habitable given the information about the planet's topography, water cover and the tilt of its axis. (p. 423)***

The unit has seven phases and begins by with an activity in which "students articulate prior conceptions." (p. 423) Gabler & Schroeder (2003) refer to this strategy as diagnostic teaching, and it is certainly an essential element of any learning experience in this area. Yet, the activity in Planetary Forecaster involves drawing color maps, an exercise dependent on visual experience and skills.

Role of the Perspectives from the Literature

As we present the findings of this study, we will refer back to these ideas from the literature to characterize some aspects of the data and draw conclusions. We will also point out places where the assumptions in some of these theories did not precisely fit respondents in this study. These young people are not simply "visually impaired middle school students." They are individuals with unique and specific histories. They are adolescents moving through developmental stages. They are country music and video game fans. Generalizations from the research and other sources are useful, but they can only go so far in helping us understand these very interesting people. Their own voices give us deeper and more focused insights in how they understand themselves and the universe in which they live.

DISCUSSION OF FINDINGS

Educational Background

Among the respondents we interviewed, students had attended the WVSDB from two weeks to eight years. The longest tenure at the school was the congenitally blind respondent who had begun his education there. Among other respondents, the pattern appeared to be that they had begun their education in public schools and then their parents or the school system had recommended they come to the residential school. One student who lived quite close to Romney did not live at the school, but rode the bus to classes each day. Among the students who had transferred from public schools, all cited missing family, friends and "living away from home" as aspects they did not like. This young man summed up well the things the respondents liked about attending public school near home.

> ***I don't get to see my family as often as I used to. And some of my friends at home, I don't get to talk to them a whole lot. . . . [at public school] There were a lot more people to talk to. And you get to go home every day. (Case 3, male, 8th grade)***

One respondent, who had been at the school only a couple of weeks, explained that she was still adjusting from being away from home. She did not like

> ***Being away from my mom. . . . . She calls me like every day. (Case 7, female, 8th grade)***

However, each of the respondents also cited factors in the reasons for their transfer that made the residential school a better option for them. While this is certainly not, nor is it intended to be a generalizable sample, these students' experiences give us some insight into the challenges of blind and visually impaired students in regular school settings.

For these pre-adolescents and early-adolescents, making friends is very important, and several noted it was easier for them at the residential school. Five of the eight respondents reported that they were bullied or "picked on" in public school. Friends, lack of bullying, and help from teachers were cited as positives of the residential school.

> ***{At WVSDB} you can make more friends that are more your age. And it's not so hard to talk to people or hear the teachers or see what they're doing. (Case 3, male, 8th grade)***

> ***Well, hmm, even though I didn't really get to experience public school because I was to out of whack, I could say that I'm forming friends more easier. (Case 4, male 8th grade)***

> ***The fact that nobody was helping me. Like my teachers wasn't helping me. And I was always getting picked on and stuff like that. (Case 3, male, 8th grade)***

Respondents also identified other factors that contributed to a good educational environment: individual help from teachers, smaller class size, and easy access with no stigma or embarrassment attached to large print materials.

> ***I've gone to public school. And they — they were not much help — not at all. . . . . Then I had to come to this school because there is more help and they don't really — and there's more help and there's big old books in print. . . . . Because when I went to the other school I had two desks. I had one desk for all my books. And one desk for where I was sitting with my desk and pencil and stuff or — (Case 5, male, 5th grade)***
>
> ***[In public school] there was like 42 students. . . . Well, it's [residential school] better in the teachers actually are like one-on-one. And the most in one of my classes, which is Home Ec, is nine students. And I help the teacher because I'm like — I mostly know what to do and I get my work done before everybody else. And the lowest in my class is three people. (Case 3, male, 8th grade)***

It is important to emphasize that this group of students and their parents had selected the option of a residential learning environment. Perhaps this indicates that their experiences may have been somewhat negative in public school settings. The nature and type of these experiences, and the specific benefits cited do provide guidance for the development of the ACTIVE system.

Experience and Skill Levels with Assistive Devices and Technology

Like other areas of technology, the range of assistive devices for people who are blind and with low vision is expanding rapidly. Based on these interviews with students and teachers, we found several patterns that will be helpful to note in the development of the ACTIVE system and lesson plans. First, several of these respondents noted being uncomfortable using assistive devices and technologies among sighted peers and in regular classrooms. As adolescents, "being different" is particularly difficult, and these devices may appear to them as markers of being different. Students in public school settings appear to have used assistive devices such as large print materials and print magnifiers. This may be due to the use of textbooks and print materials as the primary technologies for instruction in that setting. Several of the students came to the interviews with small hand-held magnifiers, but when asked, their favorite devices were CCTV devices such as CCTV systems which allowed them flexible selection and control. When using computers, students first appeared to rely on screen magnification for access, and only secondarily to computer software such as JAWs, which translates text in to audible form. All the students have some access to and experience with computers, but their keyboarding skills were probably fairly elementary and dependent on looking closely at the keyboard to search for keys. This may not be too different from their sighted peers, but may have a greater impact on their access to information.

Print Magnification

During our interviews, we heard very little about the development of Braille skills, and a great deal more about magnification of print text and pictures. We heard about the use of large print books, small hand-held magnifiers, larger magnifying devices placed over print, or through CCTV devices.

As we noted earlier, students mentioned having some access to large print books in their public school experiences, but even greater access at the residential school. Using the large print books in a public school setting was problematic for some students. Two mentioned (Cases 5, a 5th grade male, and Case 7, an 8th grade girl) mentioned being embarrassed by the using large print books in regular classes.

However, they also spoke favorably about the greater access to these types of books in the residential school—where everyone was using the same types of materials. Student's favorite devices were clearly those that reduced the stress of holding their faces closely to print materials, and allowed them to most freedom and flexibility. The two specific devices mentioned were the Flipper and the Jordy CCTV portable systems. Both these systems allow students to enlarge print materials and to focus the camera on the blackboard or teacher.

> ***I use the V-tech and magnifier. . . . It's just — it's like a little TV.***
>
> ***And it has a little stand that you put the paper on and move it back and forth. And it comes up on a screen. And you can make it bigger, smaller, different colors, like black and white. . . . . it's — it's got a big TV and then it's got a little camera thing with a stand on it. They're easier than — because I had — there are some books I still have to use a magnifier with them. And it's easier because you don't have to use a magnifier. You don't got to focus as much. (Case 7, female, 8th grade)***

One teacher mentioned the limitations of these CCTV systems in helping students understand science concepts:

> ***My students are very interested in science but they're very limited on how much information they understand. Because I see them memorizing a lot of terms but I really don't know if there's an understanding of those terms. It's really difficult for me to go over something and them — you know when you have a visual impairment it is really difficult to understand what a valley is. And now I know that the pictures in the textbook if they do — if they're low vision sometimes they can understand a picture. But if it's not high contrast it's difficult to — to make out some of those color photographs in the book. And they're very small. And then when you put them under the CC-TV, sometimes you know it's hard to make out what they are because it's black and white. (Case A)***

Computer Adaptive Devices

Like many of the teenagers we have interviewed in other settings, several of the respondents in this group used computers and technology for fun and leisure as well as for school. As we noted earlier, all but one of these respondents had some level of usable vision. JAWs (computer software that translates text into synthesized speech) and enlarged text on the computer screen seemed to be two of the most familiar and useful assistive technologies for using computers.

> ***I check my email, listen to music, do searches on some of the things I'd like to know about. . . . [I use] enlarged text and sometimes I use JAWS. . . . I don't have — I have the JAWS here and enlarged text here. But I don't have JAWS at home. (Case 5, male, 5th grade)***

One of the teachers mentioned a helpful program that made the cursor large, visible, flashing. The computer/keyboarding teacher at the school had put this program on her classroom computers.

> ***She put — she put my big curser on there to help the kids out on my classroom computer. . It's huge. It's called Biggie. And she's got a special program. I don't know if she got it free or what. But it's huge. And not only is it big and it's bold — it's colorful. But it's got like a moving thing inside so you can actually see it — you know my low vision students. And the icons have to be huge. The print under the icon should be huge so they can see it — you know without any problem. (Case C).***

But, there appeared to be a great range of experience, access, and skill levels among the group we interviewed. One difference access was related to family support. One student said she had no computer at home, because it had been stolen. Two other mentioned not having access to a computer at home. At the other end of the range, a respondent reported playing racing video games on the TV at home, bringing his laptop to school, and the different assistive devices at home.

> ***I use the magnifier that's like already programmed on the computer. And at home we have a special keyboard. Like the letters have a magnifier on top of the — things. And then I can see it magnified . . . . we use to have a flat screen with a magnifier over it. . . . . But then — now we use the magnifier for the laptop that I bring up here. . . . . The keyboard [is really helpful] because you can see the letters like from a better distance. And you don't have to strain your neck and look down at like and get really close to it. (Case 3, male, 8th grade)***

One of the teachers we interviewed believed that children with low vision probably got less computer time at home than their sighted brothers and sisters.

> ***But at the beginning of the year — I've just — I've thought about this — why they're not getting computer time at home because I know two of them have computers and three do not. But the two that do have computers, the only thing I can think of is they are low vision. Do their parents think that they — you know what I'm saying? . . . . That they don't — they can't surf the net — they can't — they don't have the vision to correctly do it. And they don't have the time to help. They need someone sitting there — I guess — that they need help. . . . But they're not given the opportunity at home I don't think. I think that's the problem. The parents are — you know busy. They're just too busy. And — and maybe they think they're getting it at school and they are. (Case A)***

Other respondents reported having no computer access at home—but used it to play games to look for songs on the Internet. Two of the students, those with additional disabilities, largely did not appear to use computers during their leisure time.

> ***Oh, my. I never really get on the computer much but if you want to know. (Case 4, male 8th grade)***

But both these respondents reported keyboarding instruction, and were familiar with using a mouse to play games like checkers.

Keyboarding Skills
Among this group, all talked about using a software program called Typing to Learn. In the student interviews, we heard fairly high assessment of their own keyboarding skills.

> ***Well, it's kind of difficult. But if I do it the wrong way I'm very fast on typing. . . . If I do it the right way I'm as slow as molasses. (Case 8, male, 8th grade)***
>
> ***Well, I'm doing this computer program and we're supposed to sit straight up, not lean forward, and not look at the computer — I mean look at the computer and not look at the keys — it says to not — not slouch. Pull our elbows in and type. And look at the TV. (Case 7, female, 8th grade)***

Teachers did not see these see keyboarding skills as well developed. One reason for this was the additional time it took in the classroom because of their still developing skills.

> ***They're computer time consists of surfing the Internet, doing web quests, and they do spelling words and math games. Very little keyboarding. I know that for a fact. (Case C)***
>
> ***Do I have to be truthful? . . . . They're not as efficient as their normally sighted peers. . . . They start keyboarding skills here at this school in 3rd or 4th grade. They're very good Gameboy, PlayStation, those kinds of skills. They have lots of those. [But] keyboarding is very stressful for them because a lot of times they can't see the monitor until somebody changes the font. Or until they get a magnification. . . . if I let them on the keyboard I waste a lot of time. So I don't always push them to the keyboard because I feel like I could use the time so much more wisely. (Case A)***

Sounds— Motivation and Spatial Cues
According to the teachers, their students love interesting and unusual sounds. All three teachers noted this, and emphasized how motivating sounds were to their students. They also suggested possible applications of sound to help visually impaired students pick up spatial information and distances.

One teacher told about how much her students enjoyed a math game, and emphasized how motivating sound was to her students who are blind or with low vision. .

.

> ***Well, Math Flash is wonderful because when they succeed they give them a succession of — like multiplication facts or subtraction facts or addition facts. There are probably 20 or so. The teacher can — can program all that in — how many they're getting. But when they get them all right it's really cool because this little guy comes across the screen — and he's big enough so my low vision kids can see it. But he makes these really, really funny sounds. And this funny music comes across there. And they think that's hilarious. They think it is hilarious. And they just love it. They love doing Math***

> ***Flash whenever they can get the chance to do it. . . . . Well, the sound is what they're after. They love that — . . . . . they just love that. They eat it up. (Case C)***

This teacher also mentioned that there was a large difference in the teaching strategies for congenitally blind student. She pointed out that sound became even more important for these students.

> ***The student that I had last year — and grant you she was only a kindergarten student. She loved to get on there [the computer] and listen to CMC [Country Music Channel] and Nick.com, because everything was music and you could hear the characters. She enjoyed it. And [the blind student we interviewed] — he loves music. And he loves the silly gadgets that make noise. He just gets a big kick out of that . . . . . — when you design something it needs to be loaded with those sort of things. But as a reward they love that. The sound is — in itself that's the greatest thing ever. (Case C)***

Another teacher explained that she had seen math software that appeared very effective in using sound cues to provide spatial information.

> ***I mean is there a way to add an audio to the spatial concepts since you don't have the visual? Could you have a certain beep for things? And as you get nearer something the beep increases in volume or speed or pitch or something? Can you add an auditory signal to make up for the lack of the spatial or the depth or the time or something? And the reason I say that is — I can't remember the name of the program but a math teacher has an audio grapher. And as the student graphs the cosine or the sine it makes a beeping noise. And as the line goes upward towards the top the pitch raises. And then as the line comes back down on the other quadrant of the graph, the pitch lowers again back to where it started. So as you're making the arch — up to the top of the coordinate grid and then back down to the axis, you have this pitch that is increasing until — — it reaches the top and then goes back down to where it started. (Case A)***

Finally, one teacher had found that interest in sound and music was a motivating factor for some of her students in learning science.

> ***a lot of kids who go to school here are very interested in music. And they're also interested in radio technology. So they've had a — a bit of physics in some of our course work here, so they kind of can relate to sound and electronics a bit. (Case B)***

Tactile Graphics

The interview protocol included several tactile maps, globes, and other objects for students to touch and manipulate. These materials were ordered primarily from home schooling suppliers, and were not specially design for visually impaired students. During the student interviews, it was apparent that some of the objects, e.g. the model of the Earth, were not quickly identifiable to the students. We discussed this with one of the teachers in her interview. She noted that by 5th grade,

> ***They [low vision and blind students in the residential school] should be familiar with tactile graphs, also maps. (Case C)***

However, she noted the "boundaries are not sharp enough" on the model we were using. She explained that the spatial contrast between the continents and oceans was not great enough for students to identify tactilely. Later, I examined some of the tactile maps in the resource center nearby. For tactile maps representing the continents, the edges and height of the continents had been exaggerated. This respondent stressed that using tactile graphics was a learned skill and that students in regular classroom might not have as much experience or access using these materials. The interviewer asked her to speculate on whether or not students would be able to discriminate tactile information from actual NASA data. She recommended haptics-based learning activities be tested to see if a person with a visual impairment, familiar with high contract tactile maps and graphics, could obtain accurate information.

There were other limits on students experience with tactile graphics. Both access and the appropriate level of detail and design, even in this specialized setting, were sometimes described as difficult.

> ***It upsets me because a lot of the books that I've received lately — even when I order them, they omit the maps or the graphs. And that's disheartening because you order a textbook hoping that you will get them so you don't have to make them all yourself. . . . . I mean some of the textbooks still say, ask your teacher to describe the map. And you're just like, the teacher can't describe the map, I need one. . . . . So I have a lot of older maps in my room that — you know are tactile. And I pull those out. But tactile graphics can become very, very stimulating if they put all the information on the graph that is in the print copy. They become too cluttered and too busy. And — sometimes I would say the experience my kids have reading tactile things is limited. (Case A)***

Time and Assistive Devices

One topic frequent topic among teachers was that learning tasks take more time for students with low vision and blindness. One teacher believed this might be the biggest challenge for students with visual impairments in mainstreamed settings.

> ***Sometimes it's just the fact that their visual impairment takes them longer to process their work. A child [who] uses large print and large materials or uses a CC TV, it just takes them longer to get from finding their place to writing it on a paper and then going back and locating their place. And that is quite time consuming for kids. And in a regular setting they can't be given that kind of time without being rushed and pushed and — and it's not that I don't want to push them and expect the best out of them. But if they have limitations they have to be given the right to work within them. (Case A)***

Reading and Listening Comprehension

A closely related topic that came up during teacher interviews was student preference for listening to information rather than reading it. Students mentioned getting tired and their necks hurting trying to decipher print materials—even with assistive devices.

Like small print. We're reading a chapter book in my class and I can see it without my glasses but I have to bring it like an inch away from my face. (Case 1, male, 8th grade)

Another thing I hate about reading small print is the fact that you've got to lean over and read and it gives you — it makes your neck hurt. (Case 7, female, 8th grade)

But both teachers and students agreed that the preferred way, particularly for blind students, to get information was through audio.

They get more out of listening to it than reading it. But listening — they go to the audiovisual library. And they listen to books rather than reading them. Because they just pick up — you know things more — or better. (Case C)

Interest Level and Motivation

As part of the interview, we asked students to rate their levels of interest in four general areas of science (1) biology/life science, (2) physics/physical sciences, (3) Earth and space sciences, and (4) environmental science. Overall, these ratings and of themselves were only slightly informative. Children in particular often wish to please the interviewer, and they were aware of the topic of the interview before it began. More useful were the explanations they gave for "liking" different areas of science. For Case 4 and Case 8, these different areas of science were not clear—they simply thought of "science" as one unified subject and making these distinctions was difficult for them without addition prompts and examples of what topics might fall under each area. In terms of general interest, Earth and space science sometimes are rated lower by females than by males, and our only female respondent did indeed say she was only "a little interested" in Earth and space science. However, she noted that she liked science in general,

I like science. It's pretty interesting. I like when we do experiments. (Case 7, female, 8th grade)

In assessing interest levels and motivation, one factor to keep clearly in mind how aware this particular group of respondents were of Space Camp for Interested Visually Impaired Students (SCIVIS). The coordinator of the national program is one a staff member at WVSDB, and a member of the ACTIVE project team. He recruited students for these interviews. SCIVIS is a week long camp that takes place at the US Space and Rocket Center in Huntsville, Alabama. It is coordinated by teachers of the visually impaired, and materials and computers in the program are accessible. Computers have been adapted for speech and large print output. Both materials and equipment used during missions are available in Braille and large print (Space Camp for Interested Visually Impaired Students, 2006). Not surprisingly, in this fairly small school, this was a highly visible and exciting opportunity—and it appears, especially, to appeal to the adventurous spirit of the boys. Four of the boys specifically cited space camp and connected it to their interest in this area. They expressed interest in space travel, and one wanted to be an astronaut.

Because I like to learn about the Earth and what it does and science itself. And space and all the different planets. (Case 1, male 8th grade)

> ***Like I said earlier, I'd really like to be an astronaut, but I'm not really sure yet. (Case 2, male, 7th grade)***
>
> ***Because the planets and the orbits. And I like watching shuttles launch — take off on that landing pad. (Case 7, male, 5th grade)***

Popular culture also appears to play a role in the popularity of this topic:

> ***Oh, okay. Well, I watched the movie Rocket Boy. That was pretty cool. So I'll give it a full 4 [the highest rating}. Because that was pretty neat. And then there was Apollo 13. And neat things like that. . . . Yeah, I loved Apollo 13. That's one of my favorite movies, too. (Case 4, male, 8th grade)***

Teachers had a somewhat different perspective. While they clearly understood the attraction and interest generated by SCIVIS, some also believed that Earth and planetary science topics were difficult to connect with student experiences and those students were not able to relate easily to these topics.

> ***I have to say that the planets are some — I mean the solar system is not something that I usually spend a great amount of time on. Because it's something that the kids don't relate to well. You know, some of them can't look up in the sky and see the Moon. They know the Sun is up there because it's shining. They can tell that. They can't see the stars. Some of them can. They don't comprehend a lot of spatial relations well because you know their — their visual limits keep them from understanding spaces. . . . . Like do they hear people talking about the constellations? Or the night sky? I mean there's just maybe a lack of exposure outside the classroom. And then when you go to address those issues in the classroom, it becomes very, very time consuming to try to make up the learning gap that you think maybe a normally sighted child might have. [With sighted children] you know they see the constellations. They see how far the stars look apart in the sky. And that there is millions of them. You know they can just put all that together. But when you go try to explain that to a visually impaired kid, then they're just like, what do you mean? All these stars are bumping into each other? All these stars are what? How did they all get out there? You know — what are they all — what do you mean they're all out there? You know it's just not comprehensible. (Case A)***

This lack of a visual experience base and everyday familiarity with the night sky is certainly an important factor to keep in mind in interpreting the students' level of knowledge. It also explains some of the misconceptions they had. It does not preclude or contradict the very real enthusiasm and motivation we found among the respondents who had or planned to attend SCIVIS.

Earth and Planetary Science

While student interviews were conversational and somewhat informal, the purpose was to assess respondents' understandings of some important concepts and principles in Earth and planetary science. While the proposed ACTIVE system focuses on comparative planetology, this topic itself is embedded within other astronomical and Earth Science concepts and principles. Using the working definitions from Davies (1973), we can assess the extent to which several important concepts and principles are understood.

In general, we found only one of the respondents (Case 1) to be what might be termed "at grade-level" with this content. Most of the other respondents had considerable existing knowledge but it was fragmented, loosely organized, and not easily or quickly accessed. Some had a few closely held misconceptions based on everyday experience. Case 8, the respondent who was congenitally blind, probably had the least knowledge overall, but was nervous during the interview. He may have had greater understanding than we found.

Underlying Concepts: Models and Systems

Two important underlying concepts in Earth and planetary sciences are *models* and *systems*. These concepts are abstractions that apply across a variety of sciences. They also have everyday language associations and connections. Everyday language connections give us an idea of the context in which respondents understand and apply these concepts.

Models and Scale Models

The concepts of models and scale may need some direct coverage in the ACTIVE materials. While most respondents grasped the idea that a model was an object that represented something else, only one could define scale and apply the concept of scale in comparing two models.

The concept of a model includes the ideas that one thing is representing another, and that there may be differences in size. A formal definition of a model is:

> ***"A small object, usually built to scale, that represents in detail another, often larger object." (The American Heritage® Dictionary of the English Language, Fourth Edition, 2000b)***

Early in the interview, the interviewer handed respondents a Styrofoam ball and asked the student to "pretend" it was a model of the Earth. Then students were asked, "What is a model?"

Only one respondent appeared to lack some understanding of the idea of a model. This was Case 8, a student who was congenitally blind. He defined a model as "I think it would be an example of it." Note that this definition does not make any distinction between the "real thing" and a representation of it.

Case 7, a female 8^{th} grader, appeared to have some understanding concept, by defining it as "A figure or something." Nevertheless, she had few associations to this idea and could provide no examples.

The youngest respondent understood the idea and connected it to some very specific sets of models in his own life, but also had an attribute of the category that went beyond the definition. We should point out that this definition also applied to the object he was holding which was part of a kit for assembly:

A model is something you put together by instruction. . . . Planets. Like there's this — like cars, planes, boats, all that stuff. My grandmother has a shop and she has tons of models. Like NASCARS you have to put together by heart. And it comes with paint, glue, screws, bolts, and tires. (Case 5, male, 5th grade)

Older respondents appeared to have more context free definitions of models. But it is interesting to note that their definitions included tactile characteristics such as texture.

It's like a diagram of the actual thing. And a model might have a flat surface or a rough surface. Or it might go up on one side and down on the other. Or it might be thin or any type of thickness. And it could be any shape and size. (Case 1, male, 8th grade)

A model can be a display of something that you can feel or see. Instead it like — a planet you can't really go and touch it, but with a model that has all the same texture — you can see what the planet is like. (Case 3, male, 8th grade)

When the concept of scale was introduced into the discussion, only one of the students was able to formulate a verbal definition that included both the ideas of the representation of the "real thing" and the difference in size.

A lot of — that's compared to a — the life size — the real thing. But it's in a smaller form. (Case 3, male, 8th grade)

The respondent (Case 8, male, 8th grade) who was blind made a connection to another verbal form of the word and after some hesitation said that scale was an "example of getting weighed and stuff."

Other respondents clearly drew a blank on this idea and frankly said so.

I don't really know. (Case 5, male, 5th grade)

I have no idea what you're talking about. (Case 7, female, 8th grade)

Later in the interview, students were asked to apply the concept of scale. The interviewer pointed out a prominent feature (mountains in the western United States including the Continental Divide) on the small globe they were holding and a similar feature on a topographical flat map of the same area. After giving them time to explore both areas with their hands, they were asked with map had the larger scale and which had the smaller scale. This idea of two maps representing the same feature did not appear entirely clear to most of the respondents, and only Case 3, who had been able to formulate the verbal definition correctly indicated that the flat map had a larger scale.

System

While the terms "solar system" and "computer system" were familiar to some respondents, only two even attempted to define the idea of a system as an abstraction. The most commonly understood attribute of a system is that it is a collection of elements. The ideas that these elements have a relationship or that they form a whole did not appear salient to most of the respondents. Explanations for this finding may be that this concept has not been taught to them, and/or that they are concrete operational thinkers who have difficulty with this abstract notion.

Another important underlying concept in astronomy and Earth sciences is the concept of a system. Upon reflection, this is quite an abstract idea. It involves (1) a group of elements, (2) relationships of some type among the elements, and (3) the formation of some larger element. A formal definition of a system is:

> ***A group of interacting, interrelated, or interdependent elements forming a complex whole. (The American Heritage® Dictionary of the English Language, Fourth Edition, 2000b)***

The interviewer asked respondents to define and give examples of systems about half way through the interview after the discussion of Earth/Sun/Moon relationships. The respondent who was blind (Case 8) did not respond to these questions and we quickly moved on. Several students responded quickly focusing on the solar system. The 5th grader immediately began to rearrange several of the balls on the table into his idea of the solar system. For him, this example was the definition. His response showed he had considerable factual knowledge about the solar system. He also used personal pronouns for objects. This is characteristic of scientific explanations of younger children (Vosniadou & Brewer, 1992).

> ***It means that the planets are all like spread apart. You've got one planet here. Smaller planets around like this. And you've got all your big planets — like this one. And this one is exactly the same, isn't it? I'll use this one. This one, and then you've got the Sun. And then you've got him. And you've got these two. And you've got — you've got him right there. (Case 5, male 5th grade)***

Not surprisingly, given the topic of the discussion, all but one gave the example of the solar system. The other frequent example was a computer system.

> ***It's a place made up of stars and planets. Case 6, male, 7th grade)***

> ***Like a computer system is — normally — well, I can't think what it is if I don't think a minute. I think one of the systems is a hard drive and if you talk about space, well, there's the solar system. But, however, I don't know where it's precisely located. (Case 4, male, 8th grade)***

Two respondents formulated the definition as an abstraction, but they only included the idea of a grouping of objects.

> ***If we have a group of things or how they work. (Case 3, male, 8th grade)***

> ***A line of different objects in a row. (Case 1, male, 8th grade)***

The following interaction between the interviewer and Case 7 shows an adolescent who deals with abstractions fairly well, who does not quite have all the attributes of this concept and therefore has difficulty defining it and giving examples.

INTERVIEWER ***Why — why do we call anything a system?***
PARTICIPANT: ***Because it has to do with more than one thing?***
INTERVIEWER: ***It has one part — more than one thing. That's — any other characteristics?***
PARTICIPANT: ***You've got more than one planet. Well, it's got more than one thing.***
INTERVIEWER: ***Okay. Would — let's say there were ten houses.***
PARTICIPANT: ***Okay.***
INTERVIEWER: ***And they were all in different states. Would that be a system?***
PARTICIPANT: ***No.***
INTERVIEWER: ***Why not?***
PARTICIPANT: ***Because they aren't in the same area?***
INTERVIEWER: ***Well, what if we had ten houses here in Romney, would that be a system?***
PARTICIPANT: ***Yes.***

(Case 7, female, 8th grade)

Earth, Sun, and Moon

Structure of the Earth

More of the student respondents were familiar with and able to name layers of the Earth than almost any other concept in the interview. Even Case 8, to whom a great deal of this content was unfamiliar, remembered that the center of the Earth was called the "core." Case 7, perhaps the least interested of the group, remembered and pointed to the crust and the core on the Earth model. She point to the mantle and guessed "liquid oxygen." Most of the other respondents named all three layers and pointed them out quickly. One reason for this familiarity may be that this content lends itself to tactile, hands-on activities. One teacher explained this.

> ***The only — I mean I've taught layers of the Earth. And typically in the same thing, I just helped them to create layers either using like a golf ball in the middle and different colors of clay on the outside. Or — I'm not sure that I've used other things. Because even when you build the layers you put different pieces of clay. If a child is blind they can still feel that one piece of clay — you know is separated from the others. (Case A)***

Equator, Poles, and Axis

Most respondents had difficulty with the concepts underlying the Sun-Earth relationship (equator, North and South Poles, axis). Note that these are abstract concepts without physical referents, difficult for many children who have not yet reached an abstract level of thinking.

Only one respondent easily identified the equator, North Pole, and South Pole on a model of the Earth and made a quick connection between the relationship between these areas and the Sun and temperature. These questions did elicit some existing knowledge from all students. But this knowledge seem more associated to the study weather and personal experience than to Earth and space science. Respondents did not easily recall this information in an organized framework.

To explore the respondents' understanding, the interviewer asked them to hold a small (6 inch diameter) form model of the Earth. This model had raised and painted areas on the surface representing the land area. The oceans were painted blue. These raised areas were not easily identified by students who could not see the visual cues. At the area analogous to the equator, the two halves of this model fit together forming an easily identifiable ridge. (The model could be separated to show the layers of the Earth.) We had place pins at either end of the model, in correct relation to the "equator" to represent the North Pole and South Pole. After handing the model to the respondent, they were asked to feel the ridge around the middle of the model, and the pins at the top. We began the questioning by asking them to identify the area on the Earth that ridge represented, and then what the pins represented. This was followed by asking them where on the Earth it tended to be colder and warmer.

All students identified the North Pole. About half the students quickly identified the ridge as the equator. Other ideas about what it might represent were also given. Case 8 said he would call it "an orbit." Case 3 said it would be the "prime meridian." Case 7 picked up a ring from the Saturn model on the table and asked if it would be "one of these?" Several never identified the South Pole, and even when there was some understanding, this information was not easily accessed. One respondent, probably searching for the word "Antarctica" gave this reply to a probe about where on the globe it tended to be colder.

> ***I believe Atlantica? . . . It's ice. (Case 7, female, 8th grade)***

Most students, when queried about where on Earth it was colder and warmer gave specific place names. Australia, Arizona, Florida, and Myrtle Beach were given as examples of places it is hot. Examples of cold places included mountains, deserts, and places where it is cloudy.

Only one student identified all the North Pole, the South Pole, and the equator and explained the reason for it being hotter around the equator of the Earth:

> ***Because the Sun is always in line or near the equator. (Case 1, male, 8th grade)***

This same respondent was the only one who identified the Earth's axis as running pole to pole and connected this to rotation.

> ***Because the Earth would be spinning and I would think no. But not unless it's tilted to spin around. Then it would be really. Because it would tilt to move around the Sun, wouldn't it? (Case 1, male, 8th grade)***

Landforms

Students appeared more familiar with landforms on the Earth surface—ideas with concrete referents. As the interviewer introduced a topographical map several respondent spontaneously identified mountains, valleys, and rivers as they explored the surface with their hands and compared it to the globe model of Earth they had been holding. Our youngest respondents identified several landforms on the topographical map.

> ***And that's the mountains right here. . . . Land and water — tons of water. . . . . You got your waters in here. . . . . And you got your mountains — Rocky mountains in there. And you've got deserts in here. It looks like deserts. (Case 5, male, 5th grade)***

One of the older respondents demonstrated a good understanding of the differences between the two models indicating they were aware of and skillful in changing perspective and reorienting themselves to information from these types of sources.

> ***And this one is flat and it has flat edges and then it goes up. And then it shows you the diagram of like where the rivers are and how the mountains go and look like from the sky, I guess you could say. (Case 1, male, 8th grade)***

As we will discuss later, some respondents were also familiar with volcanoes and craters and knew the processes through which these landforms were formed.

Earth Moving through Space

The interviewer asked respondents to hold two models, a smaller one representing the Earth and a larger one representing the Sun and to show how the Earth moves through space. All but one student clearly demonstrated that Earth moved around the Sun in an orbit, although this term was used by only some of the respondents. One respondent (Cases 1) had an understanding of both rotation around the Sun and how the Earth rotates on its axis. He used these terms appropriately to describe how he moved the objects.

All other respondents demonstrated the revolution around the Sun; they demonstrated some confusion about the Earth's rotation on its axis, and sometimes used the terms "revolution" and "rotation" interchangeably. Students were also not clear about the timeframes of these movements. Case 3, who demonstrated the Earth's rotation on its axis, had the two terms conflated:

> ***And it will spin all [around] it's rotation. And it takes approximately 2 — 3,000 years for it to completely go all the way around the Sun. (Case 3, male, 8th grade)***
>
> ***A circle. It makes a circle around the Sun. . . . . And rotates as it circling the Sun. . . . [It takes] a whole 24 hours. (Case 7, female, 8th grade)***

The Moon

As with the previous questions, Cases 1 and 3 demonstrated the clearest understanding of the relative positions and movements of the Earth and Moon through space, and Case 8 demonstrated the least. Among the other respondents, we found some rather strong misconceptions about the Moon. The most frequent misconception was share by several respondents. In demonstrating how the position and movement of the Moon around the Earth, four respondents clearly indicated some idea that the Moon "stayed" on the side of the Earth that is dark. The Moon was closely associated with night and darkness, and for some this meant the Moon traveled back and forth across the night sky from horizon to horizon in an alternating "U" shaped motion.

Case 8 had the least familiarity with the Moon, and when asked about it said, "It lights it up, I think." All the other respondents had a clear idea that Moon moved around the Earth. They demonstrated a variety of positions and movements, however. Case 6, who had only recently lost his vision, positioned the Moon "behind" Earth in relation to the Sun and stopped his explanation when he observed the Moon moving closer to the Sun in his demonstration:

> ***[The Moon] gives us our nighttime. . . . . Well, the Moon orbits around — orbits out here [holding the Moon behind the Earth] around the Earth. And when it intercepts with the Sun and the Earth I think it makes either a — I can't remember. (Case 6, male, 7th grade)***

Case 5, a 5th grader and our youngest respondent, demonstrated the clearest instance of the misconception that the Moon remains, always, on the side of the Earth that is night. Unlike Case 6 who began to get confused when he realized his idea did not hold together, Case 5 was quite convinced of his theory. He began by moving the Moon model to the opposite side of the Earth from the Sun.

RESPONDENT:	***Like this. It circles around — it circles on this side when the Sun is on this side.***
INTERVIEWER:	***Okay. It stays on the other side of the Earth —***
RESPONDENT:	***Uh-huh.***
INTERVIEWER:	***— from the Sun.***
RESPONDENT:	***Uh-huh.***
INTERVIEWER:	***Does it — okay. Does it — I understand that. But does — does it go all the way around the Earth or not?***
RESPONDENT:	***Not.***
INTERVIEWER:	***It doesn't go all the way around the Earth?***
RESPONDENT:	***Uh-uh.***
INTERVIEWER:	***It just stays on the other side of the Earth from the Sun?***
RESPONDENT:	***Yeah. And I know when the Sun comes this way it goes on this side.***
INTERVIEWER:	***Okay.***
RESPONDENT:	***So when it — so when it's — because night is only like until midnight and then it gets lighter out when the Sun is over here. And then the Moon gets over here. And then they switch — and the Moon then usually just stays over here sometimes — no the Moon stays like this from the — it stays like this all from the Earth.***

(Case 5, male, 5th grade)

This except from Case 1's interview shows that he begins with the same idea as Case 5, but as he moves the models around, he figures it out and changes his mind.

INTERVIEWER:	***How does the Moon move through space?***
RESPONDENT:	***Well, if this is the Earth, then the Sun would be right here.***
INTERVIEWER:	***Uh-huh.***
RESPONDENT:	***On this side.***
INTERVIEWER:	***Oh, I'll be the Sun. You don't have three hands.***
RESPONDENT:	***Then this would be in the same direction as the Sun. Hang on. I've got to figure this out. If the Sun is over there, then it would have to be over here.***
INTERVIEWER:	***So it has to be on the other side? You're holding it on the other side of the Earth.***
RESPONDENT:	***Right.***
INTERVIEWER:	***Okay.***
RESPONDENT:	***And then as the Sun — or the Earth moves around the Sun, then they go — let's see. The Moon goes around the Earth.***
INTERVIEWER:	***Okay.***
RESPONDENT:	***Whenever the —***
INTERVIEWER:	***So the Moon moves around the Earth?***
RESPONDENT:	***Uh-huh.***
INTERVIEWER:	***And the Earth does what?***
RESPONDENT:	***Moves around the Sun. [Moves the Earth to a position where the Moon is between Sun and Earth.]***
INTERVIEWER:	***Okay. Okay. So it wouldn't necessarily have to be here [on the side of the Earth away from the Sun]?***
RESPONDENT:	***Right.***

(Case 1, male, 8th grade)

The Solar System and Objects within It
After discussing the Sun, Earth, and Moon, the interviewer asked the respondents about other objects in the solar system and set out nine Styrofoam balls from a solar system model kit. Then the interviewer asked respondents, first, to name the planets and line them up in order from closest to furthest from the Sun.

Several things became clear as the interviews proceeded. First, verbal responses sometimes gave misleading impressions of whether or not students understood concepts because, upon probing, students did not have stable concepts of the categories of objects. That is, terms such as stars, planets, and moons were not clearly understood concepts with specific defining characteristics. In Case 7, the respondent initially stated that there were planets and stars in our solar system. While, technically, this might be accurate with the exception of the plural of "stars", her use of inclusion of the Sun as a planet indicated that she did not have clear concepts behind the use of names.

INTERVIEWER:	***What else is in that night sky?***
PARTICIPANT:	***Stars.***
INTERVIEWER:	***What are they?***
PARTICIPANT:	***Little pieces of [planet] and I don't know. The planets. The Moon, something.***

INTERVIEWER:	***Little pieces of the planet or the Moon. What is — what's the Sun?***
PARTICIPANT:	***I have no idea. It's a planet.***

(Case 7, female, 8th grade)

Case 7, a female 8th grader, who had only recently transferred from a public school, was the only respondent who could name the planets in order from closest to furthest from the Sun. Later in the interview, this respondent explained that she was recalling the names of the planets from a mnemonic she had been taught in her public school science class.

All but one of the respondents (Case 8) identified that there were nine planets, but for several this facts, which they appeared to remember from class, only returned to memory after a few minutes of handling and working on placing the planets in order. Most students quickly recalled the names of Mars, Jupiter, Uranus, and Saturn. Only one of the respondents successfully named all nine planets. Lining up the planets in order was very difficult for most respondents.

RESPONDENT:	***This is Jupiter.***
INTERVIEWER:	***That's Jupiter. And you know it's Jupiter because?***
RESPONDENT:	***Oh, no. This is not Jupiter, this is Mars.***
INTERVIEWER:	***That's Mars.***
RESPONDENT:	***Yes, Jupiter is the one with the — with the one ring around. This one has four rings. Mars has four rings around it.***
INTERVIEWER:	***Okay. And what would come next?***
RESPONDENT:	***Then Jupiter.***
INTERVIEWER:	***Okay. Mars and then you've got the big orange one as Jupiter.***
RESPONDENT:	***Then the second (inaudible) one.***
INTERVIEWER:	***What's this? This little bitty one that's out past Jupiter?***
RESPONDENT:	***I do not know.***
INTERVIEWER:	***Okay.***
RESPONDENT:	***And then I think this goes right there.***
INTERVIEWER:	***Okay. What's this one?***
RESPONDENT:	***I think it was — I'm not sure. I'm not too sure about some of these planets.***
INTERVIEWER:	***Okay. So the planets you've mentioned are Earth, Jupiter, Mars, anything else?***
RESPONDENT:	***Not really.***

(Case 2, male, 7th grade)

Case 5, our youngest respondent, revealed his interest in the topic by mentioning a new planet that had been identified from photographs and featured in the media the week of the interview (January 8, 2006, NASA, 2006). In the news reports this is called this the 10th planet in our solar system.

INTERVIEWER:	***So other than the Earth and the Moon, what are some other objects in our solar system?***

RESPONDENT:	***Other ob —there's — there's Pluto, Jupiter, Venus, and planet X.***
INTERVIEWER:	***Oh, tell me about planet X.***
RESPONDENT:	***They just found it in a different solar system away from our solar system. They just found that new planet.***
INTERVIEWER:	***So it's not part of our solar system?***
RESPONDENT:	***Uh-uh. It's not part of our solar system. We have — I know we have — Mar — Mars — I forgot Mars.***
INTERVIEWER:	***So we —***
RESPONDENT:	***That's another highest planet.***
INTERVIEWER:	***So we've got Pluto and Mars and what else? RESPONDENT: Venus, Jupiter, Saturn, and I think that's all I could name.***

(Case 5, male, 5th grade)

Case 6, a 7th grader with recent vision loss, got very enthusiastic about lining up the planets. Rather than lining them up "in a row" in order from the Sun, he placed 4 planets on one side of the Sun and 5 on the other. When asked about this he responded, "That's how it's supposed to be, after Mercury is the Sun." His arrangement resembled a static model of the solar system with four small planets lined on one side and four larger planets on the other. Most of them were in order, and he clearly understood the order of the inner planets.

Misconceptions about the Sun and Stars

For several students, the lack of consistent categories appeared to be connected to misconceptions such as those described by Vosniadou & Brewer (1992) and Salinerno, Edelson, & Sherin (2005)). As Case 2, who had attended Space Camp and was very interested in space travel and exploration explained,

> ***Sometimes the Sun explodes — . . . . And other little stars are made. Like if — if this explodes — like this — this — I think the Moon exploded one time and then made the Sun, made the Earth and the — and this and the Moon. (Case 2, male, 7th grade)***

Even respondents who showed a clear understanding of the comparative size of the planets were not sure or had alternative conceptions about the Sun. Case 6 considered what type of object the Sun might be in this discussion. While he had an idea of some of the Sun's characteristics, this idea was not generalized to the category of stars nor did they have a clear idea of relative scale.

INTERVIEWER:	***Well, what about that Sun? Are there any other things in? The space that are like that Sun?***
RESPONDENT:	***It's big.***
INTERVIEWER:	***Uh-huh. As big as our — as the Sun.***
RESPONDENT:	***Saturn and Jupiter.***
INTERVIEWER:	***Are they as big as the Sun?***
RESPONDENT:	***They're as big as this Sun.***
INTERVIEWER:	***What kind of object is the Sun?***
RESPONDENT:	***It's a — actually a big ball of gas.***
INTERVIEWER:	***Big ball of gas. Are there other big balls of gas in space?***

RESPONDENT: ***No.***
INTERVIEWER: ***There's not? It's the only one like it in the universe?***
RESPONDENT: ***Yeah.***

(Case 6, male, 7th grade)

Orbits of Planets/Gravity and Mass

All the respondents used the term "orbit" at some point during the interview. It appeared to be a familiar term, and all but one used it specifically about the Earth and Sun relationship. But, the orbital pattern of the planets was not a well-understood idea. As we noted in the previous section, one respondent (Case 6) lined up the planets with the Sun in the middle—similar to a static display of the orbital patterns. We found little evidence that any respondents had a clear mental model of the planets moving on almost a single plane around the Sun in elliptical orbits. Since the interview tone was conversational, this made gravity and mass difficult concepts to probe in relation to orbits of the planets. It is probable that respondents have conceptions and misconceptions about gravity that were not explored in the interviews.

We did find one common misperception about gravity in Case 5, our 5th grade space program fan, when discussing the Earth's movement around the Sun. He, apparently, had connected the terms "orbit" and "gravity" in his mind, but when he said them aloud, it contradicted deeply held assumptions.

INTERVIEWER: ***What do we call that movement it makes in that circle around the Sun?***
RESPONDENT: ***Gravity.***
INTERVIEWER: ***Gravity. Okay.***
RESPONDENT: ***Gravity -- oh, no, there's no gravity in space. So it's just the force of -- of space that just pushes it.***
INTERVIEWER: ***How did you learn that there was no gravity in space?***
RESPONDENT: ***By -- by astronauts.***
INTERVIEWER: ***Okay.***
RESPONDENT: ***When they go up they just float. They don't -- they don't just stand on -- stay on normal ground. They float.***

(Case 5, male, 5th grade)

This topic was discussed with teachers. We asked the asked one teacher if she thought that the common misunderstandings about gravity, weight, and mass would be harder for her visually impaired students or just about as difficult. She replied,

> ***I would say it's just as hard for them as other students. Because that seems to be one thing that you can put into concrete terms. You can put them on scales and you can put them on — you know your little — I can't even think of it. But your little mass weights and all those things. It's some — seems to be something that kids can actually put their hands on and tactilely manipulate but not necessarily grasp all the concepts. So to me, that's always been one that I thought was [hard] across the board. (Case A)***

Another classroom teacher who taught science to several the respondents said that she did not believe her student understood gravity, mass, and weight.

> ***They're not going to know. We will have to spend so much time just knowing the difference. (Case C)***

This element will need to be included in the ACTIVE lessons.

Small Rocky Planets and Large Gaseous Planets

One of the underlying ideas of comparative planetology is a typology of planets. Small rocky planets are the terrestrial planets. Large gaseous planets are also referred to as Jovian planets. Davies (1973) would refer to the understanding of these two related concepts as a multiple discrimination task.

Terrestrial Planets = Mercury, Venus, Earth, Mars

- ***Closest to Sun***
- ***Few moons***
- ***Small diameter***
- ***Thin atmosphere***
- ***High density interior***
- ***Composed principally of iron, oxygen, silica, magnesium***
- ***Asteroid Belt separates terrestrial from Jovian Planets***

Jovian Planets = Jupiter, Saturn, Uranus, Neptune, Pluto

- ***Far from Sun***
- ***Many moons***
- ***Large diameter***
- ***Thick atmosphere***
- ***Low density interior***

(Hoddell, 2002)

While we did not expect respondents to be familiar with the Latinate terminology, we did explore to see if they had some understanding of the relationship between the distance from the Sun and the composition of the planets—or if they connected order and size. We used the planet models from a solar system kit and asked the following three questions to explore respondents' understandings.

- Scientists say there are two types of planets— rocky planets and gaseous ones. Which of these balls represents the rocky planets? Which of these balls represent the gaseous ones?
- Do the rocky planets have anything else in common? Probe: Why do these planets have those characteristics?

- Do the gaseous planets have anything else in common? Probe: Why do these planets have those characteristics?

These questions were difficult for all but one of the students. Only one could make clear distinctions between these two categories. He also was able to recall more that one attribute on which the two categories of planet were different.

INTERVIEWER:	***Scientists talk about the rocky planets and the gaseous planets. Which ones are the rocky planets?***
RESPONDENT:	***Earth, Mars, Mercury, Venus.***
INTERVIEWER:	***Let's see did — and which are the gaseous planets?***
RESPONDENT:	***Jupiter, Saturn, Uranus, Neptune and Pluto.***
INTERVIEWER:	***Now, [name], did you have that in school?***
RESPONDENT:	***Uh-uh.***
INTERVIEWER:	***How do you know that?***
RESPONDENT:	***I had it once.***
INTERVIEWER:	***Well, you sure remember it. You got it. Other than where — other — do the rocky planets have anything else in common other than being rocky?***
RESPONDENT:	***They have atmosphere.***
INTERVIEWER:	***What about the gaseous planets? Do they have anything else in common besides being gaseous?***
RESPONDENT:	***Some of them don't have an as — atmosphere.***

(Case 3, male, 8th grade)

His inclusion of Pluto (which does not fit into this category system) in the large-gaseous planet category may indicate that he was using order from the Sun as a way to sort the planets into categories.

Several others had some of the building blocks for this multiple discrimination. Case 4 appeared to be identifying planets by important physical attributes like size and rings.

RESPONDENT: That one is probably — it looks big enough to be Jupiter, perhaps.
INTERVIEWER: And you know Jupiter is really big, don't you?
RESPONDENT: Yes.
INTERVIEWER: Very good. And what do you think the other one might be?
RESPONDENT: They both have rings around them, but this one — it's a guess — oh, I remember Uranus?

(Case 4, male, 8th grade)

Some respondents appeared to be putting together information from different sources. Not having firm concepts established for the stars and planets appeared to make these questions difficult. In this interview excerpt, the respondent seems to be putting knowledge together from some diverse previous experiences. Just before this exchange, the respondent had made connections to what he knew about the planets and space travel. "Mars and Mercury are gassy. No one can go there until they find a way to send a person up on Mars without being killed by the gas." (Case 6, male, 7^{th} grade) As he tried to discriminate between types of planets, this everyday use of the term "gas" made sorting out things difficult.

INTERVIEWER:	***Scientists say there are two types of planets, gaseous planets and rocky planets. Do the gaseous planets and the rocky planets have anything else in common besides being rocky and gaseous?***
RESPONDENT:	***Only their size.***
INTERVIEWER:	***Okay.***
RESPONDENT:	***They're none moving.***
INTERVIEWER:	***What about size? Which ones are big and which ones are little?***
RESPONDENT:	***The gassy ones — Mars and Mercury are small. And the Sun is big but it is a gas. Neptune —***
INTERVIEWER:	***Is the Sun a planet?***
RESPONDENT:	***It sort of is. It's in line with the planets — it's a star though. No, it — it isn't a planet though. Saturn and Jupiter are the biggest of the rockies — because of how big they are.***

(Case 6, male, 7^{th} grade)

Processes Forming Planetary Surface Features

Another important content focus of the ACTIVE program is connections between planetary processes on Earth and on other planets. This includes processes such as volcanism, impact cratering, tectonics, and gradation (or erosion). These specialized terms appeared a bit overpowering to both teacher and student respondents. Neither the term “volcanism” nor "gradation" was familiar at all to any of the respondents. When the terms "volcanoes" and "erosion" were used to define these ideas, both teachers and students made immediate connections. In both groups, when they picked up a term that was familiar they identified it in it "thing" form rather than the "process" form. But there was some underlying knowledge about these areas, but three of the process (volcanism, plate tectonics, and erosion) appeared to be understood entirely within the context of Earth science--neither students nor teachers connected these processes to other planets. On the other hand, both students and teachers connected impact cratering with other planets, but not to surface features on Earth.

Plate Tectonics

When we began to explore this area, using this somewhat technical scientific terminology, the term most respondents noticed immediately was "tectonics." As one teacher explained, this is a concept it is easy to demonstrate and teach in the classroom. Case 1 had a fairly extensive understanding of what happened in areas where tectonic plates shifted.

> ***Also there's two plates by California . . . . . And then there's two over here [Points to a mountainous area on the topographical map.] . . . . [When plates move] volcanoes erupt. Earthquakes. The thing that happens like in here — which was the — Tsunami. Mountains. (Case 1, male, 8th grade)***

Case 2 was also familiar with this concept with the drama of catastrophe appearing to appeal to him. Note he uses personification to describe the phenomenon, a characteristic of younger children before they reach abstract levels of thinking (Vosniadou & Brewer, 1992).

> ***Plate tectonics — so what they do is when they collide together — it's like — whenever it started it was — they were getting mad at each other sort of. We put them like as humans or something in science. . . . . And they were getting mad at each other. And they was trying to like attack each other. And as they were doing that, they ended up starting to make — make Earthquakes where it cracks the crust of the Earth. And it moves that part of the city or something. . . . . Because sometimes it cracks the underneath, too, and the ocean can just move away. And then as we get — and we — it'll — we connect something as it's colliding. . . . . But all they know so far it's been two under each spot. And when they get mad at each other they make a eruption where it shakes the planet. (Case 2, male 7th grade)***

Some respondents associated plate tectonics to mountain building and others to Earthquakes and volcanoes but not to both.

> ***When two plates rub against each other. A mountain is when one plate goes under another and the one — top one gets pushed up. (Case 3, male, 8th grade)***

> ***Because I know that plate tectonics, when they move together they create a fault line. And then when that fault line happens a massive Earthquake could happen. (Case 6, male, 7th grade)***

Case 5, our 5th grade respondent, Case 7 the female respondent who had just transferred to the school, and Case 8, the respondent with congenital blindness said that they were not familiar with this term.

Erosion

All the students said that the term "erosion" was familiar to them, but few provided specific examples or definitions—and even less enthusiasm when compared to the dramatics associations of plate tectonics. One teacher immediately associated erosion to the rock cycle.

> ***Yes, all the different rock types. And we covered two chapters of that already. . . . We definitely do the rock cycle, yes. (Case C).***

Impact Cratering

Impact cratering appeared to be a more familiar topic to students than to teachers. Her comment about this not being covered in her science text is something that should be explored.

> ***Right. That's not one that I even recall seeing in the textbooks. Or even science related articles that I read at home. I haven't really — unless it's under another name that I'm not — . . . Yeah. I don't remember seeing anything like that. Except you know, they might mention a crater here and there. Like especially in a math book. They'll mention — you know this crater was this wide and this deep and can you find the circumference or whatever. You know those kinds of questions. But that would be the one that I probably have not dealt with. (Case A)***

Students had much richer associations with this concept. Two students connected it to meteorite impact on Earth and on other planets. Case 2 made some interesting (and inaccurate) connections between impact cratering and volcanoes. Two students made this connection between impact craters and volcano craters, and both continued with rather dramatic story lines involving catastrophe and disaster.

> ***When it — a crater sends like a meteor or something — it comes down and reaches through our atmosphere and it comes down and makes this humongous whole like that. And it goes right into the Earth and it takes away some of the crust. And then after a while, if you leave it — after a while it grows into a volcano and in that same spot it kind of eruptions there. . . . . It could have broken off a planet. It could have broke — broken off of anything. Really. (Case 2, male, 7th grade)***

> ***And I think I know what happened one time — one time there was this — I think it was a shoot — falling meteorite — . . . . — hit the — hit the — hit the Moon and made the little craters on it from — that's what happened from — I think that's what happened. Yeah. That's what happened. Meteorites. . . . . Meteorites? They're like — like these — except they're all rocky and everything. . . . . And they — and they — every time they — when they come near the atmosphere of the Earth they start to — fire starts to come out of them. But they try to stopping them before they come into the Earth. I mean — hit something really, really — like a building. . . . Space people [try to stop it] — maybe astronauts. . . . . Because they don't want them — or maybe the police try — try stopping them with big guns trying to keep them away from our — keep them — or maybe when they — maybe when it crashes maybe astronauts got there and they take little picks and they crack of piece of the crater off. And they use that. (Case 5, male, 5th grade)***

Cases 3, 5, and 8 said that they had no connections to this term and were not familiar with it. It is likely due to developmental level that the dramatic stories came from two younger respondents —both were very interested in the space program—and the "I don't know" responses came from older students with greater levels of metacognition..

Scale of Cosmological Objects
Near the end of the discussion, the interviewer asked student respondents to define and make comparisons among the size of various cosmological objects: the universe, galaxies, the Milky Way, and the solar system. We ran out of time and this series of questions was not asked to Cases 1, 3, and 7. For the students who did respond his question was very rather difficult, and only one had clear understandings of both the terms and relative sizes. This was Case 6, a 7th grade boy with fairly recent vision loss.

INTERVIEWER: ***What's a galaxy?***
RESPONDENT: ***It's millions of light years away.***
INTERVIEWER: ***What's the universe?***
RESPONDENT: ***It's a thing made up of everything, even black holes.***
INTERVIEWER: ***Everything is in the universe. Which is bigger, the universe or a galaxy?***
RESPONDENT: ***Universe.***
INTERVIEWER: ***Which is bigger, a galaxy or a solar —***
RESPONDENT: ***Galaxy.***

(Case 6, male, 7th grade)

Case 5, who had a definite interest in the space program, did not have clear conceptions of these terms or the relative size.

RESPONDENT: ***I don't know what the universe is.***
INTERVIEWER: ***What about a galaxy?***
RESPONDENT: ***A galaxy is like all — like a far, far away from here. Very far from here.***
INTERVIEWER: ***what would be larger — the universe or a galaxy?***
RESPONDENT: ***The universe.***
INTERVIEWER: ***Which would be larger — the galaxy or a solar system?***
RESPONDENT: ***Probably the — probably the galaxy would be bigger. I think it would. I don't really know.***

(Case 5, male, 5th grade)

Case 8 said he did not find any of these terms familiar. The interviewer probed to see what other connections he might make to these topics, but provided this blind student with the verbal cue of "sky" and elicited an entirely different set of connections. This may be an example of how easy it is to move someone into an entirely different context through relying entirely on verbal cues.

INTERVIEWER: ***What are some other things that are out there in space? Or in the sky?***
RESPONDENT: ***Snow.***
INTERVIEWER: ***Snow. Up above the atmosphere — up in the night sky, what — what else is there? Up there?***
RESPONDENT: ***Freezing rain.***
INTERVIEWER: ***Okay. RESPONDENT: And maybe some wind.***

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this section of the report is to synthesize information from the literature and interviews into a form that can be applied by the ACTIVE system developers and designers. In naturalistic inquiry, we assume that each reader and user of this information comes to it with his or her own frames of reference and will understand and use the information differently. The recommendations in this report are not "better than" other conclusions and recommendations, but they should be "better informed" by both the literature reviewed and the deep consideration of the respondent perspective (Guba & Lincoln, 1989). Making recommendations also forces the evaluator to ask "So what?" about findings and translate them into design features. Readers may reach different conclusions and recommendations, based on other points of view, but conclusions and recommendations in their report should be transparent, that is, clearly based on evidence and perspectives in the previous sections.

Characteristics of Learners

Respondents we interviewed appear to share many characteristics with their sighted peers. One of the most important of these characteristics their development phase. Cognitive, social, and psychological factors are important.

In early adolescents, individuals are developing the capacity for abstract thought. However, this capacity should not be interpreted as an indication of level of intelligence. In this small population of 8 respondents, 2 individuals (Case 5, a 5^{th} grader and Case 2, a 7^{th} grader) were clearly still fairly immature cognitively. They pulled together pieces of information with little metacognition—that is a critical facility to look at their own thinking and assess it. Socially, they are still in the stage where pleasing adults is very important. Nevertheless, several others could and did clearly handle abstract concepts. Case 7 had less knowledge about Earth and planetary science. However, her reasoning and metacognition were clearly more mature. Case 1 and Case 3 were also capable of putting together abstract concepts and mentally processing them. Case 6 appeared to move between the concrete and abstract, exhibiting both types of thinking in his responses. In contrast to the "please the adult behavior" in Cases 2 and 5, these older respondents began interviews with the more typical "test adult at little before you decide she's okay" behavior.

Cases 4 and 8 apparently were individuals with multiple disabilities. This made assessing their thinking more difficult. Case 8 was clearly uncomfortable. Some of their responses reflected lack of experiences in some areas. But, Case 4, in several instances, demonstrated the use of abstract thinking. However, his dependence on verbal cues in navigating social situation of the interview and in connecting to the content limited his ability to respond. This had probably limited his productive classroom experiences.

Like their sighted peers, students with visual impairments are likely to be in this transitional stage with 5^{th} and 6^{th} graders much less ready to develop mental models of these phenomena than 7^{th} and 8^{th} graders. We will make specific recommendations about this in the following section on Earth and Planetary science.

Socially, several respondents also demonstrated characteristics of adolescents. Friends are an important part of their lives. Atypically (compared to other adolescent interviews), we heard few complaints about parents. The fact that they are living away from home, and the clear support provided by some of the parents working for opportunities and services, may make this understandable. But friends and leisure time activities such as sports and listening to music are very important. Constructing a learning environment, which builds on this characteristic, is very important. Peer group learning tasks, if design and facilitated properly, would be a good match to this development level.

Another important social task of adolescence is "acquiring education and other experiences needed for adult work" (Ingersoll, 1989). In contrast to other interviews with adolescent respondents (Tisdal, 2005a), these interview transcripts contained only one reference to adult work: Case 2 reported that he wanted to be an astronaut. Career ideas, even early impractical ones, are one context that gives meaning to educational activities. Unlike other adolescents in other studies (Tisdal, 2005a), we heard no stories about wanting to be a forensic scientists, actors, clothes designers, hairdressers, pediatricians, veterans, or astrophysicists. These early adolescent ideas about careers, which often have as much to do with identity as eventual career choice, were simply not part of these interviews.

This issue of relevance and context is particularly important for this subject area. Context provides meaning for learning. Some focus on career opportunities is important. It could provide context for several of these bright, talented adolescents' efforts toward an adult identity and can include the idea of a productive and independent future. Bernhard Beck-Winchatz points out that with today's technology for remote sensing, research using the invisible portion of the light spectrum, and digital technology there is no reason a blind person can't be an astronomer (Beck-Winchatz, 2002)-or a forensic scientist, a computer engineer, or mathematician. We also hypothesize that this lack of context may also influence the fragment nature of several of the young people's understandings.

One important difference between these respondents and their sighted peers is the real challenge of the extra time and energy required to develop mental models of spatial relationships. If these objects are moving, the task becomes even more difficult. People with visual impairments encounter objects sequentially. Patterns of movement are particularly difficult for them to perceive. Judgments about distance are dependent on time to move between objects or sound cues. Navigating space, whether it is their schools, neighborhoods, or planetary system requires greater time to collect and structure relevant information. Research indicates that people with visual impairments, even those who are congenitally blind, can and do develop these mental models (Juurmaa & Lehtinen-Railo, 1994). However, this requires activities to structure the information and time to carry out processes that sighted peers may complete more quickly. This, as we will discuss later, is the biggest content challenge for the ACTIVE system. However, conquering these spatial models does not have to be the place that instruction begins.

Educational Environment

Most students in the target audience are likely to use the ACTIVE system in a regular school setting with their sighted peers. About 74% of students with visual impairments are served in regular schools in West Virginia and 87.5% are enrolled in regular schools in the U.S. as a whole. Our respondents shared some of the challenges of that environment, and the literature cites others. Several of these findings point to important design features for the system.

First, students with visual impairments should be able to use, as close as possible, the same equipment and materials as other students in their learning environment. Two respondents told us about embarrassment in storing and using assistive devices in regular classrooms. Of the 7 boys in the study, 5 recalled being bullied in their regular schools. Some design features can at least moderate these factors.

Devices used to make the system accessible for students with visual impairments need to be as integral a part of the overall system as possible. For example, narration of text needs to be done in a way so that students with visual impairments can listen to it along with their sighted peers. High contrast graphics need to simply be part of the materials, not a special alternative for students with visual impairments. As much as possible multi-sensory cues such as sounds should simply be part of the presentation, rather than as special features for students with visual impairments. While there may need to be some activities or materials for students with visual impairment to obtain information or organize information, it should be designed for independent use at home or in a visual resource classroom. In the classroom environment, it is important for all students to use the same materials and equipment.

As indicated in the proposal, inquiry-based or problem based learning with small group authentic tasks appears an appropriate and constructive teaching/learning strategy. This often involves small group task-based teams. A good deal attention needs to be invested in developing the social structure of these groups. One recent, successful, example of careful social design was part of the Museum of Science, Boston's new traveling exhibition, *Star Wars: Where Science Meets the Imagination*. Based on previous evaluation, interpretive devices for people who use American Sign Language and for people with blindness and low vision provided extra, detailed information about exhibit objects and artifacts. In both social groups in which this evaluator viewed the exhibition, the interpretive devices provided the person with a disability with extra information to share with the group. While the person with the disability still received assistance in using the exhibition (a subordinate social role), they also played the role of expert with interesting information to share (a superior social role). This attention to social design had a substantially positive impact in the experience of people with disabilities and contributed to conversation and knowledge sharing among the group. (Tisdal, 2006)

The teacher's role in supporting productive social behavior within small groups and the classroom in general is also important. As several studies conclude (Kapperman, Sticken, & Heinze, 2002; Smith, Geruchat, & Hueber, 2004), many classroom teachers lack of training for teaching children with disabilities, creating a good learning environment, and accessing assistive devices. The ACTIVE teacher materials could productively include some additional information for teachers to help make their jobs easier and the learning environments of their students with visual disabilities more successful. Content such as this is featured in Bishop (2004).

Assistive Devices and Technology

Keyboarding Skills

We conclude that the keyboarding skills of students with visual impairments using the system would be at a basic level, but this may not be different from their sighted peers. Teachers and students disagreed about their overall level of keyboarding skills. Teachers assessed keyboarding skills as low and believed it was lower than sighted students' skills. Based on data collected in other evaluations with adolescents (Tisdal, 2005a), this may or may not be the case. In a study of 43 sighted teens between 12 and 17 years old, we found quite low initial levels of keyboarding skills. The schools in which the students in the study attended did not formally teach keyboarding. In this study, students and teachers indicated that formal keyboard instruction began in the 4th grade.

Technology and Computer Skills

Based on this study, we conclude that students with visual impairments can use standard computer equipment and haptics devices. However, based on the handling of maps and models, and recommendations by Bishop (2004), these students should be allowed additional time, before any task-based group work, to explore and orient themselves to the system.

Both teachers and students talked about these students at WVSDB being quite adept with video game equipment. All the student respondents talked about playing video games, but some, particularly those with more usable vision, appeared to play more sophisticated games using specialized equipment such as Gameboy or Play Station II.

Of the 8 student respondents, 7 indicated that they regularly used computers in their schoolwork. One teacher speculated that they may not get as much "computer time" at home as their sighted brothers and sisters. Economic differences between families appeared to be a factor.

Some common computer issues discussed by teachers and students focused on password-protected programs, having to reboot systems, and computers "hanging up." These are typical problems in school computer labs. Others were special issues. These included waiting for someone to load assistive software such as big cursors, magnification devices, and text voice synthesizers (JAWs) before a student who needed them could use them. As we recommended earlier, it would be best to handle these elements as integral design elements rather than system "extras." This makes system use easier for teachers and assistive aspects less visible to other students.

Print Magnification & Reading/ Listening Comprehension

Teachers indicated that listening comprehension for students with visual impairments was far higher than reading either Braille or print. Several of the student respondents discussed their use of print magnification systems including hand-held magnifiers and CCTV devices. Students and teachers both commented on the stress and effort required in approaching standard print with magnification. For the ACTIVE system, we recommend the use of audio narration and audio cues wherever possible. Additional information about the topic for students to explore should be provided in separate CD with digital audio. One task-group role for student with visual impairments could be exploring these information segments to provide the information to the group, thus giving them an expert role in the task. Students could listen to the segments outside class time as part of their homework. If print materials are included for students with visual impairment, they should include large fonts and black and white illustrations. If two versions are developed for sighted students and students with visual impairments, we recommend these resources be designed for out-of-class use and made as seamless as possible in the design.

Tactile Graphics

Many students interviewed quickly understood the idea of used tactile models and maps. Each, however, approached the models by first taking the time to thoroughly explore its nature and placement. We recommend that ACTIVE system designers anticipate this need for spatial orientation and tactile exploration in the design of haptics activities.

Based on student use of these materials and examination of tactile graphics in the Learning Resource Center at the WVSDB, we recommend a careful sequencing of the exploration of haptic renderings. Professionally developed tactile graphics use exaggerated spatial contrast. These models are not to actual scale and provide students with clear examples of concepts. While real data can be included later in the sequence, the design of the initial haptic experiences should be clear, high contrast, examples before students encounter more subtle topographical features. Attributes of landforms should contain audio as well as text labels.

Interest Level and Motivation

The adventure and challenge of space travel provided a strong cognitive hook into topics in Earth and planetary science. This motivational factor may be stronger for males. Several male respondents appeared enthusiastic about the adventure, challenge, and danger they perceived as part of space exploration. The 2 boys' tone and enthusiasm in these portions of the interviews was only matched by their descriptions of racing and combat video games (Case 1 and Case 6).

Space camp and this population's familiarity with SCIVIS was also a strong factor. One of the respondents had been to space camp and four other talked about it in their interviews. Using space travel as a cognitive hook in the instructional sequence and including materials on space camp, and particularly SCIVIS appears to be a good match for this content.

Popular culture should be considered in the design of the program. In a museum study on this topic, Tisdal & Gang (1994) found that many misconceptions about this topic were based on science fiction television and movies, not on folklore as some astronomy education experts assume. Student interviews were full of popular culture references. Racing and combat video games were discussed. Two respondents talked about *Apollo 13* and another cited *Rocket Boy,* a movie in which "a gentle video clerk [with] a secret double life as an intergalactic crime-fighter who must stop an evil alien from stealing the hair off human heads" (International Movie Database, 1989). The subtext of Case 2 and Case 3's disaster stories of meteorite appeared to be influenced by disaster movies. Another respondent cited the Discovery Channel as his source of information about plate tectonics. The female respondent talked about liking to dance, watching the Country Music Channel, and listen to Shania Twain, a popular country singer. In addition, a teacher described one of her student's pleasures in cartoon character voices and music on the Internet. Popular culture, particularly in its narrative form is a superb way to transmit information. For individual listening, rather than reading, it is particular effective because it places information in a memorable sequence of context through character and plot. Narrative form and popular culture references are motivating and effective teaching strategies provide common cultural references for social interaction with sighted peers.

Teachers also said that funny and unusual sounds are motivating devices for students with disabilities. One teacher pointed out how many times her students would use the computer software *Math Flash* to hear the character voice and funny sounds. Using sound as feedback and for reward is another design feature that is supported by the interviews in this study.

The interest level and motivation of teachers is also important. Teacher respondents in this study pointed out topics in this area that they avoided. Teachers appeared somewhat frustrated in approaching topics with spatial elements. This included topics such as planetary orbits and Moon phases. They said that identifying and obtaining appropriate hands-on activities is a challenge. As Kavanaugh, Agan, & Schneider (2005) point out, these topics are difficult for about half of all middle school students—even though they are specified by the standards. The ACTIVE learning system can fill a much needed niche by providing these materials. However, students with visual impairments need additional time and specific activities to support their integration of spatial topics into coherent mental models (Juurmaa & Lehtinen-Railo, 1994).

Knowledge of Earth and Planetary Science

In describing and summarizing what we learned about content knowledge, we first need to make the distinction between "amount" of information and how that information is organized. For example, Case 5, our enthusiastic space program fan, had a great amount of information in this content area. But his knowledge appeared fragmented, disorganized, and primarily at a concrete level. In contrast, Case 7, the 8th grade female respondent, had little information about this topic. However, she demonstrated that she had clearly moved into an abstract level of thinking that would allow her to “take on “ abstractions such as “systems” or process concepts such as erosions or impact cratering Cases 1 and 3 had both a good deal of information, and had organized into more coherent understandings of Earth and planetary science topics.

Underlying Concepts—Models and Systems

While there was a range of understandings, students had a better understanding and more concrete referents for the concept of a "model" than they did for the concept of a "system." Models were connected to familiar things like "model cars" and tactile graphics they had used in class. All the students immediately understood what the interviewer meant when they were handed a squish ball and told, "Let's pretend this is the Earth." All the student respondents had some basic ideas about scale, but did not have a formal vocabulary related to map scale or micro/macro scale. Specific lessons need to be included in the ACTIVE system related to scale to provide learners with a consistent formal vocabulary to categorize space and objects within that space.

Only two respondents had clear grasp of the concept of a "system." Clearly all knew it was a collection of elements, but the attribute of a relationship among those elements (an abstract idea itself) was not clearly understood. If Earth and planetary science topics are to be taught from a systems perspective, then this is an idea that needs to be included in a specific lesson and then students need to be assessed to see if they can identify examples and non-examples. The students' everyday lives include concrete familiar examples: video game systems, plumbing systems, school systems, and computer systems. Given the nature of this concept, it will probably be more difficult for 5th and 6th graders than for older students. Teacher material may need to emphasize this and the ACTIVE system may need to allow for different approaches for students on various sides of the concrete/abstract cognitive divide.

Structure of the Earth

Respondents found this idea and its parts one of the most familiar in the study. One teacher indicated she found it easy to teach in a tactile way with clay, and this may be one reason for its familiarity. This concept connects directly to plate tectonics and volcanism, and may be one of the best places to start the learning sequence for the ACTIVE system.

Equator, Poles, and Axis

Only a few respondents could identify of the Earth's equator, poles, and axis. Regional temperature differences were not clearly understood, nor were the ideas of an equator or an axis running from pole to pole. These concepts do not represent concrete matter. We hypothesize that is one reason they may be more difficult. Yet, they can be approached through a tactile graphics, and we suspect that they may not have been covered because of the difficult teachers have in teaching Earth, Sun, Moon relations—ideas for which these concepts are useful building blocks.

Landforms

After the structure of the Earth, landforms were some of the most familiar concepts in the study. These ideas, too, represent concrete matter, and can be experience through tactile graphics. One caution, one teacher explained that her students use these concepts in conversation, sometimes, without, clear understandings. For two of the respondents, Case 4 and 8, topographical maps and globes did not work as well as with other students in eliciting conversation about these concepts. These concepts, also closely connected and important in comparative planetology, could be productively included near the first of a learning sequence but only with review and practice in their identification in a tactile form.

Earth Moving through Space

Only one respondent demonstrated both revolution (i.e. orbit around the Sun) and revolving of the Earth as it moves through space. Surprisingly, none of the students connected either of these ideas spontaneously to the definitions of a day or year. Probably, these are learned concepts and they have less everyday meaning with less perception of light and dark during day and night. All the respondents did demonstrate revolution of the Earth around the Sun. Only one mentioned an elliptical orbit.

The Moon

Discussions about the Earth's moon elicited the widest range of knowledge and the strongest misconceptions in the study. None of the respondents totally understood Moon phases, and only two had a clear idea about the Moon's orbit. As Kavanaugh, Agan, & Schneider (2005) conclude, Moon phases are not an appropriate topic until students reach abstract cognition. As Juurmaa & Lehtinen-Railo (1994) report, spatial relationships, especially those involving movement, are some of the most difficult mental models for visually impaired people to construct. With the additional of the lack of everyday experience with the nature of visible light (e.g., shadows, reflection), students with visual impairments seem to find this concept extremely challenging. Yet, some of the misconceptions can be addressed. Most of the respondents did clearly understand the idea of an "orbit," and one when demonstrating the Moon's orbit had to give up his misconception that the Moon and night were always connected. Terminology of Moon phases (e.g. full Moon, half Moon) was somewhat familiar but did not appear to have any concrete meaning. Tactile experiences allowing a student to create a moon's orbit around a planet could be a productive learning activity. Sounds analogous to light might also be considered in assisting these students to understand light as a process. This is clearly a difficult and challenging area—not just for visually impaired student because it required both abstract thinking and the integration of spatial information acquired sequentially.

The Solar System and Objects with It
Like the phases of the Moon, this was the most difficult and least understood concept in the study. Student respondents frequently lacked consistent categories for objects in the solar system. Whether or not the Sun was a planet or "something else" was confusing. The idea that there are nine planets was well known, and most could name at least five or six of the planets. Larger planets, and those with rings, were the most frequently named. Only one student could name them in order from the Sun, and she did this using a verbal memory device. Size was the most salient characteristic, but scale was not well understood.

Orbits of the Planets
Like phases of the Moon, this spatial concept involving movement was one of the least understood areas in the study. While there was some idea of planets orbiting the Sun, this idea appeared vague and fragment. While discussing this topic, the two respondents appeared to have mental models related to this idea and moved quickly into a static model of the solar system. No respondent mentioned gravity as a mechanism underlying orbits, and this idea did not appear as part conceptual framework at all. Teachers believed that their students had similar misconceptions about gravity, mass, and weight as their sighted peers. Unlike the concept of a system, which may be more difficult for younger students than for older ones, understanding the orbits of the planets may require students with visual impairment to spend a great deal of time exploring or building a non-scale, static model to identify and remember the spatial organization of the planets. After accomplishing this task, the ideas of movement could be introduced and explored. Orbital traces with sound cues when a cursor moved across them might be one way to introduce the idea of motion and relative orbit in a flat plane. Non-technical hands on projects such as constructing a solar system model out of clay might be another approach that required the creation of objects by size and the organization of objects into a static pattern. The development of this mental model is the most difficult teaching/learning task for the ACTIVE designers to approach.

Small Rocky Planets and Large Gaseous Planets
While this typology was not familiar to the students, the concrete attributes of size and composition make it a likely one to precede the development of a mental model of the solar system. More abstract attributes, such as mass, do not have to be added to the typology immediately. Underlying processes in the composition, such as distances from the Sun and the effect of gravity, could be added after understandings of planet size and composition are developed.

Processes Forming Earth Planetary Features
Based on teacher interviews, this specific typology of process may not be in all standard textbooks. Teachers assessed the concepts of erosion and plate tectonics as the most familiar. Students appeared most familiar with plate tectonics and impact cratering. Volcanism was only familiar when mentioned as a "thing," i.e., volcanoes rather than as a process. We found student

respondents making many more productive connections to these processes than we did the teachers we talked. Students said they were familiar with erosion, but it did not have the drama and catastrophic attraction of plate tectonics or the devastation of a meteorite from space. One reason for the differences between students and teachers is that students appeared to synthesize information about these topics from a variety of sources including movies and TV. Teachers, on the other hand, were considering them from a professional perspective. Students did not appear to "disbelieve" that these process happened on all the planets; they had just never considered it.

No student mentioned planetary change over time. This is an important concept, and the interview protocol did not include it. Based on previous studies (Tisdal, 2005a; Tisdal & Gang, 1994), this may be an idea that may needs to be introduced on more familiar scale (e.g. human life span) and then generalized in the macro scales of time.

Starting with the Familiar and Known

One of the tenants of constructivist-based teaching and learning is to begin instruction where students are and with careful attention to their current status of the range and organization of the knowledge. Two design recommendations come directly from this analysis of content knowledge. First, even within this small group of respondents, range and organization of knowledge was very, very large. Clearly, the first activity designed for the ACTIVE system needs to elicit existing student conceptions and misconceptions. This allows the teacher to make decisions about how to adapt materials for the specific group and, perhaps, how to establish groups within a larger class.

In the curricular sequence on Earth and planetary science, instruction typically begins with the night sky and patterns of light and shadow. Curriculum designers assume these are familiar concepts. Yes, in their analysis of curriculum supporting student learning about the phases of the Moon, Kavanaugh, Agan, & Schneider, C. (2005) found these concepts were not familiar. They recommend observations of the night sky as appropriate activities for elementary students. This and most other curricula start with what is considered common knowledge for students. Museum evaluation studies indicates this starting place may be inappropriate for many children today (Tisdal & Gang, 1994). Many children live in urban settings where the night sky is not as visible or salient feature of their environment. These were familiar concepts 100 years ago when 90% of the American population lived in rural areas and on farms. Today's children also spend less time out-of-doors and in natural settings than in previous generations. Based on this study, we would recommend this general content beginning instruction with structure of the Earth, followed by landforms on Earth, and to follow this with process forming Earth's planetary surface. This would give students with visual impairments the opportunity to start this instructional sequence successfully with concepts that are less challenging than those involving special relations and movement.

While the haptics system can be useful in supporting the development of mental models of Earth-Moon relationships and the solar system, students with visual impairments may need more time with the system than other students. They may also need specific task-based activities that help them construct these mental models, e.g. constructing a static solar system themselves, making orbital patterns, and being able to create revolution on axes.

Final Thoughts

The ACTIVE interactive learning system has the potential to provide a rich, exciting learning experience for both middle school students with visual impairments and their sighted peers. If the system is designed for use in regular mainstreamed classrooms, it will have the flexibility to be adapted to all the learning environments in which students with visual impairments are placed. Based in this study, several overarching factors should be considered in the design. Technological design elements that ensure accessibility (audio narration, audio cues, high contrast graphics, sound cues) should be integrated into the overall design of the system so that students with visual impairments and their sighted peers can use them together without calling attention to the differences in visual ability. Sequencing of both content and haptic experiences is important. The lesson design should begin with activities to elicit students existing knowledge and misconceptions so teachers can make good decisions about adaptation. There should be a careful sequencing of content so students will encounter familiar and less challenging topics early in the program. Familiar topics for this group of respondents included Earth's structure and landforms. Many target audience members—both sighted and with visual impairments—are still concrete thinkers. Systems approaches are included in both the state and national standards. Based on this study and a review of the literature, we anticipate that many students may not achieve learning objectives with this content because they are not yet at a level of cognitive maturity to deal with it. Modest learning goals with simple definitions and everyday examples of systems are recommended. Haptics technology has the capacity to assist students with visual impairments in developing spatial mental models of the solar system. This, however, should not be an initial or introductory activity. Students with visual impairments need to be given addition time to explore the haptic environments to orient themselves spatially. Some activities should be included that require them to organize this information in an integrated way. Inquiry or problem-based scenarios appear to be a good teaching/learning strategy for this population and for the content.

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APPENDIX A—TOPICAL FRAMEWORK

November 19, 2005

Content

1. What is the range of understanding of the content among the target audience?
2. To what extent and in what ways are differences in understanding associated with levels of disability? Do low vision students and blind students have different conceptions and understandings based on their interaction with the world?
3. To what extent do students have misconceptions about the subject? Are these misconceptions similar to or different from their sighted peers? Do tests and assessments in this area depend on visual language and conceptions that these students need to be familiar with?
4. Are there instructional approaches, developed for the sighted, that are more or less appropriate for this audience?
5. How interested and motivated are students to explore this subject area? Do they see connections and applications to their daily lives and future?
6. To what extent and in what ways are student confident and comfortable in this subject area?

Technology

1. What is the level of skill and literacy among the students in using PC based technology, including assistive devices? (Screen magnification, text recognition software)
2. What is the range of keyboarding skill among the target audience?
3. What access to and level of literacy do students have in reading tactile graphics?
4. What access to and experiences with these devices have students had in different settings? (Home, school for the blind, public school)
5. What modes of communication have been found useful to develop teaching/learning strategies for this target audience?
6. To what extent and in what ways do students need orientation to and experience with haptics, and the specific system, needed before students engage in the learning experiences related to the content?

APPENDIX B: ACTIVE—STUDENTS 5-8TH DEPTH INTERVIEW SCRIPT

January 2006—Page 1

Case Number ______________________

Interviewer ________________________

Interview Start Time _________________

AUDIO RECORDING

My name is Carey Tisdal and helping me today is [name of pre-service teacher]. As we explained earlier, we are audio recording this interview. Here's the recorder, and I am turning it on.

INTRODUCTION

We are conducting a study for the Institute for Scientific Research. They are beginning the development a new computer program for middle school students. This program will let students explore the solar system through touch, slight, and sound. It will use information from NASA. The technology that allows exploring by touch is called Haptics. They want to make sure that system is well suited to students who are blind or with low vision. Our discussion today with will help the team design the materials in a way that makes accessible and useful to students who are blind or with low vision. They hired me to do this study. I don't work for ISR. With me is [name of pre-service teacher]. She is studying to be a teacher at [name of college], and she is going to take notes and help me with the interview.

This interview will take about 45 minutes. On the table, we have several maps and models that we are going to a little bit later in the interview. Some of the questions I will ask you about are how you have learned things in school and your opinions. Others will ask you to recall some things you may have learned. We are not testing you—we need to understand how young people in your grade level understand concepts about the solar system and the Earth. Some of these things will be familiar, but others you may not have had in school yet. That's okay—it helps us to know that. It is fine to say, "I don't know." There are no right or wrong answers—we want to know what and how YOU think about things.

Just a reminder: this interview is confidential and anonymous. That means only those on the evaluation team connect your name with what you say. We will use what you say in our reports and in discussions with people designing the materials but we will not connect your comments to your name.

Before we start, do you have any questions? [Respond to any questions the respondent may have.]

Establishing Rapport

1. First, we'd like to get to know you a little better. Tell us what grade you are in and what you like to do for fun?

Educational Background

2. Tell me a little bit more about where you have gone to school. Probes: What were some good things about going to school there? What were some things you didn't like?

Assistive Devices and Technology

3. Tell me about some of the things you do on the computer?
4. What sorts of assistive devices (for example, screen magnifiers, text readers, CCTV devices) you use when you with a computer? Probe: Where do you have those sorts of devices available to you? At home? At school? Other places?
5. Which one of these devices do you thing is most useful in helping you learn new things? Probe: How does that device help you?
6. Do you use any computer software with sound, for example, 3-D sound in computer games? Probe: What do those sounds let you do on the computer?
7. What are some of things you find the most fun and enjoyable about using a computer?
8. What are some of the things that frustrate you when you use a computer?

Interest Level and Motivation

9. How interested are you in each of the following subjects you study in school? Select one response for each subject.

Science Subjects	Not at all interested	A little interested	Interested	Very interested
Biology/Life Science	☐	☐	☐	☐
Physics/Physical Science	☐	☐	☐	☐
Earth & Space Science	☐	☐	☐	☐
Environmental Science	☐	☐	☐	☐

Probes:
Why do you like that area of science best?
Why do you like those areas of science least?

Earth and Planetary Science

Now I want to ask you some questions about Earth and the planets. For some of these questions we are going to use some balls, maps, and models.

10. Actually, my first question is about models. What is a model? Probe: What are some examples?
11. What does someone mean when they say something is a "scale model"? Probe: What would be some examples of things you know about that are scale models? Where have you used these things?
12. [Hand student topographical globe of the Earth.] Here's a model of the Earth. Feel those pins right across from each other. What do those represent? Probe: Where would the equator be on that model?
13. [Direct student to topographical flat map on the table.] Check this out over here. This is another model of part of the Earth. [Give the student time to check out the flat map.] Here my question, what do these two models have to do with each other? Probe: Which one is more realistic? Which one has a smaller scale?
14. Keep that global model of the Earth in one hand. Here's a model of the Sun. [Hand student model of the Sun.] What kind of astronomical object is the Sun? Probe: Do these kinds of objects have any common characteristics? What are they made of? How big are they in relation to other things in space?
15. Let me hold the Sun for a minute. Show me how the Earth moves through space? Probe: What do you call that? Are the North and South Poles in any particular position when the Earth moves that way? How long does it take the Earth to move that way?
16. Now, would you please show me the relationship of the Earth to the Sun as the Earth moves through space? Probe: How would you describe that? Are the North and South Poles in any particular place in relation to the Sun?
17. Where on the Earth is it very cold most of the time? Where is it very warm most of the time? What causes that?
18. Okay, hand the Sun back to me. Here a model of the Moon. [Hand student model of the Moon.] Tell me about the Moon. What is it?
19. Okay, I put the Earth and the Moon back on the table. Now let's talk about some other objects in our solar system. First, what is the "solar system"? Probe: Why do we call it a system?
20. What is a system? Probe: Can you give me some other examples of systems?
21. In astronomy, there are some words that name different things in space. In your own words, tell me what these things are. The Universe? A galaxy? The Milky Way? Probe: Which is larger a galaxy or a solar system?
22. Let's get back to the solar system. What are some other objects in the solar system, besides the Earth and Moon?

23. Some of those objects are planets. Let move over here on the table. Here are several models of the planets. Let's put the Sun here. Now would you please line them up—just in a row right now, starting with the one closest to the Sun and ending with the one farthest from the Sun? Probe: Can you name each one of them?
24. Right now, we have those balls all lined up in a line. But, in reality, they move through space? How would you describe how the planets move through space? Probe if word is used: What is an orbit?
25. All these planets orbit around the Sun. What is it that hold them in that orbit around the Sun?
26. Scientists say there are two types of planets— rocky planets and gaseous ones. Which of these balls represents the rocky planets? Which of these balls represent the gaseous ones?
27. Do the rocky planets have anything else in common? Probe: Why those planets might have those characteristics?
28. Do the gaseous planets have anything else in common? Probe: Why those planets might have those characteristics?
29. Okay, let's get back to Earth. Here's model of the Earth cut in half right down the middle. [Hand student the Earth model of layers of the Earth.] The Earth has different layers and you may have studied them in school. Tell me the names of the layers and what they are made up of.
30. Let's move over here to the large flat map of the Earth. Take a minute to explore it. It shows both the continents and the oceans. Scientist talk about a theory called Continental Drift. If you have heard of that, would you please explain it to me in your own words? Probe if there is some understanding this theory: What is the best evidence that scientist have for this theory?
31. Sometimes scientists will talk about this same thing as plate tectonics. Would you explain to me in your own words what plate tectonics are? Probe if there is some familiarity with this topic: What things happen when the plates of the Earth move? Would you tell about some of the features on the surface of the Earth that is caused by plate tectonics? Where on this map can you point out some of those features?
32. Geologists say that there are four major processes that are responsible for the features on the surface of the Earth—features like mountains, valleys, plains, crater, and glaciers. Let me tell you the name of each of these processes and tell me what you know about each of the. The first is tectonics. I already asked you about that. The second process is volcanism —what is that?
33. Another process is erosion—how would you describe that?
34. The fourth process that is part of forming the features on the Earth is impact cratering. What might make an impact crater? Where would it come from?

35. Those processes operate on Earth to form the features on the surface. But what kinds of things happen on other planets to form the features on their surfaces? Probe depending on response: Which of the planets we talked about would be the most likely for those processes to happen? Why do you think that?

Demographics

One of the goals of the new computer system is for the materials to be useful to a wide range of young people. I need to collect some information about you so we can sure we have collected information from young people with different characteristics. Your name will not be connected to any use of this information.

36. What sex are you?
(Circle one)
_____1 male
_____2 female

37. What grade are you in?
(Check one)
____ 5th
____ 6th
____ 7th
____ 8th

38. With what racial category do you identify? You may select more than one.
(Circle all that apply—you may circle more than one)
_____1 Black and African American
_____2 White
_____3 Asian
_____4 American Indian or Alaska Native
_____5 Hawaiian or Other Pacific Islander
______6 Hispanic or Latino
_____7 Some other race, please specify __________________________
_____8 Prefer not to answer

Thank you so much for your time today. I appreciated you time and thoughtful attention—here is a small gift just to say thank you.

Interview End Time _________________

APPENDIX C: ACTIVE - DEPTH INTERVIEW SCRIPT - TEACHERS

January 2006—Page 1

Case Number ___________

Interviewer _____________

Interview Start Time __________________

AUDIO RECORDING

My name is Carey Tisdal and helping me today is [name of pre-service teacher]. As we explained earlier, we are audio recording this interview. Here's the recorder, and I am turning it on.

INTRODUCTION

My name is Carey Tisdal and helping me today is [name of pre-service teacher]. We are conducting a study for the Institute for Scientific Research. They are beginning the development a new computer-based learning system. This system will let students explore the solar system through touch, slight, and sound. It will use information from NASA. The technology that allows exploring by touch is called haptics. They want to make sure that system is well suited to students who are blind or with low vision. Our discussion today with will help them design the materials in a way that makes accessible and useful to students who are blind or with low vision. They hired me to do this study. I don't work for ISR. With me is [name of pre-service teacher]. She is studying to be a teacher at [name of college], and she is going to take notes and help me with the interview.

This interview will take about an hour.

Just a reminder: this interview is confidential and anonymous. That means only those on the evaluation team connect your name with what you say. We will use what you say in our reports and in discussions with people designing the materials but we will not connect your comments to your name.

Before we start, do you have any questions? [Respond to any questions the respondent may have.]

Establishing Rapport

1. First, we'd like to get to know you a little better. Tell us about your role here at the school —how long you've been here and what you do? Probe: What grade levels do you teach? What subject areas?

ACTIVE - Depth Interview Script - Teachers
January 2006—Page 2

Earth and Planetary Science

Interest Level

2. How interested are your students in science in general? Probe: are there any differences among different types of science?
   Biology/Life Science
   Physics/Physical Science
   Earth & Space Science
   Environmental Science
3. If so, to what do you attribute this?
4. Tell me about the science curriculum at the grade level you teach? Probe: what specific topics do you teach in Earth and planetary science?
5. In general, would you say there are any concepts that are particularly challenging for your students? Probe: Why are those concepts challenging?

The project team has identified several learning objectives for the PC-based haptics learning system. I want to review these objectives with you and get you judgment about the extent to which your students understand these topics.

6. One of the objectives is for students to: *List the celestial bodies in the solar system: the Sun, planets, and Moons.* Right now, how well would your students be able to do that?
7. To what extent do you think your students would be able to distinguish between the small rocky planets and which are the large gaseous planets?
8. Two of the objectives have to do with gravity:

   Demonstrate the role of gravity in holding our solar system together.
   Describe the relationship between mass, weight, and gravity.

   One common misperceptions is confusing weight and mass. To what extent do your students have that misperception?

Another important content focus of this program makes the connections between planetary processes on Earth and on other planets. This includes processes such as volcanism, impact cratering, tectonics, and gradation or erosion. Let's take these one at a time and tell me how familiar you think your students are with each of these processes.

9. Volcanism—to what extent do your students know about and understand volcanoes?
10. Impact cratering—to what extent are your students aware of the extent of impact cratering from asteroids on Earth? Probe: What about the Moon?

11. Tectonics—what are some of the basic ideas about plate tectonics that your students would be familiar with?
12. If we gave your students this model and asked them to identify the layers of the Earth would they be familiar with that idea?
13. Right now, how familiar would your students be with the idea that same types of features made by the processes on Earth are found on other planets?
14. Assistive Devices and Technology Are there any differences between young people who have always been blind and those who became blind after they were older that we need to keep in mind in teaching concepts that involve spatial positions and relations?
15. One area we want to talk with you about is the skill level among your students in using the computers. By the way, all through this interview I'll say "your students' and what I really want is your ideas about students at the grade level you teach. Probe: What kinds of things do they do easily? What kinds of things do they need help with?
16. What level of keyboarding skills do your students have? Probe: Have they had any keyboarding instruction or did they pick it up on their own? Do they use Braille keyboards?
17. Are there any assistive devices particularly useful to your students in studying science, for example, screen magnifiers, text readers, CCTV devices) do you use when you use a computer? Probe: Where do they generally have those sorts of devices available? At home? Other places?
18. What are some of things that your students find the most fun and enjoyable about using a computer?
19. What are some of the things that frustrate your students when they use computers?

Assistive Devices and Teaching/Learning Strategies

20. As we examined several assistive devices, *tactile graphics* such as maps and globes appeared the most similar to Haptics. How much experienced do students have with tactile graphics? Probe: Are there any specific problems or areas of confusion?
21. One aspect of this program will be the capacity to spatially "zoom." The user will be able to move in larger surface area to explore a specific feature on a planet's surface such as a canyon or a landscape. This involves recognizing the differences in scale between the two. Are students you teach familiar with the concept of scale on graphic maps? To what extent would this be confusing to them?
22. What specific advice would you give the development team in developing a PC-based learning system for students who are blind or with low vision?
23. As someone who selects instructional materials for students, what do you use right now to teach concepts in Earth and planetary science? Probe: What are the strengths of these materials? What are their weaknesses?

Background

Finally, I would like know a little more about you.

24. How many years have you taught? _______

25. What grade do you teach?
    (Check one)
    ____ 5th
    ____ 6th
    ____ 7th
    ____ 8th

26. Before you started teaching here, did you teach in public or private schools? How was that experience different from teaching here at the School for the Blind and Deaf?

Thank you so much for your time today. I appreciated you time and thoughtful attention—here is a small gift just to say thank you.

Interview End Time _________________

APPENDIX D: APPLICABLE WEST VIRGINIA CONTENT STANDARDS AND OBJECTIVES

4th Grade

SC.4.3.1 identify that systems are made of parts that interact with one another.
SC.4.3.2 use models as representations of real things.
SC.4.4.30 identify the Sun as a star.
SC.4.4.31 describe the orbits of the Sun and Moon.
SC.4.4.32 describe and explain the planets orbital paths.

5th Grade

SC.5.2.1 cooperate and collaborate to ask questions, find answers, solve problems, conduct investigations to further an appreciation of scientific discovery.
SC.5.2.2 formulate conclusions through close observations, logical reasoning, objectivity, perseverance and integrity in data collection.
SC.5.4.9 explain that the mass of a material is conserved whether it is together, in parts, or in a different state.
SC.5.3.1 compare and contrast the relationship between the parts of a system to the whole system (e.g., take a part or build mechanical, electrical, or biological systems).
SC.5.4.1 demonstrate an understanding of the interconnections of biological, Earth and space, and physical science concepts.
SC.5.4.16 describe how the variables of gravity and friction affect the motion of objects.
SC.5.4.18 describe the layers of the Earth and their various features.
SC.5.4.19 identify and describe natural landforms, how they change and impact weather and climate.
SC.5.4.21 compare and explain the different rates of weathering, erosion and deposition in certain materials.
SC.5.4.22 identify land features and elevations on a topographical map.
SC.5.4.24 explore and explain how fossils and geologic features can be used to determine the relative age of rocks and rock layers.
SC.5.4.25 identify that the Earth is made of plates (plate tectonics).

6th Grade

SC.6.2.1 cooperate and collaborate to ask questions, find answers, solve problems, conduct investigations to further an appreciation of scientific discovery.
SC.6.2.2 formulate conclusions through close observations, logical reasoning, objectivity, perseverance and integrity in data collection.
SC.6.2.9 use appropriate technology solutions to gather data; graph data; interpret data; and analyze information.
SC.6.3.1 compare and contrast the relationship between the parts of a system to the whole system (e.g., take apart or build mechanical, electrical, or biological systems).
SC.6.4.1 demonstrate an understanding of the interconnections of biological, Earth and space and physical science concepts.
SC.6.4.22 interpret the relationship of mass to gravitational force (e.g., larger the mass the larger the gravitational force, the closer the objects the stronger the force).

SC.6.4.26 describe and demonstrate the forces and results of plate tectonics.
SC.6.4.28 recognize the phases of the Moon.
SC.6.4.29 investigate models of Earth-Moon-Sun relationships (e.g., gravity, time, tides).

7th Grade

SC.7.2.1 cooperate and collaborate to ask questions, find answers, solve problems, conduct investigations to further an appreciation of scientific discovery.
SC.7.2.2 formulate conclusions through close observations, logical reasoning, objectivity, perseverance and integrity in data collection.
SC.7.2.8 use appropriate technology solutions to gather data; graph data; interpret data; and analyze information
SC.7.3.1 compare and contrast the relationship between the parts of a system to the whole system (e.g., take apart or build mechanical, electrical or biological systems).
SC.7.4.1 demonstrate an understanding of the interconnections of biological, Earth and space and physical science concepts.
SC.7.4.24 explain the effect of gravity on falling objects (e.g., $g= 9.8m/s^2$, object dropped on Earth and on Moon).
SC.7.4.28 interpret and create topographical maps.
SC.7.4.32 describe and compare the physical characteristics of celestial objects.
SC.7.4.33 compare the characteristics of the members of our solar system.

8th Grade

SC.8.2.1 cooperate and collaborate to ask questions, find answers, solve problems, conduct investigations to further an appreciation of scientific discovery.
SC.8.2.2 formulate conclusions through close observations, logical reasoning, objectivity, perseverance and integrity in data collection.
SC.8.2.8 use appropriate technology solutions to gather, graph and interpret data and analyze information.
SC.8.3.1 compare and contrast the relationship between the parts of a system to the whole system (e.g., take apart or build mechanical, electrical, or biological systems).
SC.8.4.1 demonstrate an understanding of the interconnections of biological, Earth and space, and physical science concepts.
SC.8.4.26 identify the principle forces of plate tectonics and related geological events.
SC.8.4.32 diagram the motions of the Sun, Moon and Earth and explain the phenomena associated with these motions (e.g., glacial periods, eclipses, tides, meteor showers).
SC.8.4.33 compare and contrast the orbits of planets and comets.