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Technology Integration for Students with Disabilities: Empirically Based Recommendations for Faculty

Catherine S. Fichten, Jennison V. Asuncion, Maria Barile, Christian Généreux, Myrtis Fossey, Darlene Judd, Chantal Robillard, Christina De Simone, and David Wells
Adaptech Project, Dawson College, SMBD Jewish General Hospital, McGill University, Concordia University, Université du Québec, Université de Montréal,
Montréal, Quebec Canada

ABSTRACT

In 3 empirical studies we examined the computer technology needs and concerns of close to 800 college and university students with various disabilities. Findings indicate that the overwhelming majority of these students used computers, but that almost half needed some type of adaptation to use computers effectively. Data provided by the students and by a small sample of professors underscore the importance of universal design in a variety of areas: courseware development, electronic teaching and learning materials, and campus information technology infrastructure. Sex and age of students were only minimally related to attitudes toward computers or their use in our samples. Key findings summarize the problems faced by students with different disabilities as well as the computer related adaptations that are seen as helpful. These are used to formulate concrete, practical recommendations for faculty to help them ensure full access to their courses.

The advent of the computer revolution has resulted in rapid changes in both theory and practice in postsecondary education (cf. America's 100 Most Wired Colleges – 1999, 2000; Campus Backbone Connectivity, 1999; EDUCAUSE Online Guide, 2000). Multimedia, web based delivery of course materials, virtual communities, and learner rather than teacher centered approaches have resulted in a resurgence of interest in improving postsecondary teaching and learning. The excitement, however, is more evident in the

Address correspondence to: Catherine Fichten, Psychology Department, Dawson College, 3040 Sherbrooke St. West, Montreal, Quebec, Canada H3Z 1A4. Tel.++1 (514) 931-8731, ext. 1546. E-mail: catherine.fichten@mcgill.ca

literature rather than in practice (cf. The 1998 National Survey of Information Technology in Higher Education, 1998).

It is by no means proven that computer assisted instruction is superior to traditional delivery of education (cf. Russell, 1997, 1999). What is clear, however, is that in the foreseeable future newly emerging educational media are not only here to stay but will proliferate (e.g., Farrell, 1999; Mercier, 1999; Office of Learning Technologies, 1998a, 1998b). Many postsecondary institutions and faculty are scrambling to acquire the basic skills needed to function given the new realities (cf. UCLA Graduate School of Education & Information Studies, 1999).

It should come as no surprise that professors, like many other groups in postsecondary education, generally don't know what kinds of things to do to ensure that their students with disabilities have full access to their electronic course materials (cf. Banks & Coombs, 1998). Indeed, many do not know that computer technologies are accessible to students with most disabilities, including those who are blind or have low vision (cf. Apple & Special Needs, 2000; IBM, 1999, 2000; Microsoft, 1999). Paradigms for how best to incorporate computer technologies into courses in specific disciplines are not yet evolved (Cuneo, 1997). Therefore, much energy goes into the design of electronic courseware (LTReport, 1999). Regrettably, as is the case for overall institutional instructional technology planning, access concerns of students with disabilities are simply not considered by professors either.

Most professors have not thought about which features of software and hardware make these inaccessible and they have little idea about how access problems could be circumvented or solved (e.g., some educational CD-ROMs have fonts that are too small to see for some students with visual impairments; tables, PowerPoint, and Adobe Acrobat PDF files can cause problems for many students who are blind; some students have problems with accessing web sites due to screen sizes and colors; students with hearing impairments will probably miss the audio portions of video clips and have problems with audio on web pages and most CD-ROMs; some students have problems in computer labs when they need to use a mouse, etc.). Needless to say, solutions to such problems are also not evident to faculty.

The present research, which examined the computer, information and adaptive computer technology needs and concerns of postsecondary students with disabilities, highlights issues of relevance to professors and underscores the importance of barrier free, universal design in courseware, electronic teaching and learning materials, and campus information technology

infrastructure. Our research was designed with the assumption that while faculty are the experts in their disciplines, they are often poorly prepared to ensure the accessibility of their courses to students with physical, learning, and sensory disabilities (cf. Amsel & Fichten, 1990; Fichten, Goodrick, Tagalakis, Amsel, & Libman, 1990). Therefore, our objective in conducting the three studies which comprise the present investigation was to provide useful and relevant information for the postsecondary education community by ascertaining the nature of computer technology barriers and facilitators for students with various disabilities.

Universal access

Over the years, those working to promote access for people with disabilities have learned two important lessons. First is the cost-effectiveness of incorporating universal accessibility features at the outset of a project (e.g., Connell et al., 1995; Ekberg, 1999; Jacobs, 1999; NODE Networking, 1998). These ideas are exemplified in the seven principles of universal design for computer technologies proposed by Connell et al. (1995). These authors also show how these principles can be applied to both hardware and software design to ensure accessibility not just for people with disabilities but also for the safety and comfort of all.

For instance, implementing accessibility features in the initial layout of a building results in fewer design, construction and legal expenses (Falta, 1992). Second is the need to consult with progressive and sophisticated consumer groups. These individuals' diverse backgrounds make them uniquely qualified to think of creative solutions to environmental barriers created by lack of access. Consistent with this stance, here we present the views of students with disabilities, thereby allowing them a voice in formulating the accessibility agenda. Permitting students a voice in their own education is an approach that is advocated by many learning and instructional theorists and practitioners who see learning and teaching as a shared enterprise between students and teachers (e.g., Brown, 1994; McKeachie, 1994). This is relevant for accessibility issues as well as more fundamental curriculum concerns.

Postsecondary education for people with disabilities

Postsecondary education for people who have a disability is important for the same reasons as it is for nondisabled people; it helps to fulfill personal goals, allows for effective competition in the job market and contributes to independence and financial security. Estimates of the number of North American postsecondary students with some disability have ranged from 5%

to 11% (CADSPPE, 1999; Disabled Students In Postsecondary Education, 1997; Greene & Zimbler, 1989; Henderson, 1995, 1999; Horn & Berktold, 1999). Data from the United States show that graduation rates are similar for students with (54%) and without disabilities (64%) (Horn & Berktold, 1999).

In fact, postsecondary education is more important for people who have a disability. It has been shown, for example, that although employment figures for university graduates with disabilities is somewhat lower than that for their nondisabled peers (e.g., Horn & Berktold, 1999), once employed, salaries are similar, and their rates of employment are still substantially higher than that of students who did not complete university, who, in turn, fare better than those who never went to college (Government of Canada, 1996; Louis Harris & Associates, 1994). Data on postsecondary students and graduates with disabilities indicate that most want to work (Hubka & Killean, 1996).

The benefits of online education for students with disabilities have been described extensively (e.g., Shumila & Shumila, 1998) and there are data available which suggest that participation by students with disabilities in computer supports provided on campus for students with disabilities was related to better academic performance (Shell, Horn, & Severs, 1988). Moreover, people with disabilities who have a high level of computer skill were shown to have more favorable employment outcomes (Pell, Gillies, & Carss, 1997). Clearly, new information and learning technologies used for the purpose of assisting all people through life-long learning must continue to be inclusive of people with disabilities.

Wasser (1998), in applying recommendations made in Newsweek magazine to his university, refers to six important criteria for good technology access in postsecondary institutions: (1) access to university systems and the internet from a variety of locations at various times of day; (2) training on computers and the internet; (3) technical support when and where students are using computers; (4) digital libraries which provide on-line access to catalogues and electronic texts; (5) faculty support and training on integrating technology into courses; (6) responsiveness to the needs of the community (e.g., on-line application, e-mail, course and university information on the web). Although at this time this is generally not the case, the same criteria need to be applied to students with disabilities.

Present study

Training programs, case studies, demonstration projects, on-line journals of opinion, and policy statements about computer, information and adaptive

technologies for students with disabilities proliferate. Nevertheless, there is virtually no empirical research that evaluates the use or the utility of computer or learning technologies in the postsecondary education of students with disabilities. Notable exceptions concern evaluations of specific learning strategies for students with learning disabilities (e.g., Higgins & Zvi, 1995; Learning Disabilities Association of Canada, 1996; Lewis, 1998; MacArthur, Graham, Haynes, & DeLaPaz, 1996; Raskind & Higgins, 1998), and evaluations of satisfaction and media usage of students with print disabilities (Epp, 1998). In addition, three recent investigations have explored computer technology needs of postsecondary students with disabilities (Coomber, 1996; Hubka & Killean, 1999; Roessler & Kirk, 1998). However, the sample sizes of two of the investigations have been small (Coomber, 1996; Roessler & Kirk, 1998) and computer technology related questions comprised only a minor component of the single large scale study (Hubka & Killean, 1999). To the best of our knowledge, only one study (Coomber, 1996) investigated concerns of professors.

To provide more comprehensive information, between the fall of 1997 and the spring of 1999 we conducted a series of three studies where the goal was to evaluate the computer needs and concerns of Canadian students in postsecondary education (cf. Fichten, Barile, & Asuncion, 1999a). To obtain an overview of the important issues, in Study 1 we conducted focus groups with professors and with postsecondary students with various disabilities. In Study 2 we obtained in-depth information from structured interviews with students, and in Study 3 we collected comprehensive information via questionnaire from a very large sample of students. College and university students with disabilities who participated in our study had either one or more of the following: physical, sensory, motor, psychological/psychiatric, medical, learning, or other self-identified disabilities/impairments. When it came to learning disabilities, we used the definition of the Learning Disabilities Association of Canada (2000). This refers to difficulties in attention, memory, reasoning, coordination, communicating, reading, writing, spelling, calculation, social competence or emotional maturation which can affect learning and behaviour in any individual, including those with average or above average intelligence.

One question of interest concerns the relationship between age, attitudes, self-ratings, and behaviors related to computer use. The literature suggests that older individuals are likely to have less favorable views about technologies in general, and computer technologies in particular, and that

they are likely to be less efficient and comfortable with these (e.g., Czaja & Sharit, 1998; Meyer, Sit, Spaulding, Mead, & Walker, 1997). But is this true of students with disabilities, many of whom have used some sort of adaptive technology in the past? Similarly, it was also possible that one should not generalize from findings on sex differences in the nondisabled population, which suggest that although differences are slight, women are likely to have less favorable views and experiences with computers than their male counterparts (Kirkup, 1999; Price & Winiecki, 1995; Shashaani, 1997; Whitley, 1997). The present investigation also examines these possibilities.

STUDY 1

Method

In the fall of 1997 we held focus groups in a large metropolitan area to obtain an overview of issues and concerns. Of importance here are data from (1) a group of 12 students (7 female, 5 male) currently enrolled in a postsecondary educational institution and (2) a group of professors with substantial experience teaching students with disabilities from college and university arts, science, and ''careers'' disciplines ($n = 5$: 3 female, 2 male). Professors in the group had taught students with a variety of different types of impairments.

Focus group questions are available in Fichten, Barile, and Asuncion (1999b). Students were asked about advantages and disadvantages of computer and/or adaptive computer technologies for students with disabilities, their personal experiences with these technologies, and factors which prevent or help students to access these technologies. Professors, too, were asked about advantages and disadvantages and about factors which prevent or help students with access to these technologies. They were also asked about: their computer related experiences with students who have disabilities; new developments in computer technologies in their disciplines; potential benefits and limitations of computer technologies for students with disabilities; and additional computer related services from their colleges and universities that would make teaching students with disabilities more effective.

RESULTS

Responses were systematically grouped into categories; some of these were based on the questions themselves while others were derived from responses (cf. Morgan, 1988).

Students

Advantages of computers in the following categories were mentioned: computers assist with writing, help surmount barriers caused by specific impairments, help organize and speed up work, and promote personal growth. Disadvantages were noted in four major areas: academics, the need for training and assistance, attitudinal and classroom problems, and disability-specific disadvantages.

In response to the question about impediments to using computers effectively, the high cost of computer technologies and training and/or retraining were frequently noted concerns. Students also indicated problems with access to software and hardware (e.g., ''Dragon Dictate doesn't work with the cheap sound cards at my college,'' ''icons are useless for the blind''). They also noted the absence of appropriate software/hardware to assist students with their specific needs (e.g., ''there are no specialized programs for dyslexia, thus, I must still rely on a proofreader''). Students also cited attitudes as barriers (''I wanted a note taker but the professor wouldn't allow it–once I got a computer to help me take notes I had problems gaining acceptance from others in class''). They also cited lack of information about existing funding programs and policy related problems.

Professors

The professors' group focused on computers in postsecondary education in general rather than on disability related issues. Nonetheless, professors did indicate some disability related concerns: lack of information about the computer and/or adaptive computer technologies concerns of students with disabilities, lack of time to pursue further learning, and the role of students in providing crucial information about helpful computer technologies.

Professors' views about advantages were similar to those noted by the students. Some related to learning: ''in classes where technology becomes integrated, it encourages more varied working styles.'' The internet was seen as having potential (e.g., ''the internet might provide useful access and useful language changes in text/Braille/voice recognition, etc.''). Two professors noted disability-specific adaptations as advantages: ''access to information allows students with disabilities to become independent of others in acquiring information,'' ''some students can hook up the computer to a Braille printer.'')

Disadvantages noted by professors were generally different from those expressed by students with two exceptions: ''the cost of the technology'' and the generalized institutional ''lack of focus on student needs.'' Other

disadvantages noted by professors related to the use of computer technologies in general.

Professors appeared conscious of new developments in their disciplines. Responses regarding the benefits of computers ranged from how the use of computers could facilitate the professor's tasks (e.g., ''the real advantage to requiring all students to type is that it makes things much easier–no papers with 'whiteout' '') to ways of enhancing teaching in general (e.g., ''computers are useful in providing (simulations) models''). Professors also made some disability specific comments (e.g., ''we found voice input commands exciting–if you don't have manual dexterity it helps,'' ''the internet–shift from DOS (text-based) work to visual Windows (GUI)–how does it impact the blind?'' ''you've got to type fast or you get lost (if you don't have a lot of manual dexterity then it's harder to contribute to on-line dialogue)'').

Responses to a question about what computer, information and adaptive technology services the school could provide to make teaching students with disabilities more effective focused primarily on acquiring information (e.g., ''teachers need more information on technology'') and on lack of time (e.g., ''as a teacher, there's not enough time to get used to new technology – there's no advance warning as to who is bringing what (computer, information and adaptive technologies),'' ''we rely on students to tell us about the new technologies,'' ''it is helpful to have a demo of what students are using'').

DISCUSSION

Review of commonalties between the student and professor groups indicates that the most prominent element is the view that computers have tremendous potential but that they also can pose barriers. This suggests that solutions need to be found while these technologies are still in the developing stage. The following were issues noted as problematic: cost of computer technologies, the need to upgrade, and the need for training and/or retraining. Other issues include concerns about the rapid changes in software and hardware and limitations of technologies in responding to the needs of users in general and users with disabilities in particular.

Student participants were more disability conscious in their understanding of the advantages and the problems with computer applications and in finding solutions to problems. Professor participants, while less disability centered, seemed equally aware that computer and information technologies can

provide substantial advantages for students with disabilities. In fact, participants in professor and student focus groups converged in describing the advantages of computer and information technologies for students with disabilities. The most notable of these is the belief that computers can create access to information, thereby allowing students with disabilities to become independent. Responses by students with disabilities reflected Roulstone's (1998) view that using computer technologies is a way to enhance access, but that these technologies can also erect barriers. Another issue touched upon in both groups is that new computer technologies are changing the role of all who work in academic institutions.

Lack of information on the part of professors was also prominently noted. One goal here is to remedy this situation. To do so we obtained more comprehensive views and fuller descriptions of the types of computer technologies students use and find helpful in a structured interview study.

STUDY 2

Method

In the spring 1998 semester we conducted structured telephone interviews with 37 college and university students with disabilities representing all regions of Canada. Again, the main focus was on the computer, information and adaptive technology needs and concerns of students with disabilities.

Procedure

Participants were recruited through personal contacts, our student group partner (NEADS), the National Educational Association of Disabled Students and personnel responsible for providing services to students with disabilities. Interviews were conducted by telephone. A TDD (telecommunications device for the deaf) was used when necessary.

Interviews consisted of 17 sets of questions based on findings from Study 1 (questions are available in Fichten et al., 1999b). Participants provided demographic information such as age and sex. Of interest to the present investigation are students' responses to questions about their studies, the nature and duration of their disabilities, and the impact of the impairment/disability on using computer equipment and on their performance as a student. Also, on 10-point scales participants rated how often they used computers (frequency), how comfortable they were with computer technologies (comfort), and their level of expertise (expertise).

Participants

Sixteen of the 37 participants (20 females and 17 males) were enrolled at a college, 19 at a university, and 2 at distance education institutions (1 college, 1 university). Ninety-five percent of participants were students at the time of the interview; the remainder had graduated or taken a leave during the previous year. The majority (73%) were enrolled on a full-time basis. Almost half of the sample were pursuing a Bachelor's degree. Fourteen percent were pursuing a postgraduate degree, and the rest a certificate or diploma.

Mean age was 29 (SD = 11, range = 17 to 56), with most students (62%) falling into the 17 to 28 age range. Students had a variety of impairments/disabilities: 41% had a visual impairment (slightly more than 16% were totally blind and 24% had low vision) 35% had a medical or psychiatric impairment, 32% had a learning disability (this includes attention deficit disorder), 32% had problems using their hands or arms, 22% had a hearing impairment (5% used sign language and 16% had a hearing impairment), 22% had a mobility impairment, and 11% had a speech/communication impairment. Half of the sample had multiple impairments; the mean number was 1.86 per student. Approximately 3/4 of the sample had their disabilities since childhood (age less than 10) and only 8% had acquired their disability recently (past 5 years). Students were enrolled in a variety of programs, with the majority in social science, commerce, and science. Overall, students in the present sample closely resemble postsecondary students with disabilities in other investigations (e.g., Fichten et al., 1990; Henderson, 1999).

RESULTS

Different types of students

Only 2 of the 37 students indicated that they did not use computers. Thus, comparisons between computer users and non-users were not possible.

Do older students experience more problems with computers? We examined the relationship between student age and several variables of interest, including self ratings of: frequency using computers, $r(33) = -.03$, $p > .05$, expertise, $r(33) = -.04$, $p > .05$, and comfort with computers, $r(33) = -.11$, $p > .05$. None of these Pearson product-moment correlation coefficients show significant relationships.

Do female students experience more problems with computers than males? Independent *t*-tests were used to evaluate differences between the 21 female

and 16 male students on frequency, expertise, and comfort using computers. We also examined possible sex differences in age and number of impairments, as these variables may influence scores on the computer related items.

Means and test results show that computers are used frequently by participants ($M = 8.11$ on a 10-point scale), that respondents who use computers are reasonably comfortable with them ($M = 7.41$) and they consider themselves to be relatively well experienced ($M = 6.65$). Although scores of males were always greater than those of females, there were no significant differences on any of the variables. Only one variable approached significance: comfort using computers, $t(33) = 1.80$, $p < .10$; this suggests that males ($M = 8.19$) may be more comfortable using computers than females ($M = 6.74$).

What is the impact of students' impairments/disabilities? Thirty of the 37 participants (81%) indicated that their disability affects their activities or performance at school (see Table 1). As for using computer technologies, almost half of the sample (43%) had difficulties with the monitor as well as with the mouse. In addition, a substantial number of students had problems with the keyboard (23%), with diskette manipulation (14%) and with using a printer (9%).

What are the advantages and disadvantages of using computers for students with disabilities? All 35 computer users in our sample indicated advantages ($M = 3.20$ advantages per student). Six of them, however, indicated that they experienced no disadvantages ($M = 2.07$ disadvantages per student). Specific advantages and disadvantages detailed elsewhere (Fichten, Asuncion, Barile, Fossey, & De Simone, in press) indicate that computer technologies allow students access to information, promote feelings of independence and autonomy, and can compensate for students' disabilities. Key disadvantages include common complaints about computers, such as that they are not user-friendly; the necessity for continual upgrading, and cost. Students also indicated that computers often fail to adequately meet their disability related needs as products are inaccurate (e.g., dictation software), work poorly (e.g., grammar checkers), cannot cope with certain tasks (e.g., voice software cannot read graphics), and are inaccessible (can't control mouse with shaky hands).

DISCUSSION

This study provided rich detail about how the disabilities of students with different types of impairments impact on their academic lives. Best

Table 1. Study 2: Students' Responses to Questions About How Their Disability Affects Their Lives at School.

Common Concerns Of Students With Different Disabilities

- I have note takers.
- I use computers during exams with an instructor present.
- Have to study much longer hours.
- Everything takes longer.
- Extra time for exams.
- Behind other students all the time.
- Always a distinction no matter how hard you tried and succeeded.
- Always having to prove myself.
- Try too hard to make friends (self conscious because of my disability).
- Family life and social life suffer because I am constantly studying.

Students With Visual Impairments

- I can't read overheads.
- I can't take part in certain forums at school because the material is in print form.
- Tape some lectures but teachers did not always say what was written on the blackboard.
- Wait for people to take me when I need to get around the school.
- Friends walk me from class to class.
- Someone comes to the library with me to help me do research and look up info on databases.
- Catalogues in library are too small to read.
- Visual impairment makes it difficult to get materials for researching essays.
- Could not do microscope work in biology lab.
- I use large print or books on tape.
- Try to find out if books for school are on tape ahead of time.
- I have to wait for material to be put on tape.
- Difficulty accessing the internet.
- Math equations were difficult for the computer (for the synthesized speech software to properly read them).
- Did math problems on Braille then had it transcribed into print for teacher or read it to them orally or did work on tape.
- For math, hired students who would read solution sets onto tape for me.
- I was given an office because of speech on computer – because it would disturb other students.
- Oral exams.
- Have to be very organized – I felt like an administrator. Performed equally with others but worked twice as hard.

Students With Hearing Impairments

- Difficulty hearing instructor or questions from students.
- Hard to recognise speech when one talks with accents.
- Seminar classes are not accessible due to lack of technology.
- Hard to take part in study groups because I can't follow conversations because I have to lip read.
- Miss info in large groups.
- Background noise in computer labs is distracting – it's difficult to have a conversation.

Table 1. (*Continued*).

Students With Mobility And Neuromuscular Impairments

- Some doors are hard to open.
- One elevator in school and it's a long way to get to it.
- Books are too high on shelves in library.
- Elevator too narrow – I get stuck.
- Because I have to arrange transportation to and from school I cannot attend any activities on short notice.
- Home library because I can't get help on the spur of the moment or travel so far all the time to go to the school's library.
- I rent hotel rooms because there are no housing arrangements for students who live far and don't need to be at school all the time.
- Difficulty writing – can't take notes in class by hand.
- I get my notes from other people because I can't write.
- I orally tell scribe what to write when I am doing an exam.
- Use laptop to take notes.
- If a classroom or any area of school is not accessible for a wheelchair then what am I to do?

Students With Learning Disabilities

- Difficulty keeping up with taking notes off blackboard. They write faster than I write because my spelling is poor and it takes me longer to write.
- Can't write fast enough to get important info and can't remember it to write later.
- Sometimes I jump around sentences when I copy off the board.
- I can't judge distance so I generally get in people's faces (spatial problems).
- Difficulty reading textbooks.
- I can't keep up with assigned readings.
- I need extensions on papers and exams.
- Memorizing for tests is difficult. I don't retain a lot of what I read.
- Difficulty concentrating.
- Feel pressure when writing exams because instructors didn't always know about LD (learning disability) and I didn't always get extra time.
- I lose marks on spelling in class tests. This makes me more anxious.

experienced by reading the students' own words, these are abstracted in Table 1. The findings also show that computer technologies have multiple benefits for students with disabilities, but that there are also significant barriers to the effective use of computers in postsecondary education.

Although the questions were not designed to specifically study sex or age differences, the data lent themselves to an exploration of these attributes. On the three variables investigated we found no significant sex or age differences.

Only a trend was noted on the item related to comfort using computers, favoring male students.

STUDY 3

METHOD

Procedure

During the Spring 1999 semester questionnaires were made available in a variety of ways at more than 200 campuses across Canada with the cooperation of college and university personnel who provide services to students with disabilities on campus. In addition, questionnaires were mailed to the membership of our two student consumer group partners: the National Educational Association of Disabled Students (NEADS), and the Association québécoise des étudiants ayant des incapacités au postsecondaire (AQEIPS). In addition to regular print versions, questionnaires were made available in the following alternate formats: large print, audiotape, Braille, and diskette (available in EvNet, 2000). At the request of a distance education disability service provider we also prepared an e-mail version of the questionnaire which was distributed to a limited number of students. Questionnaires contained 29 groups of questions: most were closed-ended and used a 6-point Likert scale with 1 indicating strongly disagree and 6 indicating strongly agree (the measure is available in Fichten et al., 1999b).

Participants

Current or recent Canadian students with disabilities returned 736 questionnaires. Of these, 11 were excluded because the respondents had not been students during the past 2 years, leaving a total sample size of 725 (425 females and 300 males). Participants represent all Canadian provinces and territories and comprise current college ($n = 335$) and university students ($n = 294$), including 11 distance education students. Twenty-nine participants were not currently enrolled in a postsecondary educational institution but had been students during the past 2 years. Forty-eight percent of current students were pursuing a college diploma or certificate, 42% were studying for an undergraduate or graduate university degree, and 10% were taking courses outside a formal program. Responses were obtained from students at 154 Canadian universities and junior/community colleges; these represent

176 autonomous campuses, many of which are located in cities different from the parent institution. The majority of students were enrolled in arts (67%). Slightly less than a third (29%) were enrolled in science and technology programs. The programs of the remaining students could not be classified.

Mean age was 30 (standard deviation = 10, range = 17 to 75); the distribution was skewed in favor of younger students. Students had a variety of impairments/disabilities. Consistent with the Canadian trend, the largest group (37%) had a learning disability (this includes attention deficit disorder). Twenty-seven percent of the sample had a mobility impairment, 24% had a visual impairment, 22% had problems using their hands or arms, 15% had a medical impairment, 15% had a hearing impairment, 12% had a psychiatric impairment, and 8% had a speech impairment. Close to half of the sample had multiple impairments; the mean number of impairments was 1.74 per student (range 1 to 8). Half of the responses (50%) indicated that the student's disability was present since childhood (age less than 10), and only 11% of responses reflected a recently acquired disability (past 5 years), with the remaining responses indicating somewhere in between.

RESULTS

Most respondents, 692 of the 725 participants (95%) indicated that they used a computer. The proportion was the same in colleges and universities. Eighty-seven percent of computer users indicated using the internet and 41% stated that they needed adaptations to use a computer effectively (e.g., screen magnification, dictation software, Braille).

Different types of students

Do older students experience more problems with computers? We examined the relationship between student age and a host of variables related to attitudes, views and practices toward computer use. An independent *t*-test shows no significant difference between the mean age of students who use computers ($M = 29.62$) and those who do not ($M = 32.06$), $t(718) = 1.32$, $p > .05$. Because age may have been related to income and, thus, to experiences with computers, we correlated income adequacy ratings with age. The coefficient of $-.143$, while significant, is low; therefore, we did not partial out income adequacy on subsequent analyses.

Seventeen of the 32 Pearson product-moment correlation coefficients relating age and relevant variables for computer user students are significant (cf. Fichten et al., 1999a). Given the sample size, this is not surprising. However, of these, only one variable reached an r value of .20 (comfort using computers), suggesting that, in general, age was not an important factor in determining views about computers or effective use of computers in this population.

Do female students experience more problems with computers than males? As noted earlier, questions were not specifically designed to examine specific sex differences. For example, the demographic data show a slight, but significant trend for men than for women to see their financial situation as better meeting their needs ($M = 3.02$ and 2.71, respectively, on a 6-point scale), $t(709) = 2.32$, $p < .05$. There may be other differences between male and female students that could have been explored to provide a more comprehensive look at the topic. It is within this context that we evaluated how sex relates to computer use and attitudes.

Results show that male and female students are equally likely to use computers (females = 94.8%, males = 96.3%), $\chi^2 = .92$, $p > .05$. Of 32 t-tests on variables related to attitudes, views, experiences and computer related practices (e.g., frequency comfort, and expertise; time spent using computers and the internet; experiences, beliefs and self evaluation; problems with computer technologies), only 8 were significant. Males had more favorable attitudes and experiences than females on seven of these. It should be noted, however, that after a Bonferroni correction to the alpha level, only 3 of the comparisons remained significant: these show that females ($M = 5.36$ hr/wk) used the internet less than males ($M = 7.73$ hr/wk), $t(673) = 3.40, p < 0.001$, and that they were more likely to believe that computers are difficult to learn ($M = 3.05$ and 2.46 respectively on a 6-point scale), $t(654) = 3.16$, $p < 0.002$, and frustrating to use.

What kinds of adaptations to computers do students with different disabilities need? All students indicated the types of adaptive computer technologies that could be useful in getting their work done. It can be seen in Table 2 that the most popular computer technologies were sophisticated or adapted versions of mainstream equipment which students felt they needed to accommodate their disabilities. For example, the most valued technology was spelling and grammar checking, followed by a scanner and a portable note taking device that could be taken to class. Dictation software (voice recognition) and the availability of materials in electronic format (e.g.,

Table 2. Study 3: The Following Adaptive Computer Technologies Are/Could Be Useful For Students–Mean Scores.

Whole Sample		Totally blind	Low vision	Deaf	Hearing impairment
5.42	A spell checker/grammar checker	5.65	5.39	5.25	5.28
4.84	A scanner	5.37	5.08	4.55	4.63
4.72	A portable note taking device	5.13	4.45	4.28	4.38
4.68	Dictation software (voice recognition software that types what you say)		4.45		4.16
4.68	Having material available in electronic format (e.g., books, hand-outs)	5.52	4.91	4.18	4.37
4.14	Other specialized software for learning disabilities (e.g., word prediction)				
4.11	Voice control software (you give voice commands like ‘‘file’’, ‘‘Open’’)		4.02		
4.00	A large screen monitor		5.26		
3.93	A screen reader (software that reads what’s on the screen)	5.52	4.48		
3.77	Mouse adaptations (e.g., head mouse, track ball)				
3.46	Software that enlarges what is on the screen		4.98		
3.20	Keyboard adaptations (e.g., ‘‘sticky keys’’)				
1.92	A Braille printer	4.41			
1.80	Braille translation software	4.55			

	Speech/ communication impairment	Learning disability	Wheelchair user	Mobility impairment
A spell checker/grammar checker	5.39	5.73	4.84	5.38
A scanner	4.74	5.01	4.20	5.11
A portable note taking device	4.67	4.73	4.71	4.67
Dictation software (voice recognition software that types what you say)	4.10	5.00	4.60	4.71
Having material available in electronic format (e.g., books, hand-outs)	4.63	4.83	4.10	4.61
Other specialized software for learning disabilities (e.g., word prediction)	4.05	5.26		
Voice control software (you give voice commands like ‘‘file’’, ‘‘open’’)		4.37	4.07	4.42

Table 2. (*Continued*).

	Speech/ communication impairment	Learning disability	Wheelchair user	Mobility impairment
A large screen monitor		4.13		4.47
A screen reader (software that reads what's on the screen)		4.49		
Mouse adaptations (e.g., head mouse, track ball)				4.51
Software that enlarges what is on the screen				
Keyboard adaptations (e.g., "sticky keys")				4.19
A Braille printer				
Braille translation software				

	Difficulty using arms or hands	Medical impairment	Psychiatric impairment	Other disability
A spell checker/grammar checker	5.25	5.43	5.61	5.53
A scanner	4.59	5.26	5.19	5.21
A portable note taking device	5.13	4.88	5.00	4.94
Dictation software (voice recognition software that types what you say)	5.09	5.11	4.82	4.91
Having material available in electronic format (e.g., books, hand-outs)	4.61	5.01	4.65	4.83
Other specialized software for learning disabilities (e.g., word prediction)		4.49	4.70	4.27
Voice control software (you give voice commands like "file," "open")	4.69	4.59	4.06	4.55
A large screen monitor		4.47	4.54	4.56
A screen reader (software that reads what's on the screen)		4.26		
Mouse adaptations (e.g., head mouse, track ball)	4.29	4.74	4.56	4.77
Software that enlarges what is on the screen				

Table 2. (*Continued*).

	Difficulty using arms or hands	Medical impairment	Psychiatric impairment	Other disability
Keyboard adaptations (e.g., "sticky keys")		4.15		4.35
A Braille printer				
Braille translation software				

Note. Responses were made on a 6-point Likert scale, with higher scores indicating that this type of equipment is/would be useful. Almost half of the sample had more than 1 impairment. Scores equal to or greater than 4 on a 6-point scale are indicated.

books, hand-outs on diskette) were also seen as especially useful. It should be noted that while such equipment is likely to be useful for all students, for students with disabilities such technologies are a necessity. Rankings of students with different disabilities is also provided in Table 2. Fichten et al. (1999b) provide a listing of brand names of the different products students indicated could be useful in getting their work done.

DISCUSSION

The findings illustrate that students with disabilities use computer technologies and that many, including the large number of students with more than one impairment, need adaptive computer technologies to function effectively. Again, the tendency to "cross use" technologies was apparent. The data also show that, as was the case in Study 2, age and sex were only minimally associated with computer related experiences, although what differences existed generally indicate that males have more favorable views and experiences with computers than females. The same is true of age, where the data indicate that younger students have only slightly more favorable views and experiences than older students.

GENERAL DISCUSSION

Limitations of the present research

Before discussing the findings, the limitations of this investigation should be considered. On the positive side, we deliberately used several different

methods to obtain data: focus groups, structured interviews, and broadly distributed questionnaires. We took precautions to ensure that people with all types of disabilities had the opportunity to participate. Where necessary, we used alternative formats and methods of communication. The number of participants is large: close to 800 individuals in the three studies reported. This is unprecedented in research on computer needs and concerns of postsecondary students with disabilities. All regions of Canada and both college and university sectors are represented along with distance education institutions. The data gathering involved more than 150 postsecondary educational institutions. The student samples are diverse in a variety of ways: age, academic program, disabilities, and computer experiences. There are students who are ''just taking courses'' and students pursuing postgraduate degrees.

Nevertheless, the samples are neither random nor, we believe, fully representative of the populations studied. Given self-selection biases, we expect that the proportion of computer user students, as well as of individuals who are in contact with their institutions' offices for students with disabilities, are over-represented in all three phases of this investigation. In addition, when it comes to the large numbers of students in Study 3, it should be emphasized that we mailed questionnaires to the memberships of two large consumer-based groups of students with disabilities. Yet, most students with disabilities do not belong to student organizations.

Perhaps even more troubling, we are unable to calculate a ''return rate'' because of the manner in which questionnaires in Study 3 were made available to students. Some questionnaires were handed to students by college and university personnel. Others were mailed directly to students' homes. In the overwhelming majority of cases, however, the distribution method was unmonitored and uncontrolled. In many instances questionnaires were placed in public areas such as counters in offices providing services to students with disabilities or in specialized computer labs, akin to the way in which ''free'' advertiser supported newspapers are distributed (i.e., placed in boxes or racks near entrances and exits and made available for passers-by to pick up).

Yet, those indices which are available suggest that the samples in our studies have characteristics which resemble the realities of postsecondary students with disabilities. The age range of students is normative for studies of students with disabilities/impairments (e.g., Henderson, 1999; Hill, 1992, 1996; Horn & Berktold, 1999; Killean & Hubka, 1999). The sample contains more female than male students; this is characteristic of postsecondary students in Canadian institutions (Statistics Canada, 1999). The majority of

students use IBM compatible computers. Again, this is typical of post-secondary students. Even the proportion of arts and science students, as well as the high proportion of students with learning disabilities (about 1/3), are similar to other studies of students with disabilities/impairments (e.g., Horn & Berktold, 1999).

Possibly the most valuable aspect of this investigation is not the ''representativeness'' of the samples but the ability to answer specific questions requiring comparisons of different groups of students. What kinds of equipment do students with different disabilities need, want, and use? What do students with specific needs find problematic and what do they find really helpful? The study's main strength lies in its ability to provide answers to questions which examine the context specific needs of the users rather than a ''one-size-fits-all'' approach (cf. Brown, 1994), which, in actuality, fits only a limited spectrum of the population.

Use of computer and/or adaptive computer technologies by students with disabilities

Our findings show that the vast majority of college and university students, regardless of sex, age, program of study, or type of disability, can and do use computers and the internet to carry out their school work. The number and nature of the advantages that computer technologies had for participants reflect Roulstone's (1998) view that using computer technologies is a way to enhance access and break down barriers and demonstrate how critical computers are to the success of students with disabilities. On the flip side, the data also show that these technologies can erect significant barriers because of cost, user unfriendliness, rapid obsolescence, and difficulties associated with meeting students' disability related needs.

About 1/2 of the students in our samples had two or more impairments/disabilities, suggesting the need to provide accommodations to meet the needs of students with different disabilities in the same course. Multiple uses of adaptive technologies seems to be an important development, and the increasing number of accessibility features built into widely available mainstream products (e.g., Microsoft Accessibility options in the Windows 95/98 Control Panel) are of considerable interest to students with disabilities. Nevertheless, recent developments in sophisticated adaptive technologies have underscored the increasing importance of ensuring that different types of adaptive equipment be able to work together. This suggests that adaptive software and hardware in courses with a computer component need to be

installed and tested well before the start of classes to avoid unnecessary delays in a student's ability to participate owing to compatibility problems.

Sex and age differences

Although we had not set out to investigate these variables, the data in two of the studies lent themselves to an analysis of age and sex differences. The results of the two studies were surprisingly consistent, both with each other and with the literature on nondisabled individuals (e.g., Czaja & Sharit, 1998; Kirkup, 1999; Meyer et al., 1997; Price & Winiecki, 1995; Shashaani, 1997; Whitley, 1997). The findings indicate that age and sex are only minimally associated with computer related views and experiences, although what differences existed were consistent with those reported in the nondisabled populations (i.e., males and younger respondents were more likely to have favorable views and experiences than females and older participants).

Ensuring accessibility of courses to all students

Almost half of the students indicated they needed some type of adaptation to use a computer effectively, making it important to find out what computer and adaptive computer technologies students with different disabilities use and need. At colleges and universities accessibility concerns are shifting to issues such as adapted computer work stations and internet that is accessible to all. A barrier-free learning community involves universal access to information, a commodity which is increasingly made available, both inside and outside the classroom, through computer technologies. The new computer technologies also promote alternative modes of teaching and learning, mainly by making it easier for students to participate more actively in their learning. Many see this active involvement by students as fostering superior problem-solving, transfer of knowledge to new situations, and motivation for further learning for all students (McKeachie, Pintrich, Lin, Smith, & Sharma, 1990).

Universal design

Designing for accessibility in the first place is preferable to just in time adaptations that are likely to be expensive, cumbersome and often ineffective (cf. Ekberg, 1999; Jacobs, 1999). The move toward such ''universal'' and ''barrier free'' design is based on the assumption that environmental obstacles to people with disabilities also pose barriers to others (e.g., Brown & Vargo, 1993; Falta, 1992). Therefore, it is posited, good design for people with

disabilities constitutes good design for people in general. This philosophy can be extended to the classroom setting.

Designing accessible course materials is likely to benefit *all* students. For example, electronic text that can be read by a screen reader (synthesized speech) is likely to help second language students as well as students with print impairments. Reading what is projected onto the screen is helpful not only to students with visual and print impairments but also to students who have difficulty seeing the screen because they are sitting too far away. This is also likely to benefit students who learn more readily by hearing rather than seeing text-based information. Allowing students the choice to turn closed captioning on and off (text appearing at the bottom of the screen, such as subtitles on foreign films), needed by students with hearing impairments, is also likely to benefit nonnative speakers as well as students who have difficulty making out specific words on video clips and those who wish to learn how to spell technical words or names. Changing font sizes and color schemes on screen and providing a highlight tracking system, useful for those with visual and learning disabilities, could prove helpful for all learners who have difficulties managing large amounts of text on the screen. Allowing software to read what is on the screen, allowing alternative forms of input, such as dictation, and allowing people to choose auditory, written, or visual representations permit students to choose their own preferred learning modality, thereby permitting students with and without disabilities to gain control over their learning.

There have been numerous calls to consider learners' preferred modalities for obtaining information in different learning contexts as well as in instructional design (e.g., Barnett, 1992; Bradtmueller, 1979; Caudill, 1998; Cohen & McMullen, 2000; Papineau & Lohr, 1981; Reid, 1987; Wislock, 1993). Some students delight in visual-spatial learning, others prefer verbal representations, while others learn best by hearing information. As suggested by generative theories of multimedia learning (e.g., Plass, Chun, Mayer, & Leutner, 1998), many prefer a combination, for example hearing and seeing text simultaneously (Montali & Lewandowski, 1996). A substantial body of work by Richard Mayer and his colleagues support the contention that multimedia learning (presenting information in two or more formats such as words and pictures) can be superior to single ways (Mayer, 1997; Mayer et al., 1996; Mayer & Gallini, 1990; Mayer & Moreno, 1998; Mayer & Sims, 1994). This suggests that it is time to give all learners choices from which they can select conditions for learning which are optimal for them, thereby furthering

their motivation to learn (Brophy, 1987). Thus, accommodating the needs of students with disabilities results in good teaching practice that is appropriate for all students.

A small investment today is likely to pay handsome dividends in the long run. Not only is it cheaper to design for accessibility in the first place than to implement clumsy and expensive retrofits (e.g., Falta, 1992; Mary Frances Laughton cited in Harvey, 1999; NODE Networking, 1998), but computer and information technology accommodations made today for students with disabilities will benefit many sectors of society in the long run, including the aging baby-boomers, many of whom are computer literate and will soon find themselves in need of adaptations due to disabilities that emerge with aging (e.g., arthritis, visual and hearing impairments). Accessibility features created primarily for people with disabilities tend to benefit all people (Ekberg, 1999; Jacobs, 1999). Many may remember that ramps and curb cuts intended for people in wheelchairs have also benefited people with baby carriages, those moving equipment, rollerbladers, and so forth (Banks & Coombs, 1998).

Practical Implications

Professors, when thinking of students with disabilities, often think of students who use a wheelchair. When it comes to computer technologies, these students are by no means the only ones with access concerns. Even if two students have the same disability, their preferred solutions may be very different. The best thing for professors to do is to learn from their students. The professor is knowledgeable about his or her discipline and subject material. It is the student, however, who is knowledgeable about what adaptations work best for him or her. So, the first step towards making a course accessible is, ''Ask the student what would be helpful.''

The trend of integrating newly emerging educational media (e.g., math software, on-line course delivery) across the postsecondary curriculum raises concerns about the accessibility of these technologies for learners with disabilities. For example, how do you accommodate a student who is blind in a calculus class that requires graphics rich math tutor software or a deaf student who is faced with viewing video clips in an online course that is not closed captioned? More importantly, what are the implications of either excluding students with disabilities from these new learning opportunities or providing less attractive replacement activities? Although we do not have all the answers, clearly there are things that faculty can do that will assist these

learners in this ever changing environment. Using tools (such as Cast's (1999) Bobby) to check the accessibility of web sites, placing plain text or html versions of documents on web pages in addition to Adobe Acrobat ones, or choosing to use authorware (such as WebCT or Blackboard) which have some built-in accessibility features when designing online courses will go a long way toward making sure that the new technology-driven learning environment is one that is available to all.

Having said this, we also need to go beyond the notion that computers are simply enabling technologies for students with disabilities and that their use in the classroom should be curtailed. These are also transformative tools which can facilitate the use of pedagogical tools (learning strategies, teaching strategies). As transformative tools, computer technologies can help all students develop their ability for structured yet flexible inquiry and investigation so that they can link ideas, explore solutions and examine consequences to create value from information (Donovan & Macklin, 1999). Computers in class also allow faculty to be actively involved in the learning-teaching loop by becoming designers, managers, mentors, and peers for this form of learning (Hoadley, Hsi, & Berman, 1995).

Recommendations for faculty at colleges and universities

What follows is a list of recommendations for professors. Based, in part, on the findings, these recommendations are made with the assumption that faculty are interested in making their courses accessible to all of their students. The recommendations are by no means inclusive or highly technical. Instead, we have attempted to provide the minimal technical information that can allow professors to be ''electronicaly welcoming'' to their students with disabilities. As noted earlier, most of these accommodations are likely to benefit all students, not only those with special needs.

Put course information on the web well before the beginning of term

Putting one's course outline on the web is helpful for all students. Many students with disabilities have to order their text books on audiotape. Since this is a time consuming process, knowing which books to order well before classes begin is likely to benefit those students who must access course materials using alternative media. Similarly, putting assignments, handouts, lecture notes, and practice tests, and so forth, on the web in readily accessible formats (i.e., plain text or html) is likely to be useful for students who need to access print materials using alternative means. Needless to say, this is likely to

benefit all of the professor's students. Also, professors should note that some popular textbooks are now available on CD-ROM, as these may be useful for some students with print impairments, as well as for students with limited use of their hands or arms (no need to hold books or to manually turn the pages).

Make course materials and web sites universally accessible

When designing web sites, the simpler the better. Pictures and images are problematic for some students with visual impairments. These are also problematic for nondisabled students with slow modems (images take a long time to download), for busy institutional servers (loading time is slow on many institutional systems during peak usage times), and for students in countries where internet connect time is very costly.

Students who are blind

These students reported using: a variety of DOS and Windows-based software packages that use synthesized speech to read what is on the screen, specialized systems that incorporate a scanner and optical character recognition (OCR) software that turns a printed page into electronic text for speech output, portable note taking devices, and Braille printers, as well as special hardware/software combinations that take a line of text on the screen and convert it into a line of text on a Braille display. If there are no words, but simply images and dynamic graphics, there is nothing for screen readers (software that uses synthesized speech to read what is on the screen) to read or Braille displays to show (e.g., presentations written using Java or Shockwave). If possible, try to use HTML (web page) instead of Adobe Acrobat or PowerPoint presentations. At this time, elements of these file formats are problematic for some students who use screen reading technologies.

Frames in web pages, too, pose problems for many students who are blind, as do tables. Even text-based tables are problematic because many screen reading technologies read from left to right; this does not allow information to be read in columns, leaving the student to reconstruct what column headings go with what data in the table. A ''no tables'' version is best for students who are blind, and bulleted lists are preferred to tables. If tables are an essential feature, be sure to include a header row (i.e., put a verbal title for *each* column so that the student can reconstruct what information in the body of the table goes with what column title).

When you insert small pictures (e.g., GIFs and JPEGs), include ''alt'' tags (''alternate text''–these are like the little yellow ''screen tips'' descriptions

that you see when you leave your cursor on icons in Windows toolbars). There is a new picture description option for figures, graphs, or complex images in recent versions of web page editors (longdesc); this allows one to describe what an image, picture or interactive element is supposed to do. Giving appropriate descriptions of such graphics is vital if these images are essential to the learning objectives.

Students with low vision

Like their blind counterparts, these students, too, use a scanner and OCR software to turn the printed page into electronic text. They also use software that reads what is on the screen. In addition, these students use: magnification software, large screen monitors, and a variety of specialized software, as well as built-in features of mainstream software packages to change the contrast and to enlarge and otherwise make text, cursors, and other visual elements more visible on the screen. Modern mainstream programs allow for changes in font type, font size and background color, enabling students to enlarge letters and change the contrast. Most CD-ROMs and some popular software do not do this.

Projecting lecture notes from a web page or PowerPoint slides using a multimedia projector in class does not work well for many of these students unless the professor also reads what is on the screen and describes any images or interactive elements. Students who have a laptop in class may be able to follow the lecture under certain circumstances. Discussions with the institution's computer support technicians is likely to be helpful.

Students who have hearing impairments

Students with hearing impairments reported using writing aids such as spelling and grammar checkers, e-mail and chat programs (often used instead of the telephone), accessibility features built into the operating system of conventional software (e.g., visual flash instead of sounds), captions and subtitles for video clips (when available), and the C-Note System (CNS, 2000, a set-up that involves two joined laptop computers, permitting a hearing person who takes class notes to communicate what is happening in class, in real time, to a student with a hearing impairment. The student with a hearing impairment can ask questions and participate in class activities by typing on their laptop. This can be read aloud by the person who is the note taker).

As noted elsewhere, there are relatively few computer technologies available to assist students with hearing impairments. These students have

difficulty with streaming audio, audio clips, music, and the audio portion of video clips. Closed captioning (subtitles which have to be turned ''on'' by the user), long available on some televisions shows, have only recently been introduced into the digital world. Regrettably, this does not yet work very well.

A technological solution that works well for these students is e-mail and internet chat programs, including groupware which has ''whiteboard'' capability. Take note that while the student is looking at your slides, overheads, or projected web page, he or she cannot read your lips or look at the face and hands of an interpreter. Similarly, while working in a computer lab, the student may have difficulty looking at the screen while listening to your explanation about what to do. Discussions with the student about where to sit or stand and about other accommodations is likely to be helpful.

Students with learning disabilities

Adaptations that are useful for students with low vision and for students with hearing impairments can also be useful for students with learning disabilities (e.g., synthesized speech, use of specific foreground and background colors, dictation software, electronic note taker or laptop in class). In addition, dictation software, document managers and schedulers, concept mapping software (to help organize ideas), electronic dictionaries, grammar and spell checkers, and word prediction software (after typing several letters a listing of words that begin with these letters is presented, allowing the user to choose from a list) are being used by these students. Professors can help these students gain better access to their courses by ensuring that information is presented multi-modally (e.g., presenting the same information using both audio and text).

Students with speech or communication impairments

These students, like their hearing impaired counterparts, often use e-mail and chat programs. These students also use portable note taking and related communication devices to interact with others in face-to-face contexts. These occasionally have synthesized speech capability (such as that of the renowned British physicist Dr. Stephen Hawking). Professors can ensure that there is an opportunity for these students to voice their questions or comments by being sensitive to the need for extra time needed to type and for someone read the student's written questions or comments aloud if necessary. For class

presentations these students can use a word processor with a multimedia projector instead of speaking.

Students with mobility and hand/arm impairments
These students gave us a lengthy list of items including: ergonomic adaptations, a stand to hold documents to be typed, a keyguard (plastic keyboard overlay to prevent hitting 2 keys at the same time), splints and wrist rests, dictation programs and voice control software that allows hands free dictation and control of menus, word prediction software (described above), scanners, software based keyboard adaptations such as sticky keys (built-in software to allow one keystroke use of keys that require Shift, Control, CapsLock, etc.), filter keys (to instruct the computer to ignore brief or repeated keystrokes or to slow key repeat rates), mouse keys (these allow mouse movements to be emulated by keystrokes), software that allows for one handed typing (or one can use an actual one-handed keyboard), along with a variety of alternative mice (e.g., joystick type mouse, trackballs, head and foot mice). These students can also use alternate input devices such as a mouth wand (chopstick like rod with a rubberized tip for typing using one's mouth), a sip and puff device (hardware and software system to give computer commands by blowing or sucking through a straw-like device), or Morse code input. Because of the wide variations in students' physical abilities, it is not possible to make specific recommendations. As in all such situations, professors are urged to discuss possible problems and solutions with the student in questions.

Make course materials available in alternate formats
Many students profit from electronic texts. Electronic text books, ''course-packs,'' and electronic versions of all course materials are likely to be useful for all students. When making a disk version, most word processors, including those on Macintosh computers, can access ASCII text. When producing print materials for students with visual impairments, ARIAL 18 is the minimum font size for large print. Note that simply making an enlargement with a photocopier is not as helpful as using a larger font.

When the professor does not have specialized adaptive software
There are a variety of mainstream, free or inexpensive computer technologies that professors can use. A listing of some useful tips and programs is available on our web page (Adaptech Project, 2000). These are not meant to replace the

sophisticated, dedicated adaptive programs designed for individuals with specific disabilities or impairments. What makes these free or inexpensive technologies interesting for professors is that they provide ''quick and dirty'' solutions to frequent problems such as having to make a last minute handout for a student who needs an audiotape. Similarly, when a professor wants a student who is blind to read material available on disk in his/her office, free or inexpensive document reading software can be accessed. Unless the material is scientific or highly technical, these free or inexpensive technologies can read the material to the student without the assistance of a reader. Similarly, free and inexpensive magnification software can allow students with low vision to see what is on the computer screen. Captioning features of some free mainstream media players can make information more accessible to students with hearing impairments. Handing out presentation materials on diskette as well as on paper may also allow some students who bring a computer to class to participate like everyone else.

Other useful tips

Permit students to utilize ''virtual office hours'' using e-mail and allow students to: (1) use spelling and grammar checkers, (2) audiotape lectures, (3) take notes on a computer in class, and (4) submit assignments and exams in alternate formats such as e-mail, disk, fax, and audiotape.

As noted earlier, students themselves often know a great deal about what kinds of technologies are helpful. Also, most colleges and universities in North America employ someone who provides services to students with disabilities. This individual can often advise professors about typical problems and solutions. There are a variety of resources available for making science and math courses accessible to students with print disabilities. These are outside the scope of this article. However, the individual on campus who is responsible for providing services to students with disabilities is likely to have additional information.

Guidelines for making programs, activities, and on-line courses accessible have been proposed by several postsecondary educational institutions. Good examples are materials from Oregon State University, Santa Monica College, and the High Tech Center Training Unit of the Chancellor's Office of California Community Colleges. These resources, in addition to well established North American organizations and web sites that are likely to have interesting, easily implementable solutions to common problems experienced by professors, are presented in Table 3.

Table 3. Resources.

- Adaptech Project. (2000). Adaptech Project web site. Available August 22, 1999 on the World Wide Web: <http://omega.dawsoncollege.qc.ca/adaptech.htm>.
- Apple & Special Needs. Available March 26, 2000 on the World Wide Web: http://www.apple.com/education/k12/disability/message.html
- Cast. (1999). Bobby accessibility checker. Available September, 1999 on the World Wide Web: http://www.cast.org/bobby.
- Chisholm, W., Vanderheiden, G., & Jacobs, I. (1999). Web content accessibility guidelines 1.0 – W3C recommendation 5-May-1999. Available March 26, 2000 on the World Wide Web: http://www.w3.org/TR/WAI-WEBCONTENT/wai-pageauth.html
- DO-IT Program (Disabilities, Opportunities, Internetworking, and Technology). DO-IT, University of Washington, Box 354842, Seattle, WA 98195-4842. Available January 21, 2000 on the World Wide Web: http://www.washington.edu/doit/
- EASI (Equal Access to Software and Information). Available January 22, 2000 on the World Wide Web: <http://www.rit.edu/∼easi/index.htm>.
- HEATH Resource Center (American Council on Education–National Clearinghouse on Postsecondary Education For Individuals With Disabilities). HEATH, American Council on Education, One Dupont Circle, NW, Suite 670, Washington, DC 20033-1193. Available January 22, 2000 on the World Wide Web: <http://www.acenet.edu/about/programs/access and equity/heath/Resources.html>
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- Microsoft Corporation. (1999). Accessibility & Microsoft: Microsoft accessibility technology for everyone. Retrieved September, 1999 from the World Wide Web: http://www.microsoft.com/enable/microsoft/default.htm
- Oregon State University. (1999a, March). Oregon State University software access guidelines. Available e-mail address: stewarro@ccmail.orst.edu
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- Oregon State University. (1999c, March). Oregon State University hardware access guidelines. Available e-mail address: stewarro@ccmail.orst.edu
- Santa Monica College. (1999a, March). Universal access to Santa Monica College web pages. Available World Wide Web: http://www.smc.edu/centers/disabledstudent/awareness_training.htm
- Santa Monica College. (1999b). Some universal design challenges. Retrieved April 18, 1999 from the World Wide Web: http://www.smc.edu/centers/disabledstudent/challenges_for_universal_design.htm
- Trace Research and Development Center. Available April 26, 2000 on the World Wide Web: http://www.trace.wisc.edu/

CONCLUSIONS

Students with disabilities can and do use computer and information technologies to access postsecondary education. Computers are best seen as enabling technologies – ''electronic curb-cuts'' – that allow students with disabilities to prepare for and to participate in the knowledge based economy of tomorrow. To ensure that students with disabilities have ''equal'' access to course materials and the accompanying technology literacy skills we recommend that faculty dialogue with their students to find out what kinds of adaptations would be helpful. If part of the rationale for introducing ''technology across the curriculum'' is to prepare students to be technologically competent members of the labor force, then guaranteeing access to such technologies by students with disabilities is paramount.

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