



Access to Educational and Instructional Computer Technologies for Post-secondary Students with Disabilities: lessons from three empirical studies

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ABSTRACT *Access issues based on three Canadian empirical studies of the use of computer and information technologies by college and university students with physical, sensory, and learning disabilities are presented. Data were obtained between fall 1997 and spring 1999 from: (1) focus groups with students with disabilities (n = 12); (2) structured interviews with students with disabilities (n = 37) and with post-secondary personnel responsible for providing services to them (n = 30); (3) questionnaires completed by post-secondary students with disabilities (n = 725). Findings indicate that the overwhelming majority of students with disabilities use computers and the Internet, but that 41% of them need some type of adaptation to use computers effectively. Key findings emphasize advantages of computer technologies and delineate barriers to full access. Types of computer, information and adaptive technologies used by students with different disabilities are presented and emerging trends are highlighted. The goal is (1) to sensitize educational and instructional technologists, professors and planners involved in the implementation of educational media into post-secondary education curricula and (2) to demonstrate that designing for accessibility from the outset creates a more equitable learning environment that provides opportunities for all students.*

Introduction

As the global village becomes increasingly reliant on a knowledge-based economy, people with disabilities will have an unprecedented opportunity to participate fully in the social and economic life of their communities. This will happen only if

persons with disabilities gain equal access to education and the new computer and information technologies. These have the potential to enable or to create difficulties, making concerns about the accessibility of these technologies an evolving issue for the next decade.

Planning for campus-wide technology purchases and computer infrastructure improvements in post-secondary educational institutions are actively going on as this article is being prepared. It is important to ensure that the needs and concerns of learners with all types of disabilities are represented in planning decisions from their inception. Therefore, it was the goal of the present research (1) to investigate current practices and realities in the use of computer technologies in post-secondary education and (2) to highlight access needs of students with different disabilities. Specifically, we inquired about what kinds of computer and adaptive computer technologies students with different disabilities use and about what 'enablers' and barriers they experience in using computers effectively.

Post-secondary education for people with disabilities

As educational institutions rush to design and implement campus-wide computer systems and networks, consideration for the adaptations needed to ensure accessibility for students with different impairments is rarely at the top, if anywhere, on their priority list. Fortunately, the shift in educational paradigm from traditional classroom to that with a range of diverse technologies is still evolving and there is still time to address the potentially troubling situation of technological inequity. One of our goals is to prevent the exclusion of students with different disabilities from these new learning opportunities by sensitising those who are involved in designing and in making decisions about instructional technology on campus.

Use of computer, information and adaptive technologies by people with disabilities

The characteristics of some existing computer and information technologies prevent access by people with various disabilities (*cf.* Waddell, 1999). For example, some educational CD-ROMs have small print or a very light backgrounds which cannot be changed, and most video clips do not have captioning ('subtitles' which can be toggled on and off). Some people have difficulties accessing Internet web sites due to screen sizes and colors (Schoffro, 1996), while others, most notably people who are blind, have difficulties because graphic images do not have descriptive tags for text based screen readers and web browsers.

Creation of inequity: accessibility of computer technologies

In the last two decades a variety of models, including social (e.g. Oliver, 1996) and barrier models (e.g. Roulstone, 1998), have postulated that problems faced by people living with impairments are due to 'disabling environments' created by social and economic structures. Roulstone (1998) and Busby (2000) extend this concept to the new computer technologies. We are in danger of reproducing historical inequities through the failure to ensure the accessibility of the new computer and

information technologies that are rapidly becoming essential for all aspects of daily life in our global village. This, of course, includes educational institutions, including post-secondary education. Unless access is integrated at the beginning, our technological society will repeat the exclusionary errors of the past.

Access to technology in post-secondary education

College campuses are becoming increasingly 'wired' and the technology is pervading all aspects of academic life. In the United States, the Americans with Disabilities Act (ADA, 1990) dramatically transformed all aspects of living for people with disabilities; this includes accessibility of post-secondary educational institutions (Bausch, 1994) and of computer technologies (High Tech Center Training Unit of the Chancellor's Office of California Community Colleges, 1999; United States Department of Justice, 1998). Yet, empirical data about the effective—or ineffective—uses of computer, information and adaptive technologies in post-secondary education are scarce in all countries. Notable exceptions concern evaluations of specific strategies for students with learning disabilities (e.g. MacArthur *et al.*, 1996; Raskind & Higgins, 1998). In addition, three recent investigations have explored computer technology needs of post-secondary students with disabilities. 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 (Killean & Hubka, 1999). There are some American (e.g. Burgstahler, 1992, Horn & Shell, 1990; Lance, 1996) as well as Canadian studies (Killean & Hubka, 1999) on the views of personnel responsible for providing services to students with disabilities as well as about institutional concerns. In none of these, however, is the focus primarily on the broad range of computer, information and adaptive technologies needed by students with different disabilities in post-secondary education.

The present investigation

To evaluate the computer technology needs and concerns of Canadian students in post-secondary education we carried out a series of three studies between the fall of 1997 and the spring of 1999 (*cf.* Fichten *et al.*, 1999a). In Study 1 we conducted a focus group with post-secondary students with various disabilities. In Study 2 we obtained in-depth information from structured interviews with students and with personnel responsible for providing services to students with disabilities. In Study 3 we collected comprehensive information via questionnaires from a very large sample of students with a variety of disabilities/impairments. All three studies were carried out in both French and English. Although the data were collected in Canada, the implications of the findings have broad-based applications to other countries.

Study 1

Method

In the fall of 1997 we held a focus group of 12 post-secondary students (7 female, 5 male). 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 (questions are available in Fichten *et al.*, 1999b).

Results and Discussion

The findings indicate that computers have tremendous potential but that they also can pose barriers. Responses concerning advantages reflect Roulstone's (1998) view that using computer technologies is a way to enhance access. For example, the most frequently noted advantage was the potential of the new computer technologies to create access to information—the currency of learning and knowledge-based economies. Advantages in the following categories were also mentioned: assistance with writing; surmounting barriers caused by specific impairments (e.g. “for deaf or physically impaired students, it is possible to use the computer to communicate with teachers via e-mail”); organization of work and time issues (e.g. “computer work is faster and neater”); and personal growth (e.g. “less dependence”).

The data also show that these technologies can create barriers. Four major areas were cited: academics (e.g. “I forgot how to spell”); the need for training and assistance, attitudinal and classroom problems (e.g. “(classmates) are annoyed when I use a computer during exams”); and disability-specific disadvantages (e.g. “typing is very tiresome for some people with hand dexterity problems”).

In response to the question about what students felt prevented them from using computer technologies, high cost was the most frequently noted concern. Other prominent problems were the need for training and/or retraining, and compatibility issues related 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”). In addition, students also highlighted 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”), and lack of information about existing funding and subsidy programs.

The focus group results are interesting, but cannot provide either in-depth answers by individual participants or views that are representative of the population. To obtain more comprehensive views we conducted Study 2.

Study 2

Method

In the spring 1998 semester we conducted structured telephone interviews with 37 college and university students with various disabilities (20 females and 17 males) as

well as with 30 college and university personnel responsible for providing services to students with disabilities representing all Canadian provinces and territories. Respondents came from 49 different institutions: 20 universities, 26 colleges, and three post-secondary distance education institutions. Interview questions were based on findings from Study 1 (available in Fichten *et al.*, 1999b).

Participants

Students. The majority (73%) were enrolled on a full-time basis, with 95% attending school in the daytime. A majority were enrolled in social science, commerce, and science programs. Almost half 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 = 17–56), with most (62%) falling into the 17–28 age range. Students had a variety of impairments/disabilities making it difficult for many of them to operate various components of a computer system (see Table I). Half of the sample had multiple impairments; the mean was 1.86 impairments per student.

Personnel responsible for providing services to students with disabilities. Of the 30 participants (18 females and 12 males), 14 worked at a college, 13 at a university, and 3 at distance education institutions). The average official full time enrolment in institutions represented by personnel responsible for providing services to students with disabilities was 8890 (range 220–34,000, median = 7256).

Results and Discussion

What is the impact of students' impairments/disabilities? Thirty of the 37 student participants (81%) indicated that their disability affects their activities or performance at school. It can be seen in Table I that almost half of the sample had difficulties with the monitor as well as with the mouse. In addition, a substantial number of students had problems with the keyboard, diskette manipulation, and using a printer.

Paying for computer technologies located at universities and colleges. Most personnel providing services to students with disabilities indicated that government programs funded their equipment. This was closely followed by regular institutional funds. Most experienced problems with the funding, with 67% indicating serious problems.

What types of equipment are available for students with different impairments/disabilities? All universities in the sample had specialized computer technologies for their students, while only about 90% of colleges had equipment. Colleges with few students with disabilities were the ones least likely to have equipment. Universities, which generally have higher total enrollments than colleges, also had more diverse populations of students with disabilities. Thus, it was not surprising to find that universities also had more specialized equipment for their students. The types of

TABLE I. Descriptive statistics—students

Variable	Study 2		Study 3	
	Number	%	Number	%
<i>Students' Disabilities</i>				
Visual impairment	15	41	172	24
Totally blind	6	16	35	5
Low vision	9	24	137	19
Medical impairments	13	35	109	15
Psychiatric impairments	0	0	87	12
Other	0	0	91	13
Learning disability	12	32	271	37
Mobility impairment and/or wheelchair user	11	30	196	27
Wheelchair user	8	23	104	14
Mobility impairment	3	8	92	13
Problems using arms or hands	12	32	162	22
Hearing impairment	8	22	108	15
Deaf	2	5	30	4
Hearing impaired	6	16	78	11
Speech impairment	4	11	59	8
<i>Number of different impairments per student^a</i>				
1	19	51	410	57
2	8	22	171	24
3	7	19	84	12
4	2	5	37	5
5	1	3	13	2
6	0	0	5	1
7	0	0	0	0
8	0	0	1	0
<i>Difficulties operating computer components^b</i>				
Problems with monitor	15	43		
Problems with mouse	15	43		
Problems with keyboard	8	23		
Problems with diskette manipulation	5	14		
Problems with printer	3	9		

^a Data available for only 721 students.

^b Only 35 of the 37 students used computers.

equipment that institutions have available for students with different disabilities and impairments is detailed in Tables II to VI.

Slightly more than half of the students in our sample had two or more impairments/disabilities, suggesting the need for adapted work stations which can accommodate the needs of learners with various functional limitations. Our findings also revealed two important trends: (1) shared use of the same adaptations by students with different disabilities (e.g. both students with learning disabilities and visual

TABLE II. Equipment for students who are blind

Voice

- Voice synthesizer (hardware) (e.g. DECTalk)
- Screen reader (software that offers a range of sophisticated features such as reading of menu bars/icons and the ability to program what portion of the screen is to be read depending on such characteristics as the appearance of text written in specific colours, e.g.; Jaws, Artic)
- Document reader (text-to-speech software that reads text and the contents of the clipboard; e.g. ReadToMe, TextAssist)

Scanner hardware and software

- Scanning software (specialised and mainstream; e.g. OpenBook, OmniPage)
- Standalone reading machine (e.g. Kurzweil Personal Reader)

Software

- Text based browser and e-mail (e.g. Pine, Lynx)
- Specialised mathematics software

Braille

- Braille translation software (converts text into Braille code and formats text for printing in Braille; e.g. Duxbury)
- Braille printer (e.g. VersaPoint)
- Refreshable Braille display (gives a one line Braille display of what is on the screen; e.g. Navigator)

Portable

- Braille 'n' Speak (portable note taking device with a Braille keyboard and voice output)
- Type 'n' Speak (portable note taking device with a QWERTY keyboard and voice output)

Mouse Control

- Voice activated mouse
-

* 84% of institutions (16/19) which have students with this disability have specialised equipment for them.

* 50% of students use DOS-based software exclusively.

impairments reported using screen reading software); and (2) use of 'mainstream' computer technologies, such as dictation software, spell-checkers and scanners as disability accommodations. It is noteworthy that one of the disability service providers indicated being able to provide computer support services to foreign language students because of the equipment available in the specialized lab. This suggests that equipment which is of use to students with disabilities is not only useful to them, but also to other groups of learners served by post-secondary institutions.

What are the advantages and disadvantages of using computers for students with disabilities?

Only 2 of the 37 students indicated that they did not use computers. All 35

TABLE III. Equipment for students who have low vision

 Voice

- Screen reader (software that offers a range of sophisticated features such as reading of menu bars/icons and the ability to program what portion of the screen is to be read depending on such characteristics as the appearance of text written in specific colours; e.g. Jaws, Artic)
- Document reader (text-to-speech software that reads text and the contents of the clipboard; e.g. ReadToMe, Text Assist)

Scanner hardware and software

- Scanning software (specialised and mainstream; e.g. OpenBook, OmniPage)
- Standalone reading machine (Kurzweil Personal Reader)

Software

- Document manager program (e.g. PagisPro)

Monitor

- Large
- Visors and masks to cut glare

Magnification

- Screen magnification software (e.g. ZoomText, LP-Windows)

Software

- CD-ROM encyclopedia

Portable

- Type 'n' Speak (portable note taking device with a QWERTY keyboard and voice output)
- Laptop

Other

- Voice control of menus and toolbars: eyes-free and hands-free dictation (e.g. Dragon Dictate Classic Edition, Kurzweil Voice Pad)
 - Control of display through built-in features of software (e.g. zoom, font size, font and background colour)
-

* 81% of institutions (21/26) which have students with this disability have specialized equipment for them.

* Some of these students can use the equipment used by students who are blind.

computer users indicated advantages. Six students indicated that there were no disadvantages. These are listed in Table VII in rank order.

This study provided rich qualitative data that were, once more, consistent with Roulstone's (1998) views. Again, the findings indicate that there are numerous features of computer and information technologies that enable students. There are, of course, substantial barriers as well. To obtain more extensive information, a larger, more diverse sample of students, including those who do not use computers was needed.

TABLE IV. Equipment for students with hearing impairments

Software

- Spell check (usually built into word processors)
- Grammar check (usually built into word processors)
- Word prediction software (e.g. TextHelp!, Co-Writer)
- Built-in accessibility features such as visual flash (instead of sounds)
- Encyclopedia on CD-ROM
- Subtitles/captions where available
- E-mail and chat programs (instead of the telephone)

Portable

- C-Note system (note taking system involving 2 joined laptops: CNS, 2001)

Other

- Control of display through built-in features of software and operating system (e.g. visual flash instead of sounds)
-

* 24% of institutions (7/29) which have students with this disability have specialized equipment for them.

Study 3*Method*

In co-operation with personnel who provide services to students with disabilities and with our two post-secondary student organization partners, questionnaires were distributed in the Spring 1999 semester to students with all types of disabilities at over 200 Canadian college and university campuses. 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 (*cf.* Fichten *et al.*, 1999b). Our survey tool was made available in regular print as well as a variety of alternative media (e.g. Braille, large print, audiotape, diskette—these are available in EvNet, 2000 or from the authors).

Participants

We received 725 (425 females and 300 males) responses from students at 154 Canadian universities and junior/community colleges. Participants represent all Canadian provinces and territories and comprise current college ($n = 335$) and university students ($n = 294$), including 11 from distance education. Twenty-nine participants were not currently enrolled in a post-secondary educational institution but had been students during the past two years. Mean age was 30 (standard deviation = 10, range = 17–75); the distribution was skewed in favor of younger students. The majority of students were enrolled in arts and social sciences (67%). Slightly less than a third (29%) were enrolled in science and technology programs. The rest could not be classified. Students had a variety of impairments/disabilities; these are detailed in Table I. Consistent with the North American trend, the largest

TABLE V. Equipment for students with mobility and hand/arm impairments

Ergonomic

- Adjustable work station (both manual and electronic)
- Desk and chair height and angles adjustable
- Accessible study carrel
- Ergonomic chair
- Adjustable keyboard location and angle
- Monitor and PC can be raised, rotated or lowered
- Document stand (to hold documents to be typed)

Keyboard

- Sticky keys (built-in software to allow one keystroke use of keys that require Shift, Control, CapsLock, etc.)
- Software to allow for one handed typing
- Keyguard (to prevent hitting 2 keys at the same time.)
- Splints
- Wrist rests
- Key repeat adjustments (built in software that instructs the keyboard to ignore accidental or repeated keystrokes, e.g. FilterKeys)

Mouse

- Joystick type mouse
- Trackball
- Touch pad
- Ergonomic mouse
- Head mouse

Voice Input and PC Control

- Voice control of menus and toolbars: eyes-free and hands-free dictation (e.g. Dragon Dictate Classic Edition, Kurzweil Voice Pad)
- Voice recognition (dictation) software (e.g. Dragon Naturally Speaking, ViaVoice)

Alternate Input Devices

- Sip and puff (hardware and software system to give computer commands by blowing or sucking through a straw-like device)
- Mouth wand (chop-stick like rod with rubberized tip for typing using one's mouth)
- Morse input hardware and software

Scanner Hardware and Software

- Scanner (e.g. ScanJet)
- Optical character recognition (OCR) software (e.g. TextBridge, OmniPage)

Monitor and Image

- LCD projector (e.g. Proxima)

Software

- Word prediction software (e.g. TextHelp!, Co-Writer)
- E-mail account

Portable

- Franklin language master and spell checker
 - Laptop
 - AlphaSmart (portable note taking device)
-

* 73% of institutions (19/26) which have students with this disability have specialized equipment for them.

TABLE VI. Equipment for students with a learning disability

Voice

- Screen reader (software that offers a range of sophisticated features such as reading of menu bars/icons and the ability to program what portion of the screen is to be read depending on such characteristics as the appearance of text written in specific colors; e.g. Jaws, Artic)
- Document reader (text-to-speech software that reads text and the contents of the clipboard; e.g. ReadToMe, TextAssist)

Dictation Program

- Voice recognition software (e.g. Dragon Naturally Speaking, ViaVoice)

Scanner Hardware and Software

- Scanning software (specialized and mainstream; e.g. OpenBook, OmniPage)
- Standalone reading machine (e.g. Kurzweil Personal Reader)

Magnification and Display Control

- Large screen monitor
- Control of display through built-in features of software (e.g. zoom, font size, font, highlight and background color)

Software

- Document manager program (e.g. PagisPro)
- Spelling and grammar check (usually built into word processors)
- Word prediction software (e.g. TextHelp!, Co-Writer)
- Electronic dictionary and encyclopedia on CD-ROM
- Literacy software (e.g. Plato)
- Tutorials: grammar, mathematics, typing
- Flow charting/concept mapping software (e.g. Inspiration)

Portable

- Franklin language master and spell checker
 - Laptop
 - AlphaSmart (portable note taking device)
-

* 75% of institutions (21/28) which have students with this disability have specialized equipment for them

* Some of these students can use the equipment used by students who are blind, have low vision or a hearing impairment.

group of students (37%) had a learning disability. Close to half of the sample had multiple impairments; the mean was 1.74 impairments per student.

Results and Discussion

The overwhelming majority of respondents (95%) indicated that they used a computer. The proportion was the same in colleges and universities. Forty-one percent of computer users indicated that they needed adaptations (e.g. screen magnification, dictation software, Braille).

Thirty-three students (5%) indicated that they did not use a computer. When

TABLE VII. Advantages and disadvantages of computer technologies reported by students

Factors	Number of students	% of students
<i>Advantages</i>		
Word processing means no need to handwrite or retype, neat presentation, can cut & paste	19	54
Access to lots of information, opens up the world	16	46
Can work faster, easier, saves time	13	37
Independence, empowerment, autonomy	8	23
Provides access to otherwise inaccessible activities	8	23
Editing work is easier	8	23
Can work at one's own pace and schedule	8	23
Spell check, grammar check, dictionary, thesaurus	7	20
Communication is made easy	6	17
Needed to proceed in education and the job market—provides opportunities	3	9
Gives confidence, no writer's block, reduces stress	3	9
Allows one to work like the others	3	9
Internet is cheaper than long distance telephone call	3	9
Fun	2	6
Keeps students organized, allows them to find things quickly	2	6
Don't lose ideas because can get them down on paper fast enough	2	6
Cost-effective	1	3
<i>Disadvantages</i>		
Long to learn, unfriendly, frustrating	13	37
Need to keep up-to-date, obsolescence, continual upgrading, not knowing what's available	10	29
Cost	10	29
Crashes, break downs, repairs take long, lost work, unhelpful helplines, products not supported	9	26
Doesn't meet disability related needs well (inaccurate, works poorly, can't read graphics, can't operate)	8	23
Dependence on technology—what if: it breaks down; there is no computer available: no electricity	2	6
Health concerns (eye strain, voice strain)	2	6
Not available at school	2	6
Interferes with social activities	1	3
Compatibility problems	1	3
Problems with bilingual use	1	3
Hard to use on public transport	1	3

Note: All respondents listed at least one advantage. Only 29 students indicated disadvantages; the rest said there were none.

asked why, their answers reflected access issues: computers cost too much; they were generally unavailable to students; and they were too expensive to maintain. Ninety-three percent of computer users indicated that they use a computer at home and 95% used a computer at school. Eighty-seven percent of these students used the

Internet: 64% at home and 77% at school. Most students used an IBM compatible (93%); only 15% indicated using a Macintosh. Several students used both or another type of computer.

The most frequently noted reason for using the Internet is research ($M = 5.42$ on a 6-point scale). Other popular reasons include e-mail ($M = 5.30$), accessing library materials ($M = 4.40$), and entertainment ($M = 4.35$). When computer users who do not use the Internet were asked why, their responses, in rank order, indicate that using the Internet ties up the phone line, that they had no access to a computer that is equipped to go online, and that it costs too much. No student indicated that it is unavailable in their area, and very few indicated that it was unavailable at their school.

The most common problem noted by students is that computer technologies cost too much ($M = 4.80$). Other problems include: the need for continual upgrading ($M = 3.87$); and few opportunities for training on adaptive technologies ($M = 3.59$). The most common problem with computers located at school was that both mainstream and specialized computer labs with adaptive equipment were generally overcrowded.

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. 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. books, hand-outs) 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 (*cf.* Fichten *et al.*, 1999b for brand names).

Two hundred and eighty-four of the 692 computer users (41%) indicated they needed special adaptations, such as those detailed in Tables II–VI, to use a computer effectively. It is noteworthy that only 166 of the 284 students (58%) who indicated that they needed adaptations used them. When asked why they did not use adaptations, the overwhelmingly endorsed answer was that it costs too much (mean was 5.50 on a 6-point scale).

In summary, the findings of Study 3 echo those of Studies 1 and 2 and highlight a number of important trends. These include the overwhelming preponderance of computer users in the sample, the use of mainstream computer technologies as adaptive aids, the large number of students who need adaptations to use computers effectively, and the large proportion of students with more than one impairment. Again, the tendency to ‘cross use’ technologies was apparent. This was also true of the concern with the cost of computer, information and adaptive technologies, both in preventing students from using a computer and the Internet, as well as from obtaining needed adaptive technologies.

General Discussion

Our findings show that the vast majority of college and university students with disabilities can and do use computer technologies 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. The findings also demonstrate how critical computers are to the success of students with disabilities. The issue is not simply one of access to information. Rather, technological tools are seen by many as empowering students to construct and build upon their own learning. This allows them to make informed decisions about 'what' tools to use, 'how' to use them, 'when' to use them, and 'why' to use one rather than another (Brown *et al.*, 1989; Gibson, 1993; Lave & Wenger, 1991). Using technology in this manner is a concern for all students, whether they have a disability or not. The real learning objective that needs to be fostered is to scaffold students' learning so that they are strategic individuals in their environments (*cf.* Brown & Campione, 1990). Access to information is a prerequisite to getting there. A more extensive listing and description of computer technologies which are likely to be helpful is available in a resource guide intended for distribution to students with disabilities and other concerned individuals; the guide is available, in both English and French (Fossey *et al.*, 2001a, 2001b) in html and Adobe Acrobat pdf formats on the Adaptech web site.

Ensuring access: what kinds of equipment do students with different disabilities use?

Respondents in both Studies 2 and 3 indicated the types of computer and/or adaptive computer technologies used by students with different disabilities as well as their purpose. The descriptions that follow summarise these.

Students who are blind. It can be seen in Table II that these students, although relatively few in number, use a large variety of sophisticated computer technologies. The key to understanding how students who are blind use computers is to recognize that once information is available as electronic text, it can be accessed. From there, synthesized speech or Braille output devices can be used to read the material. Most students use software that reads text on the screen (called document readers); many of these can 'read' icons, tabs, and menu bars as well (called screen readers). Some of these have been developed specifically to give access to Windows-based applications. A note of caution: this development is ongoing, and not all Windows-based software is readily accessible at this time. By using a scanner and optical character recognition (OCR), printed text can be converted into electronic text. At this time, mathematical symbols, pictures, charts, graphs and complex tables remain problematic, both in print and electronic formats. In keeping with the text-based approach, students who are blind reported using text based web browsers and e-mail as well as text-based mathematics software (e.g. Maple). Laptops with screen readers and portable devices with voice or Braille output can be used to take notes. Sophisticated DOS-based word processing programs such as WordPerfect 5.1 were still the favorite for many students (50% of our sample used DOS-based programs).

Students who have low vision (see Table III). These students can either use software that enlarges the size of visual elements or they can use synthesized speech to read electronic text files. Many use both. These students generally use Windows or Macintosh operating systems. Large screen monitors (e.g. 21 inch), with or without software that enlarges what is on the screen, are also helpful. These can be enhanced with visors and masks to cut glare. Students can control the display through readily available and built-in features of popular software (e.g. zoom, font size, font and background color) to enhance contrast and visibility. These students, too, use scanners to enlarge printed materials or to convert printed material into electronic text. Electronic dictionaries and encyclopedias, a laptop (with magnification or synthesized speech), as well as a portable note taking device with a QWERTY keyboard and speech output were also reported as useful.

Students with hearing impairments (see Table IV). A variety of electronic dictionaries/encyclopedias as well as both mainstream (e.g. spell check and grammar check) and specialized writing aids (e.g. word prediction software—described below under learning disabilities) can be helpful for these students. They can also use built-in accessibility features of Windows and Macintosh computers such as visual flash (instead of sounds). When accessing video and audio clips, these students can make use of subtitles/captions where available. Also, many students use e-mail and chat programs rather than the telephone. Students can have difficulty looking down and taking notes while concentrating on the professor's face in order to lip read. This problem can be solved through a portable C-Note system (2 joined laptops: CNS, 2000). This allows a hearing individual (a note taker) to type what the professor says; this is displayed on the student's screen. The student, in turn, can type a query to the instructor which will appear on the note taker's screen.

Students with speech/communication impairments. These students, too, often use e-mail and chat programs rather than the telephone. They can also use a portable, lightweight note taker device to communicate with others in face-to-face contexts (e.g. AlphaSmart, 2001). For class presentations these students can use a word processor with a multimedia projector instead of speaking or have PowerPoint or other presentation materials projected onto a large screen.

Students with mobility and hand/arm impairments (see Table V). A variety of ergonomic adaptations are likely to be used by these students. Software-based keyboard adaptations include accessibility features such as sticky keys (built-in software to allow one keystroke to be used instead of Shift, Control, Alt, etc.), filter keys (to instruct the computer to ignore brief or repeated keystrokes or to slow key repeat rates), and mouse keys (allow mouse movements to be emulated by keystrokes). Both software and hardware adaptations can allow for one-handed typing. Students can also use a keyguard (plastic keyboard overlay to prevent hitting two keys at the same time), splints, wrist rests, as well as a variety of alternative mice (e.g. trackballs, touch pads). Many students can benefit from dictation and voice control software (control of menus and toolbars by voice). 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 (system to give computer

commands by blowing or sucking through a straw-like device), or Morse input. Some of these students, too, can benefit from electronic text (no need to handle paper) as well as electronic dictionaries and encyclopedias. Thus, scanners with optical character recognition software can be useful for these students as well. Some students also use word prediction software to speed up their typing (described in the section on learning disabilities). Portable devices such as a laptop or a portable note-taking device can also be useful.

Students with a learning disability (see Table VI). These students can make use of software and hardware already described. For example, students who have problems reading because they skip or reverse letters and those who or have difficulty reading left to right in a straight line can use software that reads what is on the screen. Equipment developed for students with low vision, or for students who are blind, can also be used by students with reading difficulties. As was the case for students with visual impairments, scanning and optical character recognition can be used to convert printed materials to electronic text, which can then be read by the computer using synthesized speech. For students who have difficulty with cursive text, a laptop or portable note-taking device can be useful. Some students who have difficulty with grammar and spelling find dictation software such as Dragon or ViaVoice interesting. As was the case for students with low vision, magnification and the ability to control the display through built-in features of software (e.g. font size, highlight and background color) can be helpful, as can a large screen monitor. Students with problems related to organization can use mainstream document manager and scheduling programs. Of course, mainstream programs such as spelling and grammar check are also important, and word prediction software can be used (the student starts typing a word and several words which complete what the student has already typed pop up, allowing the student to choose rather than type the appropriate word). Electronic dictionaries and encyclopedias are also helpful. Specialized flow charting/concept-mapping software may also be of interest. These students can also benefit from portable devices such as laptops or portable note-taking devices which can upload files into a computer.

Blurring between adaptive and mainstream technologies

We asked students in Study 3 what computer and/or adaptive computer technologies they considered could be useful in getting their work done. In rank order, the top 10 for students with all types of disabilities combined was:

- Spelling/grammar checker
- Scanner
- Portable note taking device
- Dictation software (voice-recognition software that types what you say)
- Having material available in electronic format (e.g. books, hand-outs)
- Other specialized software for learning disabilities (e.g. word prediction)
- Voice control software (you give voice commands like 'file,' 'open,')

- Large screen monitor
- Screen reader (software that reads what's on the screen)
- Mouse adaptations (e.g. track ball)

It is evident that what are generally considered mainstream technologies are, in fact, used as adaptive technologies by students with certain disabilities. For example, most people use spell checkers. For students with some learning disabilities this tool is used as an adaptive technology to help compensate for the disability. Dictation software originally intended for professionals and executives, is now used as an adaptive technology by students with a variety of hand/arm impairments and some types of learning disabilities. Screen reading (synthesized speech) technologies, originally used by individuals with visual impairments, have crossed over into the mainstream and are increasingly available for wireless telephony-based e-mail enhancements. The same is true for mainstream scanners and optical character recognition software that are used as adaptive technologies by students with visual and other print impairments.

Some technologies have remained disability specific: Braille printers, captioning on video portions of web pages and CD-ROMs, magnification programs for students with visual impairments, head and foot mice, and the audio-cord [*cf.* Phonak's (2000) MicroLink FM system] which allows people with hearing impairments who use an FM system to hear voice output from a computer.

Thus, there appear to be three categories of computer technologies used by students with disabilities: mainstream computer hardware and software (e.g. word processing software); adaptive computer technologies (e.g. Braille printer); and those which are 'adaptable' (e.g. dictation software). Students also use certain computer technologies in idiosyncratic highly creative ways, further clouding distinctions.

Although the lines between adaptive and mainstream computers are blurring in some areas, not all technologies can be considered accessible for all. As long as software and hardware are designed and built without consideration for their accessibility there will be 'issues of accommodation' in areas of technology, as is the case in architecture. Thus, a general rule still applies: computer technologies must serve as tools to facilitate the execution of daily activities, and their use must be determined by the user's needs. This can only happen if users have access to the computer technologies they need.

Equity issues

Students in all three studies told us that some of the existing computer technologies, including the Internet, cost too much for them to afford. Similarly, over two thirds of personnel who provide services to students with disabilities in colleges and universities indicated that they experienced serious problems with funding for computer technologies for their institutions. Thus, the cost of equipment is a key factor in denying students equal access to the tools needed to succeed in post-secondary education. It follows that we need funding models which take

equality into account, thereby allowing all people to participate in all aspects of society, including post-secondary education.

Canadian legal precedent indicates that equality does not necessarily mean 'identical treatment' (see *Huck vs. Odeon Theatres* in Boyer, 1985). Thus, providing access for students with disabilities to the same software and hardware as their nondisabled peers does not constitute equal treatment if students are not able to make reasonable use of these technologies (e.g. if a student who is blind cannot use the interface because it has no voice or Braille capability). To provide 'equal' treatment, the software must allow students with disabilities to use the same functions of the software as do nondisabled students.

Universal design—barrier free access

Reviewing the commonalities among all samples studied in this investigation makes it evident that the potential of computer, information and adaptive technologies to remove barriers to students with disabilities is enormous. Nonetheless, environmental barriers are continually being created and it is important to consider the context in which students with disabilities learn [*cf.* Gibson's (1993) views on ecological theory and distance education]. This makes it imperative that solutions be identified and implemented while the technologies and their implementation in post-secondary educational institutions are still in a developing stage.

Including accessibility features in software and hardware is likely to benefit *all* users. For example, software designed for students with learning disabilities which highlights words as they are being read by a screen reader (synthesized speech) is likely to help second language students as well. Allowing students the choice to turn captioning on and off (text appearing at the bottom of the screen, such as subtitles on foreign films) is also likely to benefit English as a second language students 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. 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 will allow 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 students' preferred modalities for obtaining information in different learning contexts and instructional design (e.g. Cohen & McMullen, 2000; Mayer & Moreno, 1998). Some students delight in visual-spatial learning, others prefer verbal representations, while others learn best by hearing information. It is time to give all learners equality of choice, rather than adopting a 'one size fits all' approach.

Planning for equitable implementation: recommendations for educational and instructional technologists

If new computer technologies (e.g. on-line courses, mathematics tutorials on CD-ROMs) are to become part of the norm in higher education, then there is a need to

address access by learners with disabilities. The implication of not doing this is that educational technologies become exclusionary technologies. We offer the following suggestions to those involved in technology integration into the post-secondary education curriculum.

- When conducting formative or summative evaluations of courseware, learners with disabilities should be included whenever possible. This ensures that issues of accessibility are identified and dealt with prior to implementation or adoption.
- As a matter of course, subject matter experts in the area of accessibility need to be drawn into the instructional design process.
- Authorware tools with built-in accessibility features (e.g. WebCT, Blackboard) should be selected when designing web-based applications.
- There are free web-based tools, such as CAST's (2001) Bobby, that can evaluate web pages for their accessibility and provide suggestions for making appropriate improvements. In addition, NCAM's (2001) recently released free software MAGpie (Media Access Generator) provides the facility to add captions to QuickTime, SMIL, and SAMI formats, and to incorporate audio descriptions into SMIL presentations.

Why do designers fail to incorporate such seemingly obvious and inexpensive features? In some cases, their implementation is truly difficult (e.g. interactive mathematics software). To provide alternative means of accessing this information requires the assistance of a subject matter expert who can provide a verbal 'analogue' of what is happening visually on the screen. In most cases, however, designers, planners and developers simply do not think of accessibility issues. They are inclined—due to tradition, not malice—to include the latest developments in technological innovation. Nor are they well informed about what is likely to be helpful. Yet, as noted by IBM's David Best (2000, p. 3), "digital technology and miniaturization are making it possible for accessibility to be an inherent part of any product design—if the designers think about it". When alerted to problems, our experience has been that they often opt for, "Let's just finish developing the product, and then we'll add on the accessibility features later". Needless to say, by the time the product is finished, it is much too late to redesign the essentials to permit accessibility. The American experience, where powerful laws have worked to 'sensitise' designers and developers (ADA, 1990; Schauer *et al.*, 2000; United States Department of Justice, 1998/2000), can provide an excellent starting point.

"In a time of scarce resources, the money needed to make adaptations is too much to spend on just a few students! The numbers simply don't warrant it". The argument that "granting equality to the disabled population group is not justifiable because of the cost ... or because of the inconvenience to mainstream society" (Nagler, 1993, p. 33) is often made in this context. We contend that this type of argumentation needs to be rebutted wherever it surfaces. 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), 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. Accessibility features created primarily for people with disabilities tend to benefit all people (*cf.* Ekberg, 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, etc. (*cf.* Coombs, 1998). Similarly, features that make computer technologies accessible are likely to be useful to many learners. For example, in addition to images, including alternative text (e.g. <ALT'Picture of XYZ University' >) is likely to be useful for students in countries without PPP (Point-to-Point Protocol) access as well as students with slow modems, low resolution screens, or expensive Internet connect times evaluated by the minute, many of whom have toggled the images off on their browsers.

Conclusions

The nature and implications of our findings are evident despite limitations inherent in our methodology: students with disabilities can and do use computer and information technologies in post-secondary 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 we encourage those who design, manufacture, and develop instructional materials, systems, and infrastructure to dialogue with people who are knowledgeable about the needs and concerns of students with disabilities to find out what kinds of adaptations would be helpful. This includes, first and foremost, students with different types of disabilities, as those living with the impairments best understand their needs. In this regard, it may be wise to follow Microsoft's example of hiring qualified individuals with disabilities (*cf.* Williams, 2000). Other concerned groups include personnel responsible for providing disability-related services in colleges and universities, manufacturers and developers of adaptive computer technologies, high-tech occupational therapists and adaptive technology trainers. Working collaboratively to design accessible computer and information technologies for educational use will result in more equitable instructional tools for all learners, enabling all students to utilize and to construct knowledge and to fully participate in learning.

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