ACM Transactions on Computing Education, Vol. 11, No. 3, Article 19, Publication date: October 2011.

Universal Design: Implications for Computing Education

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Universal design (UD), a concept that grew from the field of architecture, has recently emerged as a paradigm for designing instructional methods, curriculum, and assessments that are welcoming and accessible to students with a wide range of characteristics, including those related to race, ethnicity, native language, gender, age, and disability. This proactive approach holds promise for more fully including underrepresented groups in computing studies and for decreasing the need, and thus costs, for academic accommodations for students with disabilities. This article summarizes the history and development of UD, references research and practices that support the UD approach, provides examples of the strategies that apply UD to instruction and assessment, and recommends topics for future research. Although the application of UD to teaching and learning is in its infancy, the potential of UD to improve computing instruction should not be ignored. Further research could test the efficacy of specific UD practices in promoting learning in computing fields.

Categories and Subject Descriptors: K.3.2 [**Computer and Information Science Education**]:

General Terms: Human Factors

Additional Key Words and Phrases: Disability, accessibility, universal design, instruction, teaching, assessment

ACM Reference Format:

Burgstahler, S. 2011. Universal design: Implications for computing education. ACM Trans. Comput. Educ. 11, 3, Article 19 (October 2011), 17 pages.
DOI = 10.1145/2037276.2037283 http://doi.acm.org/10.1145/2037276.2037283

1. INTRODUCTION

Student bodies in higher education are increasingly diverse. It has been estimated that today one-fourth of postsecondary students are racial/ethnic minorities, more than half are women, the average student age is rising, and more than 6% of students have disabilities [Horn and Nevill 2006; Lewis and Farris 1999; Pryor et al. 2006]. In addition, student skills and experiences influence postsecondary learning outcomes (e.g., academic skills, self-regulatory strategies, reading and writing abilities, mathematics skills, time management and organizational skills, life experiences) [Santangelo and Tomlinson 2009]. Of the students who report having disabilities, the largest group is composed of students who have invisible disabilities, such as those that affect the ability to read, compute, pay attention, and interact with others. Veterans returning from recent wars are contributing to the growing pool of college students with disabilities.

Diversity issues in a classroom may include physical, sensory, learning, attention, and communication differences such as those described below.

- –Physical Differences: Spaces that are not wheelchair accessible are unusable by some individuals. Standard keyboards and mice prevent computer use by those who have no or limited hand function, unless they are replaced with expanded or mini keyboards, alternative mice, speech input devices, or other assistive technologies.
- –Visual Differences: Print, videos, and other materials with visual content erect access barriers to students with visual impairments unless large print formats, tactile materials, audio versions, and/or electronic text are provided. Students who are blind need their computer systems to convert screen text to Braille or speech. Additionally, for these students to understand content within graphic images, a software or Web site developer must include alternative text descriptions that can be read aloud by their screen reader software.
- –Hearing Differences: The audio content of videos and other multimedia is inaccessible to students who are deaf unless it is captioned or transcribed. Although some communication methods, such as e-mail, are fully accessible to them, individuals with hearing impairments may be unable to participate in on-site, telephone, or videoconferencing discussions unless accommodations such as sign language interpreters or real-time captions are provided.
- –Learning Differences: Web sites that change formats from one page to the next or crowd too much content on the screen are confusing to many students, including students with specific learning disabilities that impact the ability to read, write, or process information. Students with a wide variety of learning styles, strengths, and preferences may find it difficult to gain knowledge when course content is presented in only one way. When time provided to complete a test is inadequate, students who have learning disabilities that affect processing speed are placed at a disadvantage. Students with learning disabilities that affect their ability to interpret written text require audiobooks and/or screen reader software on computers.
- –Attention Differences: Some students are distracted by cluttered Web sites or find it difficult to pay attention to lectures or labs without printed outlines, instructions, or other organizational tools.
- –Communication Differences: Communication differences include those related to hearing ability, brain injuries, autism, native language, culture, age, or other factors. E-mail and other modes of communication that do not require the ability to hear or speak are fully accessible to individuals with speech and hearing impairments and benefit students in courses where the spoken language is not their native language. However, fast-paced on-site or online discussions, teleconferences, or audio conferences may limit the participation of these individuals [Burgstahler 2008a].

The universal design (UD) approach holds promise for addressing diversity issues such as these in order to more fully engage all students in academic studies, including those in computing. The author of this article summarizes the history and development of applications of UD in educational settings, references research and practice that supports the UD approach, and recommends topics for future research. She also shares specific strategies that apply a UD to course syllabi, Web resources, teaching methods, presentation materials, labs, and assessment instruments.

2. HISTORY OF UD

Ronald Mace—an internationally recognized architect and educator—coined the term *universal design* in the 1970s, thereby challenging the conventional practice of designing products for the average user. Through the Center for Universal Design (CUD) at North Carolina State University, he defined UD as "the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design" [Center for Universal Design n.d.]. The Assistive Technology Act of 1998 [Assistive Technology Act of 1998] provides a definition as well: "The term 'universal design' means a concept or philosophy for designing and delivering products and services that are usable by people with the widest possible range of functional capabilities, which include products and services that are directly accessible (without requiring assistive technologies) and products and services that are interoperable with assistive technologies." A familiar example of a UD feature is the curb cut, now typically integrated into sidewalk design to ensure usability not only by individuals using walkers or wheelchairs, but also by those pushing baby strollers and delivery carts.

Product developers, architects, and engineers at CUD established seven UD principles to consider in the design of any product or environment [Connell et al. 1997]:

–Equitable Use: The design is useful and marketable to people with diverse abilities.
–Flexibility in Use: The design accommodates a wide range of individual preferences and abilities.
–Simple and Intuitive: Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.
–Perceptible Information: The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.
–Tolerance for Error: The design minimizes hazards and the adverse consequences of accidental or unintended actions.
–Low Physical Effort: The design can be used efficiently and comfortably and with a minimum of fatigue.
–Size and Space for Approach and Use: Appropriate size and space is provided for approach, reach, manipulation, and use, regardless of the user's body size, posture, or mobility.

Some researchers and practitioners have used CUD's seven principles of universal design as a foundation on which to develop unique guidelines, performance indicators, or application checklists for specific domains, including those for information technology, physical spaces, student services, and instruction. For example, building on earlier work by the DO-IT Center (Disabilities, Opportunities, Internetworking, and Technology), the *AccessComputing* project at the University of Washington (UW) developed the checklist *Equal Access: Universal Design of Computing Departments* [AccessComputing 2009] to guide postsecondary computing departments in making their offerings welcoming and accessible to all current and future students. It addresses issues related to planning, policies, and evaluation; facilities; support services; information resources; computing courses and faculty; and computers and assistive technology.

3. UD AND INSTRUCTION

The application of UD strategies to instruction—where UD principles are applied to curricula, teaching methods, and assessments—holds promise as faculty try to effectively teach a student body that is increasingly diverse with respect to abilities and disabilities represented. In contrast to UD, many instructors and institutions focus only on the provision of accommodations to address disability issues. An *accommodation* is an adjustment or modification to make a product or environment accessible to an individual with a disability. Accommodation is grounded in the medical model of disability, in which a professional identifies an individual's functional "deficits" and prescribes adjustments that allow him or her to participate to some degree in the "normal" environment [Gill 1987; Hahn 1988; Jones 1996; Swain and Lawrence 1994]. Examples of accommodations include printed materials in alternate formats (e.g., Braille, electronic), extra time on tests, sign language interpreters, and assistive technology. To receive accommodations in higher education, students typically disclose their disabilities to a specified individual or office at the institution, provide acceptable documentation of their disabilities, and request accommodations that may or may not be approved by the institution. The institutional representative shares approved accommodations with faculty members, who are required to do their part in ensuring compliance (e.g., providing extra time on tests).

Whereas accommodation is a *reactive* approach to provide access to an individual, UD is a *proactive* approach focused on ensuring access to participants with a broad range of characteristics. UD is consistent with an understanding of disability as a social construct much like those related to gender, race, and ethnicity;

disadvantages associated with disabilities are considered, for the most part, to be imposed by the inaccessible design of products and environments [Gill 1987; Hahn 1988; Jones 1996; Swain and Lawrence 1994]. UD reduces, but does not eliminate, the need for accommodations for students with disabilities. For example, if a professor posts resources for her computing class online in an accessible format, no accommodations or redevelopment would be necessary if a blind student enrolls in the class. Thus, planning ahead with UD may save time in the long run.

Research and practice in the areas of civil rights, social justice, and multicultural education shed light on diversity issues with respect to race, ethnicity, socioeconomic status, age, and gender [e.g., Hackman and Rauscher 2004; Knowles 1980; Pliner and Johnson 2004]. Much research has also been conducted on the wide variety of learning styles, strengths, and preferences of students that is present in most courses [Claxton and Ralston 1978; Dunn and Griggs 2000; Kolb 1981; Wooldridge 1995]. It has been found that each student has preferred learning modes—visual, auditory, tactile, and/or kinesthetic [Wooldridge 1995], and experiences learning according to his or her dominant style as a converger, diverger, assimilator, or accommodator [Claxton and Ralston 1978; Svinicki and Dixon 1987]. The theory of multiple intelligences—linguistic, logical-mathematical, spacial, bodily-kinesthetic, musical, interpersonal, intrapersonal, and naturalistic [Gardner 1983]—describes how people perceive the world in a variety of ways. Rather than addressing only the most common learning style(s), educators who embrace UD employ a balanced mix of teaching approaches in order to address a broad range of learning differences. These include multiple modes of delivery, multiple ways for students to interact with each other and the course content, and multiple ways for students to demonstrate what they have learned. The following summary by Svinicki supports the UD strategy to engage in multiple modes of instruction.

> "It is appropriate to acknowledge that there are individual variables among students that can influence the effectiveness of instruction. However, more research is needed to verify which of the proposed differences is most strongly grounded in empirical data and has the best record of relating to learning. Until those data have been gathered and properly analyzed, our best instructional strategy to cope with individual differences is to provide an array of learning alternatives and let the learner choose among them rather than trying to force one on everyone or even on a single individual." [1999, p. 19]

UD does not require that an educator abandon his adopted teaching and learning philosophies, theories, and models—for example, differentiated instruction [Hall et al. 2003; Santangelo and Tomlinson 2009]; constructivism [Ben-Ari 1998]; self-paced, computer-assisted instruction based on behaviorist theory [Svinicki 1999]; learner-centered instruction [Barr and Tagg 1995]; socio-cultural approaches to teaching and learning [O'Loughlin 1992]. Rather, UD can make his current practices more inclusive [Burgstahler 2008b]. For example, many postsecondary educators have adopted the principles of good practice in undergraduate education that were distilled by Chickering and Gamson [1987] from the extensive research base focused on teaching and learning in postsecondary education. Table I provides examples of how UD can enhance the implementation of each of these principles so that all students benefit from the resulting practices.

Table I. UDI Applied to Principles of Good Practice

Principle of Good Practice in Undergraduate Education	Example of UD Applied to the Principle of Good Practice
Encourages contact between students and faculty.	Include a statement on the class syllabus inviting students to meet with the instructor to discuss disability-related and other learning needs.
Develops reciprocity and cooperation among students.	Encourage multiple ways for students to interact with each other—for example, in-class questions and discussion, group assignments, Internet-based communications. Assign group

	work that rewords diverse contributions with respect to skills and roles.
Encourages active learning.	Provide multiple ways for students to participate and ensure that all students, including those with disabilities, can engage.
Gives prompt feedback.	Regularly assess student progress using multiple, accessible methods and tools and adjust instruction accordingly.
Emphasizes time on task.	Ensure that all students, including those with disabilities, have adequate time to complete tasks.
Communicates high expectations.	Keep expectations high, including those for students with disabilities, and provide accommodations to level the playing field without giving unfair advantage.
Respects diverse talents and ways of learning. [Chickering and Gamson 1987]	Adopt practices that reflect high values with respect to both diversity and inclusiveness [Burgstahler 2008b, p. 31].

Research is not plentiful on the efficacy of UD as a collection of strategies to increase learning for a diverse audience. Some published studies and many practitioners suggest the value of universally designed curricula [e.g., Gordon 2002; Pisha and Coyne 2001]. However, few available curriculum products at any educational level fully embrace UD [Golden 2002; Rose et al. 2006].

The largest collection of published research studies that support specific UD instructional practices was compiled in a three-stage process by researchers at the National Center on Universal Design for Learning, a unit of the Center for Applied Special Technology [National Center on Universal Design for Learning n.d.]. In the first stage, these researchers constructed a general framework for Universal Design for Learning (UDL) using as a research basis studies in neuroscience, cognitive neuroscience, and neuropsychology. Distilled from that review were three basic learning networks in students and three corresponding UDL principles for educators: (a) provide multiple means of representation, (b) provide multiple means of action and expression, and (c) provide multiple means of engagement. In the second stage, through a meta-analysis of educational research, UDL researchers identified practices that have been found to be effective in reducing barriers to instruction and organized them around the three principles. In the third stage, they conducted secondary searches of literature using keywords and concepts suggested by the meta-analysis. Nearly 1,000 articles were eventually selected as an evidence base for nine UDL guidelines, which are listed below under each of the three UDL principles.

- Provide multiple means of representation.
  1. Provide options for perception.
  2. Provide options for language and symbols.
  3. Provide options for comprehension.
- Provide multiple means of action and expression.
  4. Provide options for physical action.
  5. Provide options for expressive skills and fluency.
  6. Provide options for executive functions.
- Provide multiple means of engagement.
  7. Provide options for recruiting interest.
  8. Provide options for sustaining effort and persistence.
  9. Provide options for self-regulation.

A total of 32 checkpoints were developed as examples of implementation strategies for the nine guidelines. Each checkpoint is quite specific. For example, checkpoint 2.5 is to provide options that illustrate key concepts non-linguistically. CAST researchers summarize their findings as:

> "In formal schooling, there is a marked tendency to present the majority of information in language, specifically in printed text. Many students for whom language is not a particular strength thus face persistent barriers not experienced by others. The experimental studies on the option of illustrating key concepts non-linguistically listed here span a range of media. There is extensive research to support the representation of information through a variety of formats: video, diagram, image, music, animation, and more."

An average of 30 articles with experimental and quantitative evidence was assigned to each checkpoint. The vast majority of these references are at the K-12 level, focus on reading and writing skill development, and test implementation of a specific strategy in a specific content area at a specific academic level. The specificity of the research articles cited is illustrated by one article title, "A comparison of two approaches for teaching complex, authentic mathematics problems to adolescents in remedial math classes" [Bottge and Hasselbring 1993]. A review of the article titles suggest that fewer than 10% of the references specifically address science and mathematics and none of them focus specifically on computing instruction. It cannot be assumed that the individual findings would be the same in situations different than tested in the studies, such as in a postsecondary computing course. The collection of research does not address the efficacy of combinations of UDL strategies applied in a single classroom.

The UD approach has been supported in federal legislation. For example, the Higher Education Opportunity Act (HEOA) of 2008 [The Higher Education Opportunity Act 2008] established the statutory definition for "universal design for learning to be a scientifically valid framework for guiding educational practice that—(A) provides flexibility in the ways information is presented, in the ways students respond or demonstrate knowledge and skills, and in the ways students are engaged; and (B) reduces barriers in instruction, provides appropriate accommodations, supports, and challenges, and maintains high achievement expectations for all students, including students with disabilities and students who are limited English proficient." The Act further promotes the application of UD and other strategies and the creation of corresponding resources for faculty and administrators that can help them make postsecondary education more accessible to students with disabilities [Gordon et al. 2009].

Research that compares the results of a course taught with and without the application of universal design principles is beginning to emerge in the literature. For example, Beckman [2009] reported offering two versions of a graduate information management course, one section taught in the way he had offered it in the past—with lecturing as the primary instructional method—and one "treatment" section taught with the addition of small group discussion as an instructional method, which is an example of the UD strategy to use multiple instructional methods. Students in the treatment section reported that they thought "the instructor was open to a variety of points of view" more often than did students in the control section; these students also performed better on essay-type exam questions than did students in the control section; and both groups performed the same on multiple-choice/fill-in-the-blank exam questions and in actual software use.

Several published articles have reported the positive reactions of students to a wide range of universal design strategies [Durre et al. 2008] and to the application of multiple modes of instruction in specific classes [Kortering et al. 2005]. Unpublished, anecdotal evidence also supports UD practices. For example, the author of this article is regularly called upon to deliver presentations on universal design, often to large audiences that may include individuals with a variety of disabilities. All presentation videos are captioned, Web site resources are universally designed, handouts are provided in alternate formats, presentation visuals use large bold fonts and are uncluttered, a microphone is used by the presenter, and, before the audience arrives, chairs are moved so that any wheelchair-users who might attend have multiple options for positioning themselves in the room. Efforts are also made to speak slowly and clearly, describe orally all content that is presented visually, avoid unnecessary jargon, define terms that might be unfamiliar to some attendees, make eye contact with and engage many members of the audience, and repeat questions asked by attendees before answering them. These proactive steps on the presenter's part minimize the need for special accommodations; typically, the only disability-related accommodation requested in these presentations is a sign language interpreter or real-time captioner by an individual who is deaf; such arrangements would be requested ahead of time by the participant from the event sponsor. Particularly positive feedback given by attendees includes appreciation for the flexibility of the seating arrangement by individuals who use wheelchairs, for video captions by attendees who are deaf and by those whose first language is not English, for orally describing visual content by individuals who are blind, and for providing materials in multiple formats by many.

Universal design of instruction has been embraced on some campuses nationwide [e.g., Burgstahler 2008b; Burgstahler and Doe 2006; Getzel et al. 2003; Gordon et al. 2009; Harrison 2006; Ouellett 2004; Shaw and Scott 2003] and many resources have been created to support faculty interested in applying UD to instruction [DO-IT; Gradel and Edson 2009-2010]. There are reports of campus-level faculty training that has included UD as a strategy to help instructors more effectively serve students with disabilities [Getzel et al. 2003; Office of Postsecondary Education n.d.], and some teaching and learning centers have incorporated UD in helping faculty develop inclusive strategies for instruction and assessment and select and develop curriculum [Darr and Jones 2008]. UD of instruction has also been embraced by professional organizations such as the Association for Higher Education and Disability (AHEAD), which launched the Universal Design Initiative in 2001 in support of its mission to "dynamically address current and emerging issues with respect to disability, education, and accessibility to achieve universal access" [AHEAD n.d.].

To facilitate the application of UD concepts in a classroom, some practitioners who have applied the UD approach have described specific strategies that have a foundation in research or practice. For example, collaborators in projects funded by the U.S. Department of Education [DO-IT 2007] at the UW DO-IT Center in Seattle developed guidelines for faculty to use in applying UD to their instruction and computer labs [Burgstahler 2007a, 2007b; DO-IT]. The initial checklists were created after a review of literature that identified evidence-based or other promising practices that embody the UD philosophy to make instruction more inclusive of individuals with diverse characteristics [Bowe 2000; Bruch 2003; Burgstahler and Doe 2006; Burgstahler et al. 2005; Cunningham 2003; Hitchcock and Stahl 2003; Johnson and Fox 2003; Mason and Orkwis 2005; McAlexander 2003; Mino 2004; Moriarty 2007; Orkwis and McLane 1998; Pedelty 2003; Pieper 2005; Rose et al. 2005, 2006; Rose and Meyer 2002; Savidis and Stephanidis 2005; Scott et al. 2003; Silver et al. 1998]. The checklists continue to be enhanced as new research and promising practices are reported in the literature. In an informal iterative process, UD was applied to instruction, services, physical spaces, and technology on more than 20 campuses in projects hosted by the DO-IT Center. Specific strategies were modified based on formative feedback from faculty and administrators of participating postsecondary institutions. As revealed in the final project report, outcomes from faculty training using content in the UD materials were assessed with multiple measures. Post-training surveys suggest increased knowledge and skills of faculty after participation in training offerings and faculty intentions to incorporate specific UD strategies into their teaching practices. Implementation of a quasi-experimental research design resulted in evidence of increased grade point averages of students with disabilities in courses taught by trained instructors when compared to those they taught before training; students with disabilities in a comparison group of untrained faculty did not show an increase in grade point averages over the same period of time [DO-IT 2009].

4. EXAMPLES OF UD STRATEGIES EMPLOYED IN A COURSE

The DO-IT checklist regarding the application of UD to instruction is not meant to be comprehensive and has not undergone rigorous testing with respect to student outcomes. Rather, it provides suggestions from practitioners for educators to consider as they begin to explore how the UD approach might be integrated into the following eight aspects of their instruction and assessment:

–Class Climate: Adopt practices that reflect high values with respect to both diversity and inclusiveness.
–Interaction: Encourage regular and effective interactions between students and the instructor and ensure that communication methods are accessible to all participants.
–Physical Environments/Products: Ensure that facilities, activities, materials, and equipment are physically accessible to and usable by all students, and that all potential student characteristics are addressed in safety considerations.
–Delivery Methods: Use multiple instructional methods that are accessible to all learners.
–Information Resources/Technology: Ensure that course materials, notes, and other information resources are engaging, flexible, and accessible for all students.
–Feedback: Provide specific feedback on a regular basis.
–Assessment: Regularly assess student progress using multiple, accessible methods and tools and adjust instruction accordingly.
–Accommodation Plan: Provide accommodations for students whose needs are not met by the instructional design [Burgstahler 2007b, p. 2-5].

As an example of how UD could be applied in a computing course, an instructor might choose to integrate the following strategies within her teaching and assessment practices:

–Select printed materials and prepare a syllabus early to allow students the option of beginning to read materials before the course begins and allow adequate time to arrange for alternate formats, such as books in audio format or in Braille.
–Include a statement in her syllabus inviting students to meet with her regarding learning challenges, disability-related accommodations, and/or computer and technology lab access issues.
–Provide a comprehensive syllabus that includes learning objectives, a grading rubric, course assignments and deadlines, test dates, and student resources.
–Arrange seating to ensure each student has a clear line of sight to her and visual aids and allow room for wheelchairs in multiple locations.
–Give students scaffolding tools such as outlines, graphic organizers, and copies of projected materials with room for note taking.
–Use large, bold fonts on uncluttered overhead displays.
–Speak aloud content presented with visual aids.
–Face the class, speak clearly, make eye contact with all students, and refer to students by name.
–Incorporate background and contextual information.
–Present content in a logical order, summarize what has been covered periodically, and emphasize major points.
–Avoid unnecessary jargon and complexity; define new terms and acronyms.
–Provide multiple examples of specific concepts to make them relevant to individuals with diverse characteristics with respect to gender, ethnicity, race, socioeconomic status, age, ability, disability, interest, and life experiences.
–Repeat questions asked by students to ensure all have heard them.
–Encourage students to share multiple perspectives and model mutual respect.
–Avoid drawing undue attention to a difference, such as a disability.
–Put class notes and assignments on a Web site in an accessible, text-based format.
–Provide multiple ways to demonstrate knowledge, allow ample time for tests, and use a testing format that is consistent with teaching practices and assignments.
–Provide regular feedback and corrective opportunities (e.g., allow students to turn in parts of a large programming project for feedback before the final project is due and give students some credit for correcting errors after an assignment is first submitted).

–Know campus protocols for getting materials in alternate formats and arranging for other accommodations for students with disabilities.
–Make sure that assistive technology can be made available in a computer lab in a timely manner when requested.

If these strategies simply sound like good teaching practices, they should. UD is an approach for designing instructional methods, curriculum, and assessments that are welcoming and accessible to students with a wide range of characteristics, including those related to race, ethnicity, native language, gender, age, and disability. Educators have intentionally adopted practices to make instruction more inclusive since the beginning of time. Their strategies are grounded in research (e.g., the use of multiple modes of instruction, design features that make a Web site accessible to individuals who are blind), some are commonly accepted as inclusive practices (e.g., putting a statement on a syllabus to encourage students to discuss their learning needs with the instructor, including examples in class that appeal to students with a variety of backgrounds), and some have emerged through previous teaching experiences in a specific content area and academic level. The author of this article, for example, remembers a professor in a mathematics teaching methods course she took in her undergraduate work who repeatedly said that, when teaching a new mathematics concept to students, present it in three different ways—ideally using three different senses—in order to address the wide variety of learning styles of students and as well as to promote deeper understanding of the concept for all students. One can argue that this approach could today be classified as UD.

In applying the UD philosophy, an instructor considers diversity issues in making broad teaching method, curriculum, and assessment choices, but also in implementing specific methods. For example, using small group discussions is often promoted as a UD strategy that increases the overall engagement of more students in a class and leads to increased learning. However, some students may actually learn more effectively from a lecture. It's the *combination* of small group discussions with lectures that exemplifies a UD approach. And, applying UD to both the small group discussions (e.g., taking steps to ensure that all participants are engaged) and the lectures (e.g., describing verbally all content that is presented visually) furthers the UD approach. As another example of the continuum of a UD practice, putting class notes on a Web site may be an important step toward a universally designed course; making sure that these materials are posted in a format accessible to students who are blind and using screen reader software is another step toward a course that fully embraces UD. In short, a professor who adopts the UD philosophy is never done, but rather is always exploring ways to make a course more inclusive of everyone who might take it.

5. ONE COMPUTING PROFESSOR'S EXPERIENCES IN APPLYING UD

For several years, Daniela Marghitu of Auburn University has embraced the UD philosophy as she delivers computing and IT courses [Auburn University n.d.]. Students enrolled in her classes have included those with limited vision and hearing, motor disabilities, emotional difficulties, speech difficulties, and learning disabilities; students whose first language is not English; individuals with behavioral, attention, and motivational challenges; students from various cultural backgrounds; and students classified as gifted.

Specific UD strategies Marghitu has employed—and shared with the author of this article through in-person and e-mail correspondence—include developing accessible online portals for students and instructors; using educational technology with supports to serve students with a wide range of needs, including those related to disabilities; providing recordings of lectures; employing a variety of instructional approaches; and designing course PowerPoint slides to be accessible to individuals with disabilities. She has also trained graduate teaching assistants to effectively work with students who have special needs.

Anecdotal evidence suggests that inclusive strategies make Marghitu's courses welcoming and accessible to students with and without disabilities. She has witnessed how new technologies, when used by instructors who are dedicated to engaging all students, offer increasing options for responding to the multifaceted individual differences in the student population. Students with and without disabilities have reported that they benefitted from having course materials available online and have praised features such as pre-tests that allow them to identify what knowledge and skills they need to gain.

Two students with visual impairments who earned the highest possible grades in the COMP1000 Personal Computer Applications traditional course expressed gratitude for making the course lab and instructional materials fully accessible to them. Another student with a visual impairment enrolled in the COMP10003 Personal Computer Applications Independent Learning course reported that she could complete all course requirements by using her personal computer without accommodations from the disability services office. Students with learning disabilities reported that they benefited from Web-based training that allowed them to go through instructional materials multiple times and successfully search for answers themselves instead of having to ask questions in class or during office hours. Their feedback suggests that these instructional features increased their confidence in pursuing computing fields. Students who are deaf and those for whom English is a second language specifically reported benefits of the online course feature that displays content presented in videos and audio PowerPoints as transcripts. Marghitu continues to integrate new inclusive practices into her teaching and expects that they will continue to address the increasing levels of diversity that she has witnessed in her classes.

Marghitu and two of her graduate students, Fuller, and Brahim, have published their experiences in developing a universally designed portal for the Auburn University IT minor [Marghitu et al. 2009]. Positive feedback from traditional and distance learning students has encouraged them to further develop their IT minor courses in sync with the technical trends and job markets, eliminate the gender gap among students, and more fully address the needs of students with disabilities [Marghitu et al. 2008, 2009].

6. UD IMPLICATIONS FOR COMPUTING EDUCATION RESEARCH AND PRACTICE

After reviewing some of the current interests of practitioners and researchers as reported in computing education literature, the author of this article identified four ways in which UD might contribute to research and practice in the future. They are discussed in the paragraphs that follow.

6.1 Broadening the View of Diversity

Some articles that address diversity [e.g., Buerck et al. 2003; Wilson 2002] present issues that could be enhanced when viewed through a universal design lens. UD might broaden a researcher's or practitioner's view of diversity in the classroom from considering only issues facing women and minorities to include those that impact students with disabilities as well. For example, one research study identified factors that promote success in an introductory college computer course [Wilson 2002; Wilson and Shrock 2001]. The model presented includes twelve possible predictive factors—math background, attribution for success/failure (luck, effort, difficulty of task, and ability), domain-specific programming experience, previous non-programming computer experience, and gender. Using a universal design lens, the impact of disability and other diversity characteristics could be explored in future research with respect to this model.

6.2 Identifying and Enhancing Existing UD Practices

Without necessarily referencing UD, some articles in computing education report and test teaching strategies that some might classify as UD because they hold promise for making computing instruction more inclusive.

Examples include offering students a variety of assignment options in response to their diverse interests and needs [Davis et al. 2001]; presenting material in multiple ways [Pollard and Duvall 2006]; reducing lecture and increasing interaction [Pargas 2006; Pollard and Duvall 2006]; integrating a project-based approach in computing instruction [Barron et al. 2002]; creating an active learning environment [Pollard and Duvall 2006]; providing frequent assessments and feedback [Moskal et al. 2004; Pargas 2006]; supporting kinesthetic learning [Pollard and Duvall 2006]; employing multimedia [Kleinman and Entin 2002; Moskal et al. 2004] and making sure it is accessible to students with disabilities [Marghitu et al. 2009]; using scaffolding, mnemonic, and other learning aids [Chang et al. 2001; Linn 1995; Pollard and Duvall 2006]; and adjusting instruction to address a variety of learning styles [Buerck et al. 2003] and cognitive development [Buck and Stucki 2001]. Testing of such promising practices in future research could be enhanced through further consideration of UD issues. Questions addressed could include, for example, "How can classroom interactions be increased in such a way that students who are deaf are fully included?" or "How can a multimedia learning tool be made accessible to students who are blind?"

6.3 Considering UD Issues in Learning Theories

Some articles in the literature point to specific learning theories that can guide an instructor's approach to teaching. For example, constructivism "is a theory of learning which claims that students construct knowledge rather than merely receive and store knowledge transmitted by the teacher" [Ben-Ari 1998, p. 257]. Researchers exploring such theories could enhance their work through consideration of diversity issues, such as "How might the presence of Asperger's syndrome impact the way a student constructs knowledge?"

6.4 Including UD as a Computing Curriculum Topic

By considering users with diverse characteristics, including abilities and disabilities, it can be argued that the UD approach to design leads to better design of products, including those in the computing field [O'Leary and Gordon 2009]. Computing instructors should therefore consider how their courses might increase in quality by infusing the UD philosophy within their curricula. For example, if the creation of application software is part of an assignment in a computing course, the instructor could require that students apply UD principles as they develop their software interfaces so that they are usable by all potential users, including those with disabilities.

6.5 Measuring the Impact of UD on the Computing Learning Environment

Researchers and practitioners have identified the learning and communication climate of typical computing courses to be isolating, combative, defensive, impersonal, and hierarchical [Barker and Garvin-Doxas 2004; Waite et al. 2004]. Many of the behaviors in these courses inhibit collaboration and acceptance of diverse perspectives and abilities. Researchers in this area have suggested that instructors can make communication choices (e.g., collaborative processes incorporated into computing assignments) that lead to a more supportive climate for learning. Ultimately, such choices may increase the participation of under-represented groups and help meet the demand for computing professionals with collaboration skills valued by industry [Barker and Garvin-Doxas 2004; Waite et al. 2004].

The points made in the paragraphs above are consistent with recommendations made by Holmboe et al. [2001] in an article that examines the nature and scope of computer science education research. In this article, the authors argue that a weakness of existing published research is that few articles reference pedagogical theories underlying the research. The authors propose that future researchers in this area make a stronger connection between their work and the theoretical frameworks used in education and psychology disciplines such as cognitive science and pedagogy. They conclude that more empirical research and comparative evaluation is needed to explore and validate effective teaching practices in computing fields. Such research could lead to recommended teaching strategies to maximize learning outcomes for all students in specific computing courses that are evidence-based.

7. CONCLUSION

Faculty members, including those in computing fields, face an increasingly diverse student body that includes growing numbers of students with disabilities. What might be the first response of a professor when a student who is blind enrolls in his computing class? Would he look forward to the unique perspective this student brings to the field and classroom or only be concerned about what accommodations might be necessary and how much time they might require to implement? An important step to creating a welcoming and inclusive classroom environment for all students is to truly value diversity in all of its many forms—to see, in this case, differences in visual abilities as a normal, interesting part of the human experience. Originally applied to the development of physical spaces, technology, and consumer products, UD has more recently emerged as a paradigm for the development of instruction, curriculum, and assessment. The UD philosophy encourages instructors to apply a mix of teaching and assessment strategies to address diversity and strive to implement each strategy so that it is inclusive of and accessible to all students. This approach potentially reduces the need for disability-related accommodations and benefits many students, including those with undisclosed disabilities and those for whom English is a second language. However, further research is required to identify and test the efficacy of specific UD practices when applied to computing instruction.

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This article is based upon work supported by the National Science Foundation (Grant #CNS-0837508, CNS1042260, HRD-0833504, and HRD-0929006. Any opinions, findings, and conclusions or recommendations are those of the author and do not necessarily reflect the policy or views of the National Science Foundation, and you should not assume their endorsement. Author's address: S. Burgstahler, DO-IT and Accessible Technology Services, UW Information Technology, University of Washington, Box 354842, Seattle, WA 98195; email: *sherylb@uw.edu*.
DOI 10.1145/2037276.2037283 http://doi.acm.org/10.1145/2037276.2037283

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Last modified: Wednesday January 11 09:54:12 PST 2012