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Developing an Online Accessible Science Course for All Learners

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The American with Disabilities Act (ADA) of 1990 was a landmark legislative initiative that outlined the protection of individuals with disabilities. Title III of the ADA directs that public facilities make reasonable efforts to control discrimination and support accessibility policies, practices, and procedures (Council for Exceptional Children, 1994). The 1997 amendment of the Individuals with Disabilities Education Act (U.S. Congress, 1999) stipulates that students with disabilities are to be educated in the general education curriculum. Institutions of Higher Education are not immune from these policies. In addition, common actions like course development and teaching must include considerations and compliance with the ADA and IDEA guidelines. These guidelines have also extended to the realm of computer technology in recent years (e.g., Chalfen & Farb, 1996; Mendle, 1995) especially as they pertain to online delivery of instruction. The U. S. Access Board (2001), a governing body charged with helping U.S. federal agencies reach Web accessibility, announced a set of guidelines that comply with Section 508 of the 1998 Rehabilitation Act. The result was that all federal agencies had to alter and or develop Web sites that were accessible to those with disabilities. Web page authors can also integrate the same guidelines into generic Web sites, as well as online courses offered at universities (e.g., Robertson, 2002; Robertson & Harris, 2003).

Traditional modes of science instruction have included lecture and presentation by instructors, and different methods and accommodations have been made to include people with disabilities as learners (e.g., Munk, Bruckett, Call, Stoehrmann, & Radandt, 1998; Stefanich, 2001). In recent years online instruction has quickly risen in popularity among universities and colleges as one mode of instruction (Kiefer-O'Donnell & Spooner, 2002). Even though the use of online instruction has progressed quickly, online learning accommodations for people with disabilities has lagged behind other curricular issues (Gardner & Wissick, 2002). The purposes of this paper are to exam online Internet content of an Earth and environmental science (EES) course and determine if the format and design of the Internet content is appropriate for students with visual disabilities. The course used external Web sites on the Internet as the main source of content; thus, the study focused on the impact of an online course design on a specific community of learners and suggests how instructors at all levels might need to revise curriculum that uses the Internet for content to meet the learning needs of some marginalized learners.

Literature Review

Science Education

National reform documents in science (e.g., *National Science Education Standards* [National Research Council, 1996] and *Benchmarks for Scientific Literacy* [American Association for the Advancement of Science, 1993]) stressed the need to develop scientific literacy in *all* students. In order to achieve this goal of "science for all," the science documents suggested that the teaching and learning of science should be achieved using an inquiry approach that includes hands-on experiences. In addition, a distillation of these and other curricular documents suggested, among other items, that there should be more emphasis on understanding science concepts, learning science in the context of active and extended inquiry, and integrating cooperative learning. Gardner, Mason, and Matyas (1989) stated that teachers should use more hands-on/minds-on experiences to increase the speed, ease, variety, and efficacy of learner engagements for underserved and underrepresented students. Some special educators have identified science as a content area to be a particularly well-suited area for students with disabilities due to the hands-on and interactive nature of teaching and learning (e.g., Mastropieri & Scruggs, 1992a). Mastropieri and Scruggs (1992b) also reviewed the literature and found that many science curricula for students with disabilities share in common problem solving, thinking, and scientific processes.

Although these documents promote "science for all," some have criticized exactly what that means. For example, Holahan and McFarland (1994) defined 'all' as "operationally meaning 90% or more" and determined that the remaining 10% were students with disabilities. In terms of curriculum design and instructional implementation, the national documents offer no guidance or description for the needs of students with disabilities. Cawley, Foley, and Miller (2003) suggested that curriculum developers use principles of "universal design" to comply with national standards for student with disabilities. There seems to be a gap between what national science documents recommend as effective teaching and the availability of curricula for students with disabilities to learn science.

Online Aspects of Teaching

Although there have been suggestions and approaches for making content more accessible for students with disabilities in traditional settings, there are fewer examples when applied to the online environment (e.g., Gardner & Wissick, 2002). The meaning, implementation, and application of content take on a different perspective. In order to adhere to the principles set out in national science reforms documents, online science instruction needs to include interactive graphics, simulations, collaboration, and diagrams to enhance topical and conceptual learning. However, because of the complexity of information on some Internet sites, accessibility becomes an issue (Wong, 1997). For example, science virtual dissections or simulations cannot be "translated" and students with disabilities cannot realize the experience of 'participating' in science, because these students cannot feel, see, hear, or direct science content without the use of very expensive tools.

The Trace Research and Development Center at the University of Wisconsin at Madison produced the Unified Web Site Accessibility Guidelines (Vanderheiden & Chisholm, 1998). These guidelines were transferred to the Web Accessibility Initiative of the World Wide Web Consortium (W3C, 2005). Using the 1999 Unified Web Site Accessibility Guidelines, the W3C produced HTML Author Guidelines -- version 1.0 . Since then a newer version of the guidelines has been introduced (W3C, 2005). According to the guidelines, measures for improving accessibility fall into the following categories: (a) structure—HTML documents should use markup to convey meaning and less for format and layout pages; (b) navigation—authors should support keyboard-only navigation and methods to facilitate orientation; and (c) alternative content—authors should always provide alternative ways to access information presented with images, sounds, applets, and scripts (Chisholm & Vanderheiden, 1999b). These recommendations have been categorized as Priority 1, 2, and 3 errors. Priority 1 errors involve issues that make it impossible for one or more groups to access information about the Web site. These issues must be addressed to consider the Web site minimally accessible. Priority 2 errors make it difficult for users to access Web site content. Priority 3 errors may be addressed by Web developers and make it somewhat difficult for readers to access information in the Web page.

The W3C's commitment to lead the Web to its full potential includes promoting a high degree of usability for people with disabilities. The Web Accessibility Initiative (WAI) of the W3C produced the *Web Content Accessibility Guidelines 1.0* (Chisholm & Vanderheiden, 1999a) to promote content accessibility. The guidelines did not discourage content developers from using images, video, and other multimedia tools, but rather explained how to make multimedia content more accessible to a wider audience. The *Web Content Accessibility Guidelines 1.0* document is organized around two general themes and 14 guidelines and principles of accessible design. The themes are (a) ensuring graceful transformation and (b) making content understandable and navigable.

Developmental Research

The online EES course was developed with the intent of maximizing available online and multimedia content for the students. This approach necessitated a circular nature of curriculum revision that included research, data collection, interpretation, and modification. The process of curriculum development outlined in developmental research involves the integration of curriculum research and design. Gravemeijer (1994) characterized this process as “educational development,” which is guided by theory and also produces theory. “In general, curricula are developed to change education, to introduce new content or new goals, or to teach the existing curriculum according to new insights” (p. 445).

Although most strategies for instructional design and curriculum development are grounded in an empiricist framework, developmental research gains its validity by recognizing ongoing and changing views of altering current ways of doing. For example, Freudenthal (1991) discussed the use of thought experiments in physics as a means by which instructors could envision proper teaching, based not on prior experimental results but through rational thinking. In developmental research, the evolutionary aspect of the process is highlighted because it reflects a nonempiricist approach that does not focus on results. This bricolage concept reflects the practical aspect of adapting curricular means to the goals of a community of practice. These goals can reflect the practical and contextual nature of teaching and learning in different environments.

The online environment is a contextual setting in which alteration is needed so that proper instruction occurs. In addition, when dealing with disability issues of instruction, the ways in which teachers use the Internet must be studied in hopes of finding appropriate models of instruction.

Development research exemplifies the theoretical goal of content dissemination for teaching and learning in the online context while considering students with disabilities. Content should be accessible and available for all groups or communities of people and inherently developed for such access. The course development must reflect the communities of practice of the teachers and the students while attending to the process of curricular revision. In addition, communities of individuals define what is curriculum, how curriculum is implemented, and who benefits from curriculum.

The purpose of this paper was not to explore the design of online content or the effect on students with disabilities, but to examine the development of a course that uses external Internet Web sites to supply the bulk of the course content. Even though the *Web Content Accessibility Guidelines 1.0* focus on design of specific pages, they can also be used to help evaluate a course that includes online content from external Internet Web sites. Little research has been done to date that addresses the issue of online teaching and learning as it pertains to curriculum development in regards to accessibility issues. The research questions that guided this study were as follows:

1. What is the accessibility of the content within different domain types (i.e., .com, .edu, .gov, and .org), and how might this effect online curriculum development?
2. What are the accessibility errors and examples of the Internet Web sites used for content delivery in an online Earth and environmental science course?
3. What are the potential implications of the accessibility errors on specific EES topics?
4. What is the "ease of fix" for making improvements in the online science content pages?

Methods

As previously mentioned, the purpose of this study was to examine the degree to which the content of an online EES course that uses external Internet Web sites is accessible to certain communities of practice (i.e., students with disabilities). Specifically, the external Web sites from different Internet domains in the course were evaluated by software that identifies types of presentational and design errors. These errors are then categorized by severity and "ease of fit."

Course Description

Beginning in 2003, all North Carolina high school graduates had to complete a course in Earth and Environmental Sciences. Based on the number of students graduating each year (~60,000), a total of approximately 800 teachers in 400 high schools are needed to teach the mandated new courses. There exists a gap in the number of qualified teachers needed to teach these courses in the high schools. One solution was to offer a graduate level EES course so that teachers could become certified in this area. It was decided that an EES course should be designed and delivered via distance education technology (online) so that more preservice and in-service teachers could more easily take the course. This online course allowed for the retooling and development of secondary science teachers. Although the course management software (Blackboard) for delivering this online course was accessible and complied with ADA guidelines, there was no indication that the content developed for the class was accessible to people with disabilities.

The purpose of the EES course was to prepare and retrain secondary science teachers in the content of EES. In order to accomplish this purpose, external Web sites were chosen to provide content that had moving images, dynamic and colorful diagrams, tables with data, and simulations. These Web sites more accurately displayed and reflected the type of teaching as outlined in the *National Science Education Standards* (NSES; National Research Council, 1996), which states that science should be engaging, involve hands-on and minds-on activities, and be applicable to a students' life. The course content, outline, and presentation followed the North Carolina Standard Course of Study and all of its themes and subthemes. The seven themes (the lithosphere, tectonic processes, origin and evolution of the Earth, hydrosphere, atmosphere, solar system, and environmental stewardship) were presented over 21 classes, and the course content was divided into these allotted classes based upon the teaching experience of a university geologist. Veal, Kubasko, & Fullagar (2002) reported the effectiveness and description of the online course. In summary, each class contained a written section summarizing and relating subthemes for the major themes. Within the summaries, teachers were referred to external Web sites (using pop-up windows) that provided most of the content information.

Web Site Labeling

The Web sites were labeled based upon their generic designation and domain registry. For example, the Web sites from universities or university-sponsored programs were designated .edu. In some cases the designation was not apparent. Many of the Web sites originating outside the US did not follow the American convention. For example, http://www.bbc.co.uk/education/rocks/rockcycle.shtml is sponsored by the British Broadcasting Company and was labeled as .com. In another example, the Exploritorium site in San Francisco was labeled .org even though the URL contained .edu. The Canadian and British universities had URLs that did not indicate that they were .edu sites, but were still labeled as .edu.

Web Site Inclusion and Alteration

There were 342 external Internet Web sites used for the 2002 summer course. The external Web sites in many cases were chosen because they provided animation and/or demonstrated the content in alternative ways other than just text. The Web sites were separated into four domains. The education and government sites were by far the most abundant resource for information on the EES themes. The Web sites chosen for this course went through an examination process that included initial discovery; review by a geologist, a marine scientist, a science educator, and one geology and four science education graduate students; and evaluation by the first two cohorts of teachers who took the EES course in previous summers. As part of a class assignment, teachers who completed the course prior to 2002 evaluated some of the Web sites for their effectiveness in teaching and learning. Feedback from these teachers and their assignments allowed the course developers to keep existing Web sites or locate new Web sites to use in future course offerings.

Evaluation Process

Each Web site was evaluated using Bobby 3.2 by the Center for Applied Special Technology, 2001 version, which is no longer available online. Bobby was a software tool that was used to analyze Web pages for the accessibility to people with disabilities. It accomplished this by comparing the coding in the selected Web page with the coding standards developed by the WAI. Once Bobby had completed its analysis it created a detailed report that was used to identify and correct accessibility errors on the Web page. These reports were extensive and provided a measure of the extent to which a Web site was accessible for people with disabilities. The type of accessibility error (e.g., images without alternative text, links without alternative text, and pages not usable without frame), the severity of the error (e.g., Priority 1, Priority 2, Priority 3), and the ease with which the error can be fixed (e.g., easy, moderate, hard) were provided in a summary report. By correcting these errors, tools such as Web page readers can then be used by persons with disabilities to help them read and correctly interpret the content of a Web page. Scores for each external Web site used in the course were tabulated by severity and analyzed based upon the Web site's domain. There were many accessibility issues that Bobby 3.2 could not detect. For example, Bobby could not determine programmatically if the Web site was following accessibility principles and could only list the potential risks of any technology that was used. Currently, there is a newer version of Bobby software entitled WebXACT that is now distributed by the Watchfire Corporation. "WebXACT is a free online service that lets you test single pages of web content for **quality**, **accessibility**, and **privacy** issues" (Watchfire, 2005). This software has the same basic functions as the version used for this study, and can be used for Web sites currently.

Results

A total of 342 science Web sites were evaluated for this study using Bobby 3.2. Of the total, 29 Web sites were not found due to URL changes during the time between the course offering and the analysis, resulting in 313 sites being used in the evaluation. Results from this evaluation process provided a measure of the extent to which a Web site was accessible for people with disabilities. Reports generated form the analysis of each Web site were tabulated and summarized.

Research Question 1: Accessibility of Internet Domains

Table 1 represents the percent and number of Web sites approved by the Bobby analysis for each Internet domain. The .com domain, which usually has private entities with little or no federal funding, had the most unapproved Web sites at 82%. This was followed by the .edu and .org Web site domains with 78% and 63% unapproved Web sites, respectively. Only the .gov domain had fewer than 50% unapproved Web sites. Still, any number of unapproved Web sites should not be used if students with certain disabilities took a course that used so many external Web sites.

Table 1
Percent and Number of Approved and Unapproved Web Sites by Internet Domain

Domain	**Approved**		**Unapproved**	
	Percent	Number	Percent	Number
.com	18%	6	82%	27
.edu	22%	27	78%	94
.gov	56%	69	44%	55
.org	37%	13	63%	22
Total	37%	115	63%	198

Research Question 2: Accessibility Errors and Examples

This question sought to illuminate potential accessibility error priorities, which are items that affect the ability of the end user to abstract content and meaning. The different Internet domains (.com, .gov, .edu., and .org) were nondistinguishable in terms of priority type errors, thus Table 2 represents the mean and standard distribution for the number of accessibility errors (Priority 1) per Web site and the number and standard deviation for the *potential* accessibility errors (Priority 2 and 3) for all domains and their errors. The next three tables contain the sorted data by priority level used in the analysis. In tables 3, 4, and 5 only the top few errors are reported for each priority level. For example, for Priority 1 errors, only the top errors found in more than 50% of the Web sites, are included. For Priority 2 and 3 errors, only the top errors found in more than 72% and 92% of the Web sites are reported, respectively. This was done for two reasons. First, the range of errors for the four Internet domains was 55-63. The top 44 errors were the same for each Internet domain, and the percentage of homepages with common errors bottomed out at 3%. Second, since Priority 1 errors are the most important for designing accessible Web sites, we focused on those errors that were found in the majority (greater than 50%) of the Web sites. For the Priority 2 and 3 errors, we arbitrarily choose the first point in the data where the separation between errors was greater than 10%. All of the selected errors paint a portrait of all of the reported errors associated with the Web site development.

Of the 314 science Web sites available for evaluation, 94% of the Web sites had at least one accessibility error. There was a mean of .7 Priority 1 confirmed accessibility errors on the Web sites. This result indicates significant accessibility issues that can hinder the reader's access to information on the Web site. Additionally, the potential Priority 1 accessibility errors reported were 7.75. This indicates that several potential accessibility issues per Web site exist that could severely limit a readers' access to the information. Priority 2 and Priority 3 errors averaged 2.47 and 1.65, respectively, while potential Priority 2 and 3 errors averaged 13.90 and 2.15, respectively. While these errors are not as severe as Priority 1 errors, they can still affect the degree to which a reader can access a Web site.

Priority 1 Errors. The most common Priority 1 (Table 3) accessibility problems identified in the referenced science Web site were (a) not using an alternative method to convey information that appears in color, (b) not using an extended description for an image that conveyed important information beyond what was contained in the alternative text, (c) not providing structural markup to identify table rows and columns that serve as headers, (d) not using alternative text for all images, and (e) not identifying headers for table rows and columns. All of these errors have to be changed in order for the Web site to be accessible. These errors also reflect the difficulty in presenting science process and science content online as outlined in the NSES.

Table 3
Priority 1 Accessibility Error, Percentage of Homepages With Error, and Ease of Fixing Error for All Web Sites

Error	%	Fix
If you use color to convey information, make sure the information is also represented another way.	91%	M
If an image conveys important information beyond what is its alternative text, provide an extended description.	89%	M
If a table has two or more rows or columns that serve as headers, use structural markup to identify their hierarchy and relationship.	71%	M
Provide alternative text for all images.	57%	E
For tables not used for layout (for example, a spreadsheet), identify headers for the table rows and columns.	52%	E

There are different ways to present information on a Web site rather than using color, yet in science, color often represents layers of information necessary for understanding subtleties among concepts. For example, when displaying rocks and minerals of different colors, sometimes it is difficult to convey in an alternative text format the shades of color within the rock that highlights the rock's minerals. One solution would be to use black text only and define completely the pictures in the alternative text fields. Another solution would be to use hot spots. Along similar lines, when the alternative text fields are used, adequate and very descriptive information must be conveyed. Many of the Web pages used in this course did not offer enough alternative information for the images.

Science, by nature, relies on observation. Color and pictures represent concepts, information, and understanding that may translate poorly to certain students with disabilities when accessing the information online. For example, a Web site on geologic maps from the United States Geological Survey that shows ages of sandstone in a particular area was evaluated as not accessible. Providing alternate text for an image or hot spot means that when the reader is browsing the page they can move their pointer over the image or hotspot and a message will appear that provides some information about the item in question.

Another error found involved the use of tables. Most Web sites that presented data or information for analysis provided no markup language or identified headers for rows and columns. For example, an online earthquake activity asked students to use real earthquake data to determine the epicenter. In another example, a graph of monthly El Nino sea level data supplied by the National Oceanic and Atmospheric Administration would not have been read or deciphered by a student with disabilities.

Priority 2 Errors. The most common Priority 2 (Table 4) accessibility problems identified in the referenced science Web sites were (a) not contrasting sufficiently the foreground and background colors, (b) not avoiding the use of deprecated language, (c) not avoiding movement in images, and (d) not adding a descriptive title to links. For example, the John Hopkins University Applied Physics Laboratory provided excellent relief maps of landforms and elevations. The slight color contrasts of the maps are important in applying the knowledge of landforms and elevation to environmental issues and weather. The Web site entitled, "Population in the New Millennium: 6 Billion and Beyond," is hosted by The Public Broadcasting System (PBS). The site is based on a PBS television program pertinent to the topic of overpopulation. Some of the language on this Web site is deprecating. Most examples of deprecating language were found in the environmental sections of the course content such as "The relentless overdeveloping of the marshlands..."

Table 4
Priority 2 Accessibility Error, Percentage of Homepages With Error, and Ease of Fixing Error for All Web Sites

Error	%	Fix
Check that the foreground and background colors contrast sufficiently with each other.	94%	E
Avoid use of deprecated language features if possible.	83%	M
Avoid using movement in images where possible.	83%	E
Add a descriptive title to links when needed.	83%	E
Mark up quotations with the Q and BLOCKQUOTE elements.	72%	M

In a different example, the Museum of Paleontology at the University of California provides animations of the continents changing positions during geologic time. The animations highlight and reinforce still images of divergent, convergent, and transformational plate tectonics. A Web site from the National Aeronautics and Space Administration on solar flares has a paragraph description of a solar flare. The paragraph contains highlighted words that take the reader to a long list of vocabulary terms. A highlighted word, contrary to a picture, does not have alternative text. In addition, at the bottom of the page icons are followed by a brief (not descriptive) title of a link to another Web site describing the new content.

Priority 3 Errors. The most common Priority 3 (Table 5) accessibility problems identified in the referenced science Web sites were (a) not including keyboard shortcuts to frequently used links; (b) not specifying a logical tab order among form controls, links, and objects; and (c) not identifying the language of the text. Modifying a Web site based upon these types of errors is not necessary, but should be completed so that the experience a person with disabilities has online is somewhat equal to that of a person without disabilities. The first two Priority 3 errors involve navigation within the Web site. Many people with disabilities need extra keyboard tools for navigating through the myriad of information presented in different formats on a Web site. Software readers also need information about the type of language, French for example, contained in the Web site. One of the first tasks a software reader does for Web pages is read or determines the language so that the listener will know the language for communication purposes. Providing the Web site with a tag indicating the language would facilitate the use of time for initiating reading software.

Table 5
Priority 3 Accessibility Error, Percentage of Homepages With Error, and Ease of Fixing Error for All Web Sites

Error	%	Fix
Consider adding keyboard shortcuts to frequently used links.	94%	M
Specify a logical tab order among form controls, links and objects.	93%	M
Identify the language of the text.	92%	M

Research Question 3: Online Earth and Environmental Science Content

Many of the Web sites used for this online course were unacceptable for people with disabilities. Are there certain scientific concepts that are more readily accessible than others online? Table 6 presents a breakdown of the EES course themes by content topic and lists the percent approval of the Web sites used. The solar system is the most inaccessible content online, while the origin and evolution of the Earth is the most accessible content online. One possible explanation is that narration on the origin of the universe is the best method for detailing or showing this content.

Table 6
Number and Percent of Approved and Unapproved Web Sites by Geology 130 Content Theme

Unit	Theme	Approved		Un-Approved	
		Percent	Number	Percent	Number
1	Lithosphere	40%	25	60%	37
2	Plate Tectonics	32%	12	68%	25
2	Origin and Evolution of the Earth	39%	14	44%	61
3	Hydrosphere	48%	25	52%	27
3	Atmosphere	37%	18	63%	30
4	Solar System	15%	6	85%	34
4	Environmental Science	43%	15	57%	20

Plate tectonics was the second theme that had a high unapproved rate of accessibility. One potential issue here is map reading and development as part of the skills and knowledge outlined in national and state standards. The maps and overlays of map reading do not lend themselves well to the online nature for particular communities (people with disabilities being one). This issue is compounded when colors and contrasts are important for deciphering maps. A second issue is the simulations that are presented to show plate movement and tectonic forces. Many of the sites chosen for this course used simulations of folding and fault movement to explain the content.

The lithosphere may have presented a particularly interesting aspect to teaching and learning science online. The majority of this content was focused on rock and mineral identification, the rock cycle and types, and layers of the Earth. One method for learning rock and mineral identification is through hands-on labs in which several physical characteristics result in identification by using a dichotomous key. These tactile process skills may be too difficult to present and learn online.

Discussion

The results of this study suggest that the online Earth and environmental course was not adequate in providing content in a manner that is acceptable for different communities of practice (i.e., people with disabilities). By running the analysis of the external Web sites used in the course, course designers and science teachers can more readily alter the existing course based upon online design principles. In addition, the results suggest that particular science topics are more readily accessible online than others.

Internet Domains

Certain Internet domains have achieved a higher level of Web accessibility as a result of complying with the federal guidelines, while other domains have not. The results suggest that the .gov domain is the most readily accessible, but there is still a lot of work to achieve before there is full compliance with the federal guidelines. Agencies and individuals are slow to comply with these guidelines for making their Web sites accessible. Even though .gov and .edu domains are striving to make more sites accessible, there are many other sites containing valuable information that is presented in a manner that reflects the majority of learners and follows national guidelines for teaching and learning science.

The software program used to analyze the Web sites in this study was limited to mostly issues pertaining to visual disabilities and how screen readers may address the disabilities. Those people who take online courses, because they are physically unable to attend face-to-face courses or because online courses are more convenient for a number of reasons, may not be marginalized for this type of course. Those teachers confined to a wheelchair or with motor difficulties may learn from the presentation method used in this course, but may not learn well if the requirements include hands-on activities.

The question that surfaces from this discussion is which disability community should be considered when designing and teaching curriculum that uses Internet Web sites? The apparent answer is not easily determined. Although the software used to evaluate these Web sites looked at mostly visually related issues, designers and teachers need to take into account all possibilities; or should they? As evidenced by the .edu domain, most university professors or centers do not create Web sites (and presumably their online courses) with the disability community in mind, especially the specific types of disabilities within the larger community. This study would suggest that the current state of the Internet is marginally accessible to people with visual disabilities, and teaching science that uses the Internet for content should not be recommended. This implies that all teachers who instruct students with disabilities evaluate Internet Web sites prior to instruction.

Design of the Online Course

The use of external Web sites as course content creates its own benefits and problems. The benefits are the use of expert knowledge, multimedia methods for knowledge transfer, and select content. The problems can be associated with finding appropriate sites that people with disabilities can access. If using or referring to external Web sites, the curriculum developers need to consider the content, domain registry, and multimedia aspects of the Web sites. Even though the .gov domain Web sites should be compliant with section 508 of the 1998 Rehabilitation Act, there exist Web sites with invaluable information and experiences that may never be accessible. There exists a dilemma for course developers; does one develop for the masses and assume no modifications, or make the modifications so that the online course is accessible to all? The former scenario is the easiest since most curriculum developers do not know how to make the required modifications, and they realize that the probability of having a student with disabilities in their online course is close to zero. The later scenario is less likely, but when necessary there exist institutional structures that will help the developers alter the curriculum and instruction.

Freudenthal (1991) reported that rational thinking was one method by which instructors could design a course or activities. Experts in the field of science education, marine science, and geology have developed this particular course. This type of development reflected a non-empiricist approach in which individuals' skills and prior knowledge were used to design, develop, and implement an online course. By using national standards in science, principles of best teaching, and individual experiences in online teaching and learning, the developers designed and taught the course. If the Web Site Accessibility Guidelines were used in the development, then a more empiricist approach would have been taken, but this may have neglected the spirit of teaching and learning science as outlined by the national standards. What resulted from this apparent contradiction among communities involved is the practical and contextual nature of the online content.

Gravemeijer (1994) stated that "educational development" was guided by theory and produces theory. In this study, the body of knowledge for teaching and learning science (e.g., Resnick, 1987; Roth, Anderson, & Smith, 1987) was used to develop the course. Since the course's inception in 2000, various research studies have been completed on different aspects of the course's effectiveness. For example, Veal, et al. (2002) studied the effectiveness of the online course for learning EES content of inservice and preservice teachers. In another study, Veal, Brantley, and Zulli (2004) looked at instructional design principles for online learning and how this affects the structure of the course. In another study, Veal and Trygstad (2004) looked at the technology self-efficacy of the students and whether certain variables were predictive of future online course enrollment.

The development, design, and implementation of this course included large bodies of research on teac hing and learning online. The theory indicated best practices for presenting the online course. The continual process of altering the design and approach of teaching online is a result of external and internal theory. External theory comes from research that studies certain variables outside the community, content, or context of the current course. Internal theory is developed through self-study on one's own course development. What is needed is more research similar to this study that looks at the content of online courses and Web sites and how they can be altered to include different communities of people with disabilities.

Curriculum and Content Understandings

The results of this study indicate that science content is currently not adequately presented online for people with visual disabilities. This study also suggests that certain topics within a science domain are more appropriate for people with visual disabilities in the online milieu. This would neglect certain concepts and processes of science for the online format. In this study, the astronomical concepts were deemed the most in-accessible. This could be the result of the types of images and data presented. The nature of astronomy is based upon images and inferential data collected through radio telescopes. Thus the presentation of these data does not impart a format that is accessible. There is not enough data alone from this course to speculate on the generalizability of these results, but the results are presented to help stimulate further research and discussion about content and topic specific issues for different communities of practice who learn online.

If science curriculum is to be developed properly online and follow the methods advocated by the NSES, then different and new mechanisms for conveying process skills are needed. Development and money are needed to change most sites so that they are accessible. Most people who design Web sites do not take into account Web accessibility issues. Simulations, pictures, graphs, and maps are pieces o f online content that will be difficult to make accessible. In addition, the process skills surrounding learning (data collection, organization, and analysis; observation; and inferring) become severely limited in the online format.

Research Question 4: Making Improvements to Online Courses

Table 7 presents the priorities, errors, explanations, and "ease of fix" for the Web sites in this study. Most of the errors are readily remedied with some simple design features and html coding. The problem may be the resources and knowledge that individuals or organizations have in making the commitment to implementing these changes. For example, one of the most frequently found errors in the reported Web sites was "not using alternative text for images." For web designers, the fix is simply an added script in a text box. A more difficult fix is required if science should be taught online and follow hands-on and interactive guidelines set by science standards. The fixes are exponentially more problematic. For example, if no "structural markup to identify table rows and columns that serve as headers" is provided, then the idea of having the Web site as a basis for data collection and organization cannot be accomplished. Another item that is problematic for online science teaching and learning is the use of movement. Simulations (e.g., Jimoyiannis & Komis, 2001) and animated gifs are excellent methods for presenting conceptual issues and higher order thinking skills in science to people online. The fix is not to include these, but this advice contradicts what the national science standards suggest.

Ultimately, the fixes are relatively easy considering the guidelines for making an online course accessible. The problem is when the instruction becomes content specific and the online format is intended to imitate correct methods for teaching and learning science. New design principles for science need to be separated and developed for online teaching and learning. At the same time, people or organizations publishing online should spend the extra time and money to make their sites accessible. Teachers of students with disabilities need to be aware of appropriate methods for science instruction and how Internet Web sites can be used with the different communities of practice.

Limitations

The majority of the limitations for this study center on the specific nature of the course content and the selected external Web sites. This study could have looked only at one science topic and analyzed all Web sites found in a particular search engine. Although this may have merit in terms of the randomization of Web sites, the results and algorithms would still limit it provided by different search engines. The Web sites analyzed in this study were purposefully chosen for their content and presentation method that aligned with principles of best science teaching and learning. The second limitation was the lack of analysis for a second offering or revised edition of the course. This would have shown the "educational development" of theory and research affecting change and development of new theory.

Conclusion

In light of the growing emphasis of including students with disabilities in the standard course of study and the use of technology to extend and support educational opportunities for marginalized communities, this study addressed a topic that is of critical importance to the training of both special and general educators at all levels. Further, the content focus on science education is a particular strength because this area often takes a backseat to reading, mathematics, and literacy. National standards in science seem to be in direct conflict with appropriate methods for presenting science content online. In addition, the methods for appropriate online science instruction may also be in conflict with the Web Accessibility Guidelines. Classroom teachers and curriculum developers, which may be teachers also, need to decide first what and how they will present online content. Next, the sociocultural communities of students need to be considered. In practical terms there may not be enough time or money to adequately design curriculum for online courses and make the content accessible for learning by students with disabilities. The value of these findings suggests that teachers who use the Internet for science content (or any other subject for that matter) should be aware of accessibility problems of external Internet Web sites and how this will influence curriculum modifications. Additional research is needed to analyze ho w science topics can appropriately be presented online to people with disabilities.

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Table 2
Accessibility Errors Categorized by Priority

	Accessibility Errors			Potential Accessibility Errors	
All Web sites					
Severity	*M*	**SD**		*M*	*SD*
Priority 1	.73	.629		7.75	1.79
Priority 2	2.47	1.42		13.90	2.15
Priority 3	1.65	.81		13.06	1.73
.GOV Web sites					
Severity	*M*	**SD**		*M*	*SD*
Priority 1	.54	.667		7.92	1.79
Priority 2	2.51	1.32		13.86	2.06
Priority 3	1.60	.69		13.26	1.80
.EDU Web sites					
Severity	*M*	**SD**		*M*	*SD*
Priority 1	.83	.506		7.48	1.65
Priority 2	2.19	1.14		13.55	1.83
Priority 3	1.56	.59		12.68	1.57
.ORG Web sites					
Severity	*M*	**SD**		*M*	*SD*
Priority 1	.83	.747		7.51	2.12
Priority 2	2.63	2.02		13.69	2.42
Priority 3	1.91	1.67		12.74	1.90
.COM Web sites					
Severity	*M*	**SD**		*M*	*SD*
Priority 1	.97	.585		8.36	1.69
Priority 2	3.15	1.69		15.58	2.59
Priority 3	1.82	.465		14.03	1.47

Table 7
Priorities, Errors, Explanations and Ease of Fix for Web Sites With Reported Errors

Priority	Error	Explanation	Fix
I	Not using an alternative method to convey information that appears in color	The site uses color to recognize information. A colorblind person may need to identify a color.	Provide an alternative tag, which is a piece of code that is embedded in the Web page that when a user moves the browser over the page there is a pop-up message.
	Not using an extended description for an image that conveyed important information beyond what was contained in the alternative text	For example the graph, only the name of the graph is given but the data and relationships in the graphs are not given. Student wouldn't be problem solving if answers are given. Does not follow a constructivist learning style. (Blind)	The fix is to describe everything in terms of relationships among data while sacrificing the students' ability to problem solve and conclude on their own. Unless the description is done in such a manner that they have to solve. Audio file.
	Not providing structural markup to identify table rows and columns that serve as headers	Embedding tables within tables and not providing directions for how the table should be read or navigated. For example, up to down or left to right.	Identify a column and rows as rows and columns.
	Not using alternative text for all images	There is no text to describe or title the image.	Provide a label or title of the image.
	Not identifying headers for table rows and columns	Headers provide a navigation tool for readers and identify the structural markup. Labeling of columns and rows are not done.	Label the headers of a table.
II	Not contrasting sufficiently the foreground and background colors	A person who is colorblind needs to have enough contrast of colors to distinguish between items.	Use contrasting colors in images, diagrams, and charts.
	Not avoiding the use of deprecated language	Avoid using language that talks down to the reader.	Re-writing the text.
	Avoiding movement in images	Do not provide simulations, animated gifs, and video.	If the animated gif is used to provide information, alternative text is needed to provide an explanation of the movement and concepts. Provide sound or transcript of the video.

	Not adding a descriptive title to links	A type of the alt tag. The description tells the person where the links will take them.	Provide the description.
III	Not including keyboard shortcuts to frequently used links	Exclusion of an alternate mean of navigating the page.	Include the keyboard shortcuts.
	Not specifying a logical tab order among form controls, links, and objects	Exclusion of an alternate mean of navigating the page.	Include the tab shortcuts.
	Not identifying the language of the text	There needs to be an indication of the language used in the Web page.	Provide the language tag at the beginning of the Web page.