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Impact of Modifying Activity-Based Instructional Materials for Special Needs Students in Middle School Astronomy

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Abstract

Middle school students who have special needs because they are learning disabled require targeted attention in our nation's pursuit of improved science achievement for all students. In early 2006, the Lawrence Hall of Science conducted a national field test of a newly developed GEMS (Great Explorations in Math and Science) space science curriculum package for middle school students. During this field testing, we modified a subset of the curriculum materials to reflect the principles of best practices in working with special needs students, specifically learning disabled students, in a subset of the field test classrooms to determine if these students scored differently on the assessments than students in the larger assessment database. Results suggest that many students, not just those with special needs, demonstrate achievement gains using instructional materials purposefully aligned with research- informed principles of best practices for special needs students.

1. INTRODUCTION

The National Research Council's National Science Education Standards (NSES) (1996) and the American Association for the Advancement of Science's Benchmarks for Science Literacy (1993) advocate that astronomy, and indeed all of science, should be taught with an increased emphasis on conceptual understanding and a decreased emphasis on memorizing long lists of names, disconnected facts, and plug-and-chug formulae. Without question, this notion is much easier to say than to put into actual classroom practice. As one of many examples of how challenging it is to fully realize this goal, consider that the teaching of seasonal changes due to the Earth's tilt to middle school students, roughly 11–14 years of age, has long been the bane of astronomy teachers the world over (Bailey & Slater 2003). The scientifically accurate reasons for the seasons are clearly an important part of the standards documents and is required for all students regardless of aptitude, background, or opportunity. In fact, the NSES promotes that all school-age students understand that "objects in the sky have patterns of movement. The sun, for example, appears to move across the sky in the same way every day, but its path changes slowly over the seasons." In addition, students should understand that "seasons result from variations in the amount of sun's energy hitting the surface, due to the tilt of the earth's rotation on its axis and the length of the day." Yet, students have tremendous difficulty internalizing these concepts accurately.

Given that educational research can inform instructors and curriculum developers about the challenges of teaching students about seasons, curriculum developers are finally in a position to use this information to teach all students. However, the catch phrase "*all* students" represents a tremendously wide and diverse group of learners. One particularly notable group of students included in the category of "all students" are those with special needs. This article addresses the specialized curriculum and instructional needs of students learning astronomy who are identified as being "learning disabled."

2. BACKGROUND

The federal No Child Left Behind Act of 2001 clearly states that all children deserve a highly qualified teacher and that all U.S. schools and students will increase achievement to meet higher standards. These ideals also apply to special needs students who need access to in-depth, challenging curricula so that they can participate fully in personal growth, obtain meaningfully satisfying careers, and contribute to society. Department of Education reports suggest that 10%–12% of the total population of school-age children in the United States are classified as having a disability that requires special education services (National Center for Education Statistics 2007). In addition, 30%–40% of the larger school population also may be at risk for school failure and experience problems much like students with mild to moderate disabilities. Unfortunately, simply adopting educational standards for all students does not automatically ensure acceptable academic achievement for diverse students (Gustafson 2002).

Despite the profound changes in the philosophies of science education and special education over the last few decades and the introduction of new technologies into classrooms, there has been insufficient change in science classrooms. Recent research suggests that today's students are especially poised to use and benefit greatly from classroom technologies because of their comfort with technology and the potential for connection with real-world learning. However, lack of adaptation and change is likely to interfere with the success of significant numbers of special needs students (Peterson-Karlan 2005). In view of current classroom realities, technology has the potential to be a basic tool to assist special needs learners in becoming more fully participating members of regular classrooms. Lewis (1998) has convincingly shown that learning activities aligned with a variety of technologies have positive benefits for diverse student populations, particularly special needs students. The present exploratory research study, which attempts to provide a descriptive example of an effective, technology-based instructional strategy that bridges the areas of science education, special education, and technology education, was undertaken with the goal of improving achievement among all students. As a result, the following research question was developed and pursued: Are the scores and work products of students with learning disabilities significantly different when these students are provided with technology-based instructional activities that have been modified according to the best practices for working with special needs students?

3. THEORETICAL FRAMEWORK

Morocco (2001) argued that science concepts are inherently complex and cannot be meaningfully understood through a single isolated learning experience. For Morocco, understanding concepts is most often demonstrated by knowledge use beyond the context in which it was learned. This can be developed through authentic tasks, anchored instructional environments, cognitive strategies, social mediation, and constructive conversation (Morocco 2001). Ogens and Koker (1995) similarly proposed that scientific literacy incorporates not only content knowledge but also underlying principles and a social impact component. Bybee (2002) expanded his definition of scientific literacy as a continuum of understanding and brought in the notion that another important characteristic of scientific literacy is that it is inclusive rather than exclusive—a most important facet considering the diversity of student ability levels present in a typical urban classroom.

Contemporary science education practices emphasize active learning—that is, that students will have a better understanding of, and be more interested in, science if they are intellectually engaged in the doing of science (Blosser & Helgeson 1990). However, other research by Lord (1999) provides some limits on the constructivist notion of science education by noting that even though an assignment may have a "hands-on" form, students may not actually be engaged in processes that lead to understanding. We know that students construct understanding by "an iterative process of theory building, criticism, and refinement" (Bransford, Brown, & Cocking 2000, 183). Bransford et al. also described the model of the inclusive science teacher as guide; supporting students as they explore problems should be part of the shared responsibility of learning within a community of scientific practice. Much of this is well summarized by Sanger (1997), who noted that the types and natures of students' connections are based in their experiences.

There is a broad spectrum of disabilities found in classrooms across the United States. However, McCann (1998) reported that over half of all students receiving special education services have been diagnosed with learning disabilities. Brownell and Thomas (1998) quoted Margo Mastropieri in making a definitive point: Science is a particularly good subject for students with disabilities "because science focuses on everyday life and daily experiences we have interacting with our environment" (119). Indeed, many students with disabilities could perform at a cognitively higher level than reading scores would initially indicate given the right learning environment (Rose & Meyer 2002). Some schools in the Rose and Meyer study were able to show no measureable achievement gaps among diverse students; these schools emphasize several key strategies that benefit all students. These strategies include emphasizing reading skills, teaching higher order thinking skills to all students, reteaching content using a variety of approaches, ensuring that all students are participating, and creating an affective connection for all students (Bell 2002). Given the robustness of science as a disciplinary pursuit, it is not surprising that science instruction has been readily identified by special educators as an especially accommodating area for special needs students (Cawley et al. 2002). In this sense, students must attempt to make sense of new information by incorporating it into their own prior knowledge and experience.

Technology projects that incorporate principles of situated learning (principles such as authentic context, and social interaction and collaboration) have been shown to provide an effective framework for learning (Basden 2001). Technology, in its broadest sense, begins with problems that children find important and naturally engages them by using their preexisting cognitive resources to encourage expansion of problem-solving strategies while providing a further context for communication and organization (Benenson 2001). As such, technology effectively becomes a basic tool to allow special needs learners to become more fully participating members of regular classrooms. Lewis (1998) has convincingly shown that learning activities that are aligned with a variety of technologies have positive benefits for diverse student populations. Some of these inclusionary classroom benefits include the promotion of positive attitudes, an emphasis on inquiry and process approaches to learning, and affirming student strengths. Targeted technologies can help students overcome print and communication barriers, learning disabilities, and both hearing and physical impairments. Technology has great potential for learning disabled students because it can provide contextualized (i.e., grounded in a meaningful conceptual framework) learning environments (Lewis 1998), and students in technology-rich environments show often academic achievement in all subject areas (Butzin 2001).

4. RESEARCH APPROACH AND METHODS

The researchers conducted an extensive literature review prior to carefully selecting the lessons that might be problematic for special needs students and in preparation for purposefully modifying the curriculum materials using best practices for teaching special needs students. Our research question encompasses three distinct areas within the educational research literature: science education, special education, and educational technology. Within each of these three areas, several themes emerge, as illustrated in Figure 1.

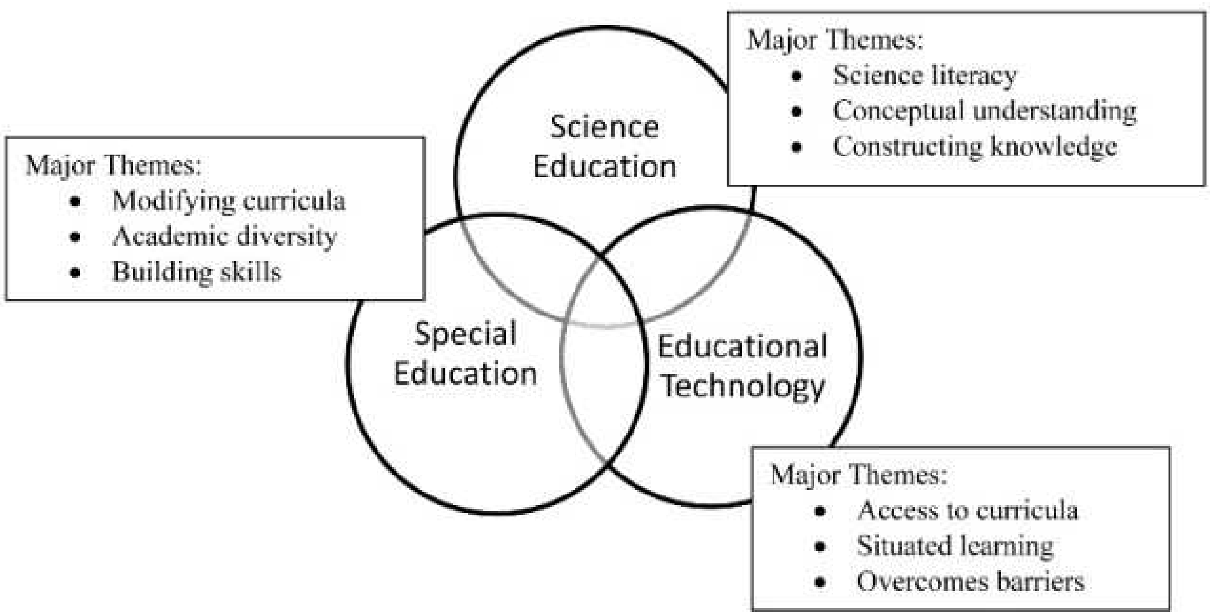

Figure 1. The Intersection of Three Fields of Study

A summary of specific problems and proposed solutions from the literature most pertinent to astronomy educators is presented in Table 1.

Table 1. Problems and Solutions

Area	Issue	Solutions	References

Science education and learning disabled students	The science class is potentially one of the more promising classes in which to provide an appropriate education in the least restrictive environment (LRE) because it has the potential (a) to allow students to interact, share, and collaborate during their learning; (b) for teachers and students to assist one another during instructional activities; and (c) to offer a variety of multimedia opportunities for learning and performance. This is especially important at the middle school level as students are preparing for the academic demands of secondary school.	Learning science has both cognitive and affective implications for students with LD. In this context, computer technology provides cognitively engaging and motivating instructional tools for individualizing the mode of delivery; developing expert tutors; anchoring instruction; integrating science with other subjects; reducing cognitive load on working memory; and motivating students to stay on task.	Cawley, J., Hayden, S., Cade, E., Baker-Kroczynski, S. (2002). "Including Students with Disabilities into the General Education Science Classroom." *Exceptional Children*, 68(4), 423–436. Kumar, D., & Wilson, C. (1997). "Computer Technology, Science Education, and Students with Learning Disabilities." *Journal of Science Education and Technology*, 6(2), 155–161.

Information processing	The learner must orient himself or herself to the instructional situation by becoming aware that a learning situation or opportunity exists.	Because many students have difficulty distinguishing between relevant and irrelevant information, cueing and directing student attention through the instructional representation could allow cognitive resources to be directed to the most relevant material.	Patrick, M., Carter, G., & Wiebe, E.(2005). "Visual Representations of DNA Replication: Middle Grades Students' Perceptions and Interpretations." *Journal of Science Education & Technology*, 14(3), 353–365. Yong, F., & McIntyre, J. (1992). "A Comparative Study of the Learning Style Preferences of Students with Learning Disabilities and Students Who Are Gifted." *Journal of Learning Disabilities*, 25(2), 124–132.
	Need to promote student attention or reception of incoming information.	Promotes student reception of incoming information: text, audio and multimedia options for gaining information.	Kumar, D., & Wilson, C. (1997). "Computer Technology, Science Education and Students with Learning Disabilities." *Journal of Science Education & Technology*, 6(2), 155–160. Deshler, D., Ellis, E., & Lenz, B. (1996). *Teaching Adolescents with Learning Disabilities* (2nd ed.). Denver, CO: Love Publishing Company.
	Learner must draw on appropriate prior knowledge to conceptualize or make logical associations with the new information.	Computerized modules anchor instruction by allowing students to revisit problem situations and gain meaningful understanding of the topic they learn.	
	Support student use of learning strategies (establishing a purpose, setting goals, activating background knowledge, predicting, visualizing, prioritizing, looking for patterns of information, and organizing information).	Content is reduced to simple elements, and components are then integrated. Students must be engaged in tasks that will require them to apply and generalize. Cues are provided to use cognitive strategies and take overt action.	
	Appropriate reinforcers to increase motivation permit students to have a certain amount of control and to make choices about their learning to enhance motivation and independent decision making.	Students have a choice of modules and sequence of presentation.	Yong, F., & McIntyre, J. (1992). "A Comparative Study of the Learning Style Preferences of Students with Learning Disabilities and Students Who Are Gifted." *Journal of Learning Disabilities*, 25(2), 124–132.

Reading	More easily perceiving a row of text on a page makes the text easier to read. Fewer attentional resources are required for the process of reading.	Simplified text Serif font	Gasser, M., Boeke, J., Haffernan, M., & Tan, R. (2005). "The Influence of Font Type on Information Recall." *North American Journal of Psychology*, 7(2), 181–188.
	Good readers are able to identify key ideas from text and discriminate their relative importance.	For each topic, key ideas are presented on one screen before students continue to interactive details.	Deshler, D., Ellis, E., & Lenz, B. (1996). *Teaching Adolescents with Learning Disabilities (2nd ed.).* Denver, CO: Love Publishing Company.
	Students with learning disabilities prefer an auditory learning mode.	Audio is an integral part of this program to build on student strengths.	Yong, F., & McIntyre , J. (1992). "A Comparative Study of the Learning Style Preferences of Students with Learning Disabilities and Students Who Are Gifted." *Journal of Learning Disabilities*, 25(2), 124–132.
Short-term auditory memory	Students with LD tend to have problems with short-term and working memory.	Stress important details; ensure that students have the prior knowledge/prerequisite skills needed to understand and make connections with new material; give students time to rehearse and elaborate on new information; and provide opportunities for students to practice material under different conditions and with different tasks to promote comprehension and transfer.	Deshler, D., Ellis, E., & Lenz, B. (1996). *Teaching Adolescents with Learning Disabilities* (2nd ed.). Denver, CO: Love Publishing Company.
	Content enhancement	Advance organizers; visual displays graphically depict lesson; study guides highlight critical content information, audio recordings, and computer-assisted instruction.	

Vocabulary	Students with learning disabilities often have inadequate vocabulary knowledge and difficulties with learning. Students with disabilities have a fragmented and less complete knowledge of words, as well as a narrow understanding of particular word features.	Practice is critical to vocabulary acquisition that, in turn, may lead to maintenance and generalization.	Jitendra, A., Edwards, L. , Sacks, G., & Jacobson, L. (2004). "What Research Says about Vocabulary Instruction for Students with Learning Disabilities." *Exceptional Children*, 70(3), 299–323.

Each of the modifications we made followed a similar research-informed, strategic approach to accomplish several goals:

- To focus student attention on the most relevant aspects and important details of the lesson information
- To present information in a variety of modalities
- To simplify text but not content
- To provide avenues for vocabulary acquisition by all students

Whenever possible, we provided opportunities for students to gain some degree of personal ownership in the learning process by giving them wide choice in the sequencing of obtaining scientific information. Additionally, the modifications present students with a number of experiences designed to encourage them to compare their alternative ideas with new information and develop an accurate representation of important concepts. Furthermore, the computer-mediated instructional modules often use voice descriptors and visual cues to lessen cognitive load and allow attention to be given to the most important information. Data were routinely separated onto different screens to promote student focus on relevant information for each section. Four examples showing before and after modifications are shown in Figures 2–5.

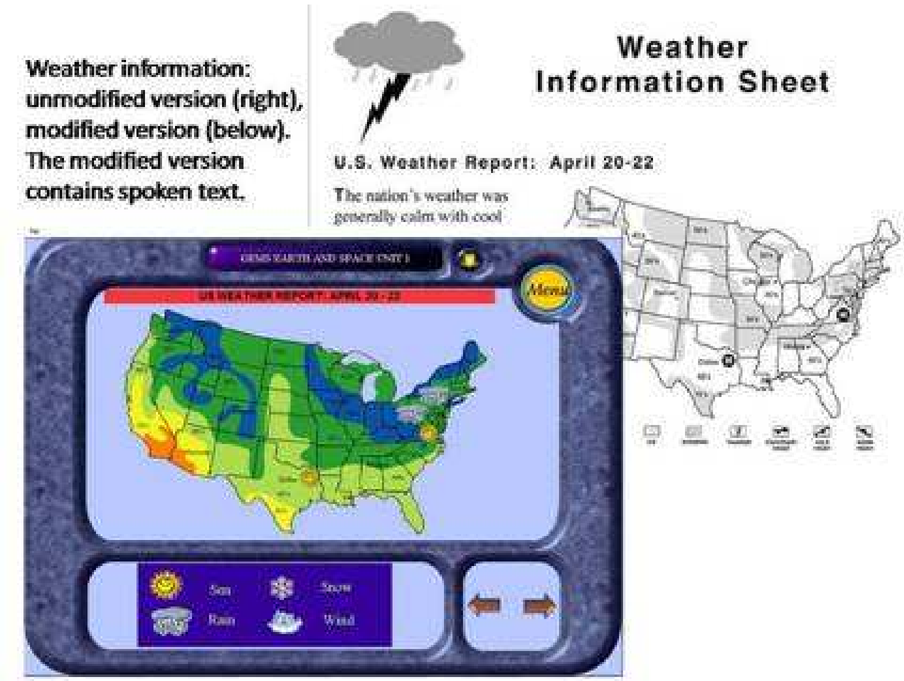

Figure 2. Comparison of weather data

Figure 3. Comparison of satellite data

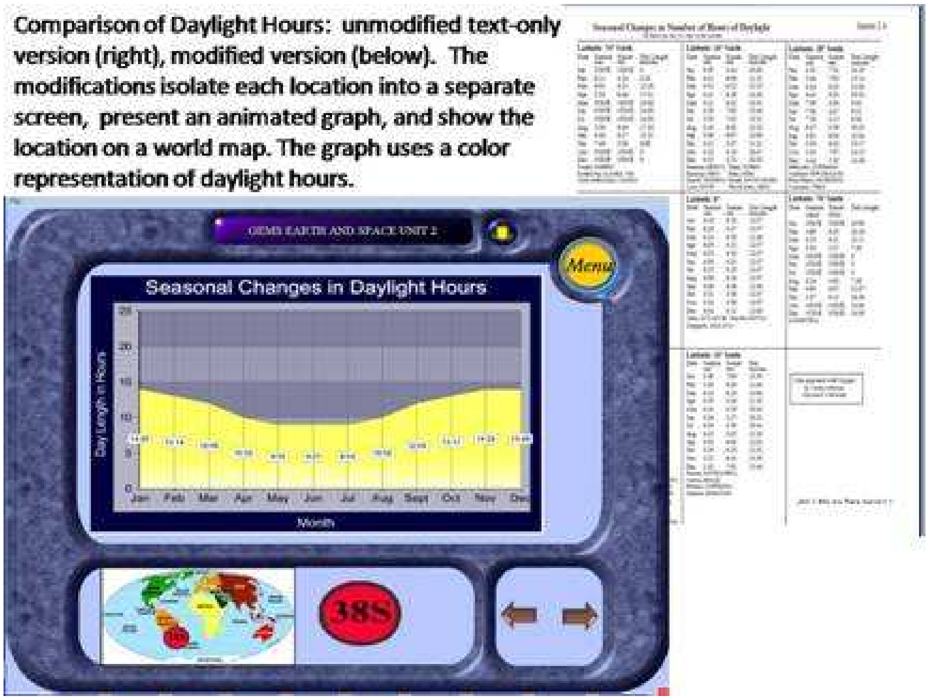

Figure 4. Comparison of daylight hours

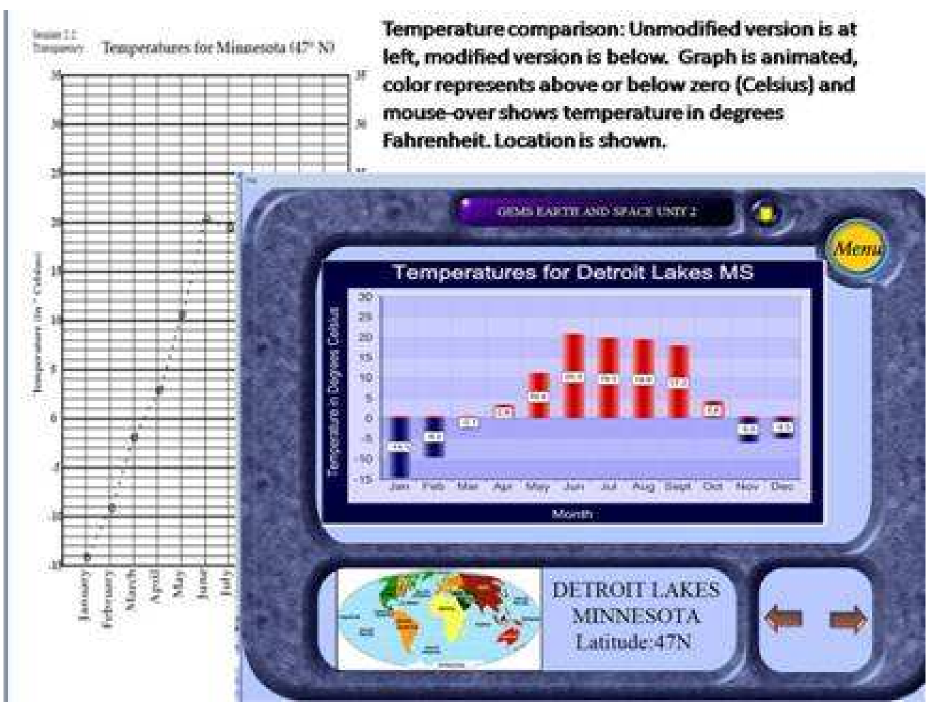

Figure 5. Temperature comparison

To pursue our research question, a four-group pretest/posttest quasi-experimental design was adopted. The four groups were (1) regular education students who participated in the unmodified curriculum, (2) special needs students who participated in the unmodified curriculum, (3) regular education students who participated in the modified curriculum, and (4) special needs students who participated in the modified curriculum. Evaluators from the Lawrence Hall of Science (LHS) collected cognitive pretest and posttest data for hundreds of middle school students across the nation as part of their national field test. These pre- and posttests consisted of six multiple-choice and written open-response questions (see the appendix). The targeted participants in the research reported here were middle school students who were identified by their teacher as receiving special education services but were enrolled in regular education science classes. Because special needs students reflect a quite small demographic group of students who are difficult to study in the best of circumstances, these participants were selected as a convenience sample of classrooms that were in the same geographic region as, and personally known to, the researchers. Students in the unmodified classrooms participated in the activity-oriented field test curriculum, which was common to all students within a particular class. Students in the modified treatment group received modified instructional activities that were mediated by a computer, and they used best instructional practices for students with special needs. Student responses were given randomly assigned tracking numbers, which allowed for pairing of pre- and posttest scores. Each student-participant completed a handwritten pretest administered at the beginning of each of the four units of study. This test was designed by the assessment and evaluation team at LHS. After taking the pretest, the students participated in either an unmodified or a modified curriculum. In this context, an unmodified classroom means that the students used the originally produced GEMS (Great Explorations in Math and Science) space science print instructional materials without computer-aided modifications. The vast majority of students in the national field test participated in the unmodified version.

LHS staff coordinated all the teachers who participated in a national classroom field testing of their revised space science curriculum. In all, more than 50 teachers participated at some level. Each student was identified by an anonymous code number assigned by the team at LHS. This code identified each student’s teacher, grade level, classroom section, gender, and whether the student had an active Individual Education Plan (IEP). The presence of an IEP in the student’s record was used as a proxy for identifying the individual as a special needs student. For the present study, four of the teacher-participants who agreed to participate were from the area in which the researcher lived. With the full knowledge and encouragement of the national field test team, these teachers agreed to use and administer the assessments for the modified versions of all four activity units that constitute the space science sequence. Student demographics were nearly identical across all schools, buildings, and classes and can be summarized as students at risk for school failure and students from low-income families (the schools have greater than 90% of the population on free and reduced lunch); a large number of the students had an IEP.

The participating teachers who used the modified version of the curriculum chose to use it for all their students: regular education and special needs students. At the beginning and conclusion of each module, student-participants completed handwritten tests. The only difference between the pretest and posttest was that the question sequence was changed slightly. All surveys were submitted to the national office by participating field test teachers, and a subset was randomly selected for scoring at LHS. Copies of all tests were sent to the researchers for our analysis.

5. FINDINGS

The performances of these four groups were compared on two separate quantitative measures. The first measure evaluates how well groups' overall gain scores (posttest minus pretest) compare for each instructional unit as determined by a scoring rubric provided by the LHS assessment and evaluation team. The second measure compares the groups' gain scores (posttest minus pretest) for an individual assessment item most closely related to the curriculum modification, again as guided by the provided scoring rubric.

The major finding of this work is that most special education students demonstrated substantial gains only when using the modified curriculum. Special education students who did not have access to the modified curricula showed a 7% decrease in gain scores. Regular education students who used unmodified curriculum showed an 8% average gain from pre- to posttest, whereas special education students who did not have access to the modified curricula showed a 7% decrease in gain scores. On the other hand, regular education students who used the modified curriculum averaged a 9% gain in their scores from pretest to posttest scores, whereas special education students averaged a 7% gain. In general, special education students who were taught using the modified materials had gains greater than any special education student who was taught only with the unmodified materials. Some individual special education students gained as much as 30%, and more than half increased at least 10% or more using the modified curriculum, as compared with only a 15% gain for just one of the special education students who used the unmodified curriculum; there were no other improvements over 10% within that group (see Table 2). It should be noted that the number of special needs student-participants with matched pretest and posttest surveys was quite small. This was due in large part to teachers having relatively few special needs students in each classroom. In fact, it required extensive effort to successfully acquire even the 21 matched data pairs presented here. Although we would have greater confidence in our results if there were larger numbers of students, we do judge this to be a reasonably credible sample for this exploratory study. Unfortunately, because the numbers of special education students participating in the field tests were small, we could not undertake a vigorous quantitative analysis of the results. Nonetheless, a qualitative inspection of these results gives some warrant to the claim that differences in student achievement gains do exist, depending on the set of curriculum materials with which they have engaged.

Table 2. Comparison of Overall Gains from Nationwide Aggregate, Unmodified, and Modified Groups

	Special needs students' pre/post gain	**Regular education students' pre/post gain**
GEMS aggregated	8 % mean correct gain (seventh grade)	
Unmodified curriculum	-7% (*n* = 6)	8% (*n* = 43)
Modified curriculum	7% (*n* = 15)	9% (*n* = 96)

Another relationship that appeared was related to how many items students were able to list when given an opportunity to provide student-supplied responses. As an example, students were asked, "What comes to the Earth from the Sun?" After scoring with the GEMS rubric, the responses were tallied for each student in the modified and unmodified groups. Special education students who used the unmodified curriculum did not demonstrate a noticeable increase in the number of their responses to the question (see Table 3). Students in the modified curriculum not only showed increases in the number of their responses, but most also showed improvement in the quality of responses, based on the GEMS rubric (Table 4). In addition, responses from special education students in the modified curriculum group were consistently within the range of responses found among the general education population, whose number of responses also increased. These data suggest that most special education students demonstrated substantial gains in learning the content using the modified curriculum, but not the unmodified curriculum.

Table 3. Unmodified Curriculum Group: Special Education Students' Responses to the Selected Question

Student	Pretest responses	Posttest responses
119	uv rays, light, heat	light
105	energy, heat, air	energy, air, water, sun, wind
006	hot wind, cold wind, light, heat	heat, light, air
009	sunlight, heat	light, heat
026	heat, light	light, heat
020	steam, light	heat, light, energy (listed twice)

Table 4. Modified Curriculum Group: Special Education Students’ Responses to the Selected Question		
Student	**Pretest responses**	**Posttest responses**
011	heat, uv rays, global warming	heat, rays, uv rays
016	particles, light, rays, radiation, heat, life	meteors, sunlight
051	rays	heat, light
053	light, heat	heat, light, energy
054	fireballs, heat, fire, light	solar flare, light, heat, energy
063	energy, light	energy, light, cancer, see it, heat
064	<blank>	xray, heat, energy
067	rays, heat, light	uv rays, sunlight, heat
070	energy, heat, oxygen, dry	heat, energy, light, oxygen, cme
108	light, energy, heat, skin cancer, elipses [sic], asteroids	light, energy, solar flares, heat, explosions
113	light, ultraviolet rays, warmth	heat, xrays, uv, solar flare, light
154	heat, uvlight, energy, solar rays	heat, rays, solar flares, energy
203	heat, light	energy, light, cancer
160	light, cancer, solar rays, heat	light, fire, spots, strang [sic] stuff, energy, dar(illegible)
209	light, energy, heat, electricity, power	energy, sun light, gas, heat

6. DISCUSSION

Both the quantitative and the qualitative analysis of the student work products strongly suggest that the scores and work products of special needs students are indeed substantially different when provided with technology-based instructional activities modified according to best practices for working with special needs students.

Two overarching observations are evident from these pretest–posttest four-group study results. First, gains in students' pretest to posttest scores were notably higher for the special education students who used computer-mediated instructional approaches that were designed using best practices identified for instruction of students with special needs. Second, the proportion of special needs students who provided more scientifically accurate and extended responses was much greater among the special education students who used the modified materials as compared with those who did not. Both of these results are consistent with previous findings presented in the literature (Rose & Meyer 2002). Sadler (1998) suggested that students do not simply move from inaccurate to accurate thinking and that it is difficult to construct a precise model that shows the flow of how students' understanding of scientific concepts evolves during instruction. This analysis supports Sadler's evolutionary perspective in that this study reveals subtle evolutions in student thinking. Although Sadler's work on learning astronomy did not look at special needs students specifically, the results of the current study targeting special needs students confirms a continuum of student understanding along which students can move. In addition, not all the regular education and special education students in this study demonstrated a fully mature and scientifically accurate understanding at the end of instruction, but the shifts they did show are strong indicators of conceptual progress.

Most important, special needs students in this study who used the modified materials demonstrated more conceptual growth than did the special education students who used the unmodified materials. Their responses demonstrated important conceptual movement from naïve understandings toward more scientifically accurate conceptions to a much greater degree than did the students who were taught only with the unmodified, conventional materials. Moreover, a related and somewhat serendipitous observation during this study was that regular education students also seemed to benefit from instruction designed with best practices for special needs students.

The results of this exploratory study lend support to dispelling some common (mis)conceptions of teachers regarding students with special needs and teachers' ability to engage these students successfully in science classrooms. To be blunt, there seems to be little evidence for the widely held yet tacit assumption that traditional, non–special needs students are somehow educationally disadvantaged when teachers "dumb down" curriculum by purposefully modifying materials for special needs students. In this project, the curriculum materials were most certainly not dumbed down in any sense; rather, we were able to purposefully use the best practices for working with special needs students to modify the curriculum and still maintain the intended level of academic rigor. Indeed, it could be argued that the intellectual engagement of the materials was actually enhanced overall because the ideas became more accessible to a larger group of learners These findings are consistent with the notion that when all students have the opportunity to deepen understanding through educational materials that are designed to meet their learning needs, opportunities for achievement are enhanced. Contemporary classroom instruction is indeed complex and demanding, but appropriate tools and instructional materials can help mediate learning for a wide range of students. In doing so, technology-based interventions have the potential to improve instruction for many students typically found in American classrooms across content areas and among general education as well as special education students.

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APPENDIX

Click here for the appendix in PDF.

Appendix URL: http://aer.noao.edu/auth/olsen.slater.appendix.pdf