Education and Information Technologies 7:3, 225–235, 2002.

Design and Development of a Bilingual Multimedia Educational Tool for Teaching Chemistry Concepts to Deaf Students in Greek Sign Language

MARIA E. PANSELINA
Special High School for the Hearing Impaired, 164 52 Argyroupolis, Greece
E-mail: panselina@chem.uoa.gr

MICHAEL P. SIGALAS
Department of Chemistry, Aristotle University of Thessaloniki, 540 06 Thessaloniki, Greece
E-mail: sigalas@chem.auth.gr

CHRYSSA TZOUGRAKI *
Department of Chemistry, University of Athens, 157 71 Panepistimiopolis, Greece
E-mail: tzougraki@chem.uoa.gr

Abstract

In this paper the design and development of a multimedia system which serves as a bilingual chemistry educational tool for deaf students is presented. Details of the architecture of the tool, its functionality and formative evaluation results are also presented. Furthermore the process to arrive at the chemistry terminology in Greek Sign Language used throughout the tool is briefly described.

Keywords: hearing impaired, Greek Sign Language/GSL, multimedia/hypermedia, interactive learning, chemical education

Introduction

The turning point for the education of deaf people came when the sign language has been accepted by linguistics as a true language system offering a way of expression and not as a crutch for those who could not speak (Stokoe and Battison, 1981). As in the case of spoken languages, in each country a national sign language is used with its own grammatical structure and syntax. Thus, the American Sign Language (ASL) is mainly used in the United States of America and Canada. The Greek Sign Language (GSL) is used by 42,600 or more users, including 12,600 deaf children and 30,000 adults (Sandhu and Wood, 1990). It is based in the American and French Sign Languages with some local variations built in the 1950's (Grienes, 1996).

Although the research and practice on deaf people's education has been a subject of intensive activity, the teaching of science to deaf students has not been sufficiently studied

* Corresponding author.

(Lang *et al.*, 1994; Lang and Propp, 1992; McIntosh *et al.*, 1994; Roald, 2001). Often, the goal of science teaching is the improvement of reading and writing skills of the deaf students, and not the science as such (Livingston, 1997), or at least the science knowledge as a side issue (Yore, 2000). In the last two decades, a great effort has emerged to include science topics in the curriculum for the deaf people (Stewart, 1996). On the other hand, although multimedia technology (Brusilowsky, 1996) has been used in the descriptive presentation of sign language symbols and concepts (Vanderheiden, 1994; Stefanidis *et al.*, 1995; EU-BET, 1997; Pyfers *et al.*, 1998a, 1998b; EU-Projects, 1999; Markellou *et al.*, 2000), no multimedia tools exist with application on science education of deaf people using the sign language.

This paper discusses the design and development of a multimedia tool focussing in chemistry education of deaf students in High School, delivered via CD-ROM and the WWW (Panselina, 2001). This prototype has been developed within the framework of a project aiming to:

- The development of a working chemistry terminology in Greek Sign Language (GSL).
- The design and development of multimedia bilingual educational material and tools for Greek deaf students.
- The study of the deaf student's interaction with the computer as a teaching tool.

The design of the multimedia tool developed has been based on the extensive use of GSL and on the principles and practice of bilingual–bicultural education (Kannapel, 1978; Strong, 1988). In bilingual education when the secondary language has been digested in great extent, it can be used for the access to science information (mainly at its written form). But, when the science information in the secondary language becomes too complicated to be apprehended, it is expressed in the native sign language.

The multimedia tool presented here utilizes new technologies to provide chemistry lessons in GSL and could be used as a self pace learning tool, in a distant learning environment through World Wide Web, as well as a presentation tool integrated in the chemistry curriculum. It presents various types of information to the trainees giving them the chance to browse the information in the way they wish to. The presentation of the various chemistry topics is achieved by a series of dialogs between two deaf people. The structure of the dialogs is based on constructivist paradigm (Sutton, 1992; Egelston-Dodd and Himmelstein, 1996), where the participants observe, make, test and if necessary revise hypotheses and turn the tested hypotheses in theories. Within the dialogs a set of newly developed chemistry terms in GSL are used. Furthermore, the tool serves also as an evaluation tool through self-rating questions.

The importance of the system according to preliminary formative evaluations, as well as its tentative applications can be summarized as follows:

- It will serve as a tool for trainees wishing to follow chemistry lesson at self-pace or from a distance.
- It will further extend and propagate the Greek Sign Language.
- It will provide to deaf students new educational opportunities.

In the following sessions we describe the different elements and the learning material of the system, the design considerations and choices, the graphical user interface and the user

interaction process. Finally, the main results of a formative evaluation of the tool as well as the project's future plans are briefly outlined.

System Description

Design and programming considerations

During the design and development of the system, attention has been focused on certain usability features, that would ensure the system's compatibility with user's requirements, expectations and needs. The results of formative evaluations have been proven valuable in this respect. The usual graphical metaphors have been used for designing all the buttons. The same navigation buttons are used in all sections of the tool. So, the user does not need to memorize the graphics and the related functions.

The tool has been developed with the Macromedia Director authoring tool (Macromedia Inc., 2000). The users can use it from a CD-ROM or the World Wide Web. During development the ease of delivering the tool through the World Wide Web has been taken seriously into account, using the Shockwave plugin at the client side (Macromedia Inc., 2000). Thus, the graphics and the video clips are small enough in order to be transferred in reasonable times even at low bandwidths.

Development of chemistry terminology in GSL

The chemistry working terminology used through out the multimedia tool has been developed by a group consisting of three chemistry teachers, a deaf linguist who also has a chemistry diploma, and two deaf students, native signers, who have been taught Chemistry. Concerning the Chemistry teachers M. Sigalas and C. Tzougraki teach at the University and M. Panselina teaches in a Special High School for hearing impaired students and uses GSL. The group worked together to find ways to sign the chemical concepts trying to compromise between their scientific validity and the ordinary ways to use GSL. This was a demanding task as a lot of international chemistry terms have their counterpart in Greek language. For example the term "atom" has its origin in the Greek word "atomo", which besides the scientific meaning has also the meaning of "person". As a result of this work the sign representations of 114 chemistry terms have been developed.

System structure

The structure of the system is presented schematically in Figure 1. It consists of a series of modules which, as will be described bellow, are interconnected via navigation buttons or text hyperlinks.

The basic menu In the basic menu page (Figure 2) the various menu items are shown as bulleted titles. The user by clicking the appropriate menu item can choose to enter to the following modules:

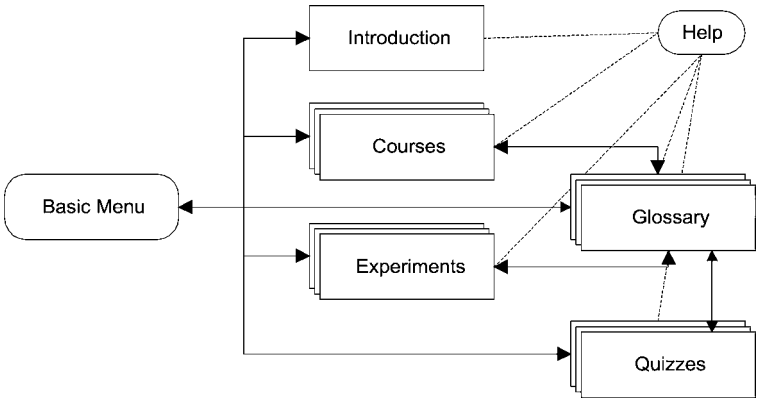

Figure 1. System structure.

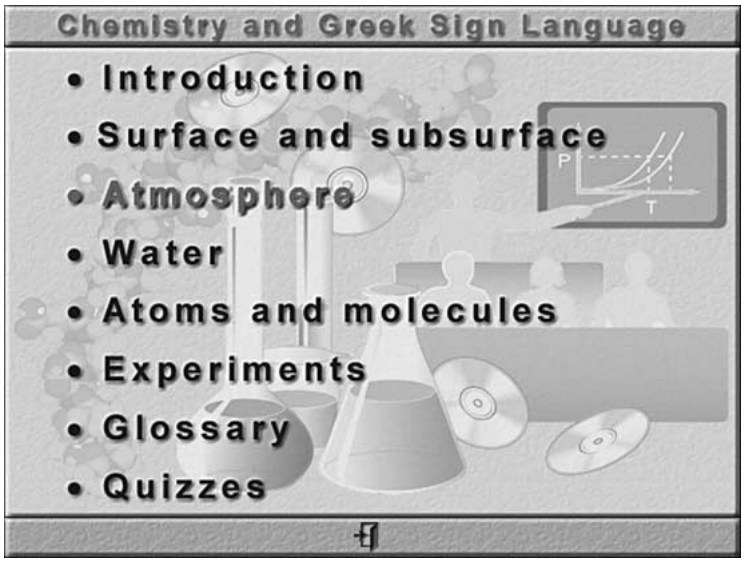

Figure 2. The first level menu with links to the course topics, the glossary, etc.

- An introduction module (first menu item), where information about the purpose and the functionality of the system are given both as text and as video clips in GSL.
- A chemistry topic among the four covered at present (second to fifth menu item).
- The experiments module (sixth menu item), where a series of experiments related to the above chemistry topics are presented.
- The glossary module (seventh menu item) where all the chemistry concepts and terms are presented in GSL, as well as alphabetically in Greek language.
- The quizzes module (eighth menu item).

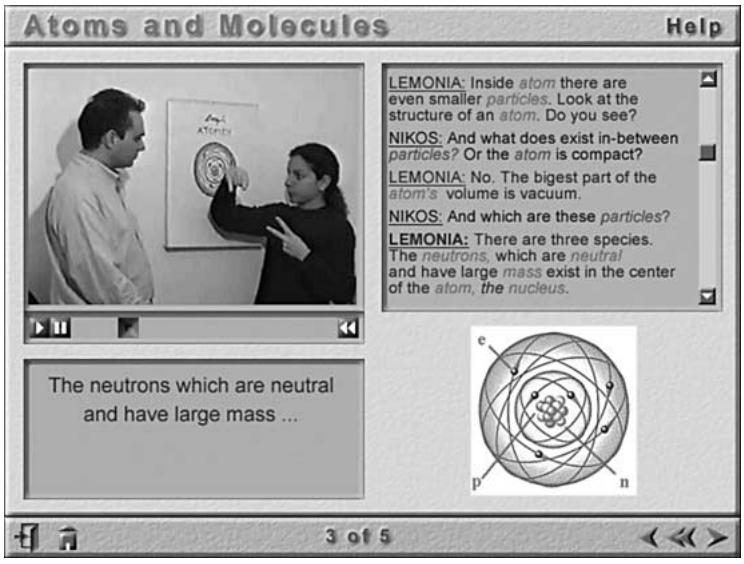

Figure 3. A system screen shot with a part of the "Atoms and Molecules" topic.

- The exit button ("door" like button at the bottom bar of the layout) for exiting from the system.

Chemistry topics

The chemistry topics covered by the system at present are the following:

- surface and subsurface,
- atmosphere,
- water,
- atoms and molecules.

The layout for the "Atoms and Molecules" topic is shown in Figure 3. The layout of the other topics is exactly the same. The top bar contains the title of the topic (left) and the "help" button (right). The bottom bar contains the "Home" and "Exit" buttons (left) allowing the user to go to the basic menu screen or to exit from the system, respectively. In the right side of the bottom bar there are three self-explanatory buttons, which allow the user to go to the next, previous or first screen of the particular topic. Each topic consists of five to eight screens. Thus, in the center of the bottom bar the number of the current screen and the total number of screens are given.

The center main part of the layout is virtually divided to four sections. In the upper left section (a) the video clip of a particular dialog fragment is presented. The corresponding text for the dialog is shown in the upper right section of the screen (b). When the user clicks on the name of an interlocutor or anywhere within a sentence of the text his/her

name turns to bold (see Figure 3, fourth sentence) and the corresponding part of the video is played. While the video is played small parts of the sentence are presented in the bottom left section of the screen (c) with synchronization with what is presented in GSL. When the dialog deals with particular chemistry concepts or terms, a number of related icons, schemes or photos are displayed in the bottom right section of the screen (d).

Concerning the control of the video clips the user can also use the control buttons of the video section (a). The "play" button plays all the video for the particular part of the dialog and the "pause" or "rewind" buttons pause or rewind the video, respectively. The student can use the dragger control of the video to view the video in any speed or even frame by frame in order to see in detail the movements of the signs used within the dialog. When the control buttons are used for playing the videos, the related text and icons are also displayed in sections (c) and (d).

Finally, chemistry concepts and terms used within each dialog are displayed in slightly different color and in italics. They serve as hyperlinks to the glossary of the system, which will be described later.

Experiments module

In this module a series of chemistry experiments are presented. Each experiment is related to a chemistry topic covered by the system. The system presents the purpose, the theoretical basis, the instruments and chemicals used and the procedure of each experiment. The layout for the experiment "Hardness of Water" is shown in Figure 4. It is analogous to that used for the presentation of the chemistry topics, except that the text section covers all the

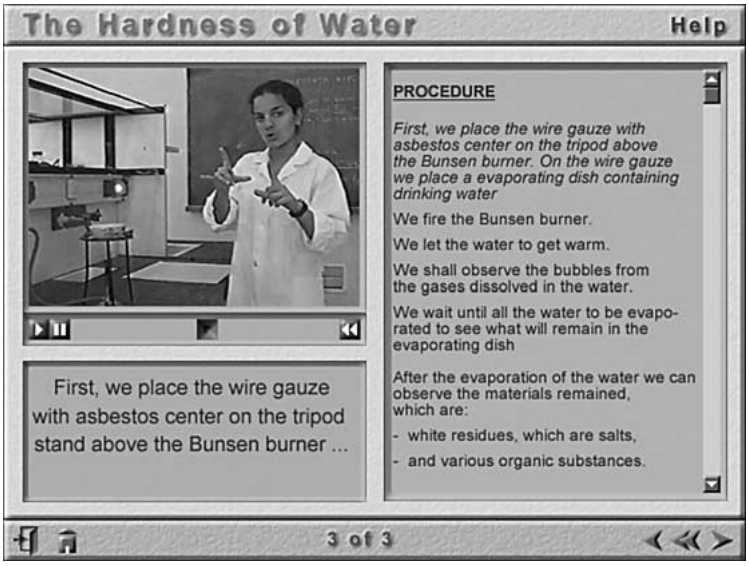

Figure 4. A system screen shot with a part of the experiment "Hardness of Water".

right section of the screen. When the student clicks anywhere within a sentence of the text, the corresponding part of the video is played. The functionality of various buttons is the same as that described in *Chemistry Topics module*. In the video clips presented a tutor or student performs the experiment and simultaneously describes it in GSL.

Glossary module

In this module, all the chemistry terms and concepts used throughout the system are presented in GSL, as well as in Greek language, alphabetically organized. The layout for the glossary module is shown in Figure 5.

The glossary works in two ways. When it is used as a standalone-vocabulary module the user can browse throughout its contents. He/she chooses the initial letter from the letter buttons in the bottom bar and then he/she clicks the particular term from the list in the bottom left part of the screen. The term turns color and font face (italics) and its GSL interpretation is displaced in the video section. For each term an appropriate icon, scheme or photo is displaced simultaneously in the right side of the screen.

When the user enters the glossary module through a hyperlink from a chemistry topic, the system enters automatically the appropriate letter section, activates the particular term from the list and displays the video with the GSL interpretation. In this case the user can return back to the chemistry topic using the "back" button at the rightmost side of the bottom bar, even if he/she continued to browse within the glossary. In any case, the user can control the video with the already described control buttons.

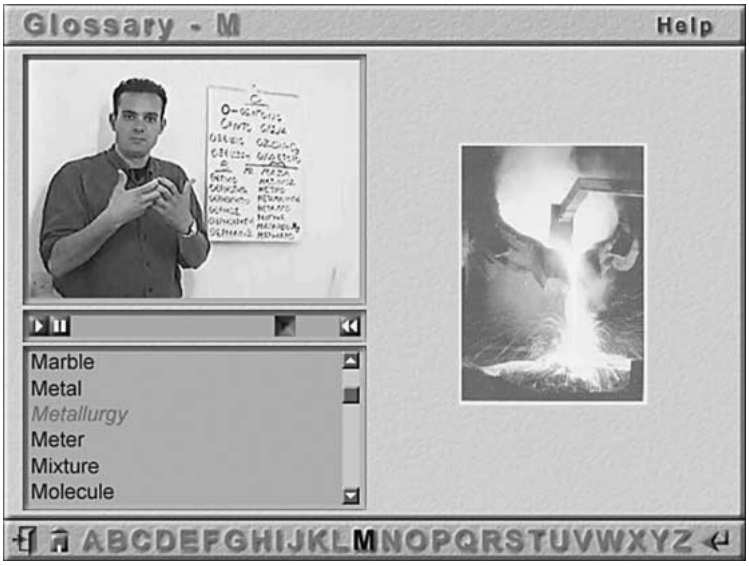

Figure 5. A system screen shot from the glossary module showing the term "Metallurgy".

Figure 6. A system screen shot from Greek to GSL quiz.

Quizzes module

The quiz module has been developed in order to give students the opportunity to exercise themselves in the use of the terms in GSL. Upon selection by the user it serves as a GSL to Greek quiz or a Greek to GSL quiz. The layout for the Greek to GSL quiz module is shown in Figure 6. In each case a set of fifteen randomly selected multiple choice questions of a certain level of difficulty are posed to the student, who can freely browse the questions, reply to any number of them, change his/her reply on any of them and finally check his/her answers by selecting the button at the center of the bottom bar.

Help system

The "Help" button is available in each module at the rightmost side of the top bar. It points at a static help screen, which is similar to the layout of the module the user browses. The directions about the functionality of the buttons or the various parts of the particular module are given as tool tips, while the user rollovers the mouse within them.

Formative Evaluation

During the develoment of the bilingual multimedia tool presented a prototyping approach has been adopted, characterized by a self-consistent process of design, development, formative evaluation and team discussion. Thus, formative evaluations were an integral part of the process of design and development of the tool presented, in order to optimize its

effectiveness. In the micro-evaluations carried out, a small group of deaf students in the second and third year of high school used certainly parts of the material developed in a computer room. The feedback expected from these evaluations was the pedagogical effectiveness, the ease of use of the graphical user interface, the frequency of use of the various model of the tool, etc. Furthermore, teachers of special school for deaf students have also participated in the formative evaluations.

Deaf students enjoyed working with the bilingual tool. The advantages of the tool they mentioned can be summarized as follows:

- The navigation within the tool is self-explanatory and easy to use.
- The inclusion of chemistry terms in GSL within the tool permits their familization with the terms.
- The presentation of the education material in the form of a dialog makes it more interesting and comprehensive.
- The simulation existence of the dialogs in both GSL and written language (bilingual method) familiarizes the students with the secondary language.
- The existence control that they have on the video clips.

Among all the forms of information presented in the tool, the students valued the video-clips most. In their first contact with the software they tend to play the video-clip for the whole dialog at once, using the play button. After a period of time, depending on the particular student and the number of chemistry terms and concepts presented in the certain dialog, they started to watch the dialog sentence by sentence by clicking the appropriate sentence in section (b) of the screen. Concerning the glossary the students tend to use it mainly as a vocabulary through the hyperlinks found within the dialogs. Only few of them used it as a standalone application by browsing within it.

The results of the formative evaluations provided information and suggestions for the technical improvement of the software. Among those of particular value in an early stage of evaluation, was the demand of the students for an extensive control over the video-clip. They preferred to play each video-clip again and again and to have access to its speed. Based on these findings the set of controls for playing, pausing and rewinding, as well as the dragger have been added to the video section (a) of each screen. After that the students frequently used the dragger to watch the video at the speed they want.

Another feature of particular importance emerged during formative evaluation was the use of icons, schemes or photos presented in section (d) of the screen. It has been found that large amount of such information results in a dispersion of the students' attention to both the video and its relation to the written text. Thus, in the final version of the tool the icons, schemes or photos have been reduced to the minimum required for the clarification of the terms and concepts presented.

Finally, the reaction from the educators was positive and discussions with them were focused on methods of integration of the multimedia tool in their curriculum in the form of a presentation tool and not as a self pace educational tool.

Future Work

The extension of the system described in order to cover all chemistry topics taught in Greek high school is in progress. Furthermore, we are going to include a search facility in the tool. By this the student will be able to find and browse within all the occurrences of a chemistry concept or term in the whole educational material. Upon completion of the system the extensive use of the system as both a self pace chemistry education and a presentation tool, as well as the systematic evaluation of its effectiveness, lay within our future word.

Acknowledgements

We would like to thank Dr. Ch. Papaspirou, a deaf linguist and chemist, for useful discussions and suggestions concerning the development of chemical GSL glossary. Many thanks are also expressed to N. Issaris, a deaf GSL teacher, and L. M. Gamalia, a deaf student, for their collaboration and participation in the dialogs presented on the videos.

References

Brusilowsky, P. (1996) Methods and techniques of adaptive hypermedia. *User Modeling and User-Adapted Interaction*, **6**(2), 87–129.

Egelston-Dodd, J. and Himmelstein, J. (1996) A constructivist paradigm in science education for students who are deaf and hard-of-hearing. *Journal of Science for Persons with Disabilities*, **4**(1), 21–27.

EU-BET (1997) EU-BET, European Association for Bilingual Education, Training and support for the deaf and those with associated communication needs, http://www.sign-lang.unihamburg.de/signingbooks/Links/eubet.html.

EU-Projects (1999) EU-projects involving sign language/information access for deaf people, http://www.sign-lang.unihamburg.de/signingbooks/Links/projects.html.

Grienes, B. F. (1996) Ethnologue: Languages of the world, Internet version: http://www.sil.org/ethnologue/countries/Gree.html.

Kannapel, B. (1978) Linguistic and sociolinguistic perspectives on sign systems for educating deaf children: Toward a true bilingual approach. In *American Sign Language in a Bilingual, Bicultural Context*, F. Caccamise and R. Hicks (eds). Silver Spring.

Lang, H. G. and Propp, G. (1992) Science education for hearing-impaired students. State-of-the-art. *American Journal of Deaf*, **127**, 860–869.

Lang, H. G., McKee, B. G., and Conner, K. (1994) Characteristics of effective teachers: A descriptive study of the perceptions of faculty and deaf college students. *American Annals of the Deaf*, **138**(3), 252–259.

Livingston, S. (1997) *Rethinking the Education of Deaf Students: Theories and Practice from a Teacher's Perspective*. Heineman, Portsmouth, NH.

Macromedia Inc. (2000) Macromedia Director Shockwave studio 8.0. Macromedia Home Page, http://www.macromedia.com.

Macromedia Inc. (2000) Shockwave plugin. Macromedia Home Page, http://www. macromedia.com.

Markellou, P., Rigou, M., Sirmakesis S., and Tsakalidis, A. (2000) A Web adaptive educational system for people with hearing difficulties. *Education and Information Technologies*, **5**(3), 189–200.

McIntosh, R. A., Sulzen, L., Reeder K., and Kidd, D. H. (1994) Making science accessible to deaf students: The need for science literacy and conceptual teaching. *American Annals of the Deaf*, **139**(5), 480–484.

Panselina, M. (2001) Bilingual model for chemical education to deaf students supported by educational multimedia software. Masters Degree Thesis, Department of Chemistry, University of Athens, Greece.

Pyfers, L., Robinson, J., and Schmaling C. (1998a) Signing books for the deaf in EU-countries: State of the art, Signing Books for the Deaf, EU-Telematics Application Programme DE 4209, Deliverable 3.1.

Pyfers, L., Robinson, J., and Schmaling C. (1998b) Different approaches in the production of signing books, Signing Books for the Deaf, EU-Telematics Application Programme DE 4209, Deliverable 5.1.

Roald, I. (2001) Norwegian deaf teachers' reflections on their science education: Implication and instruction. *Journal of Deaf Studies and Deaf Education*, **7**, 57–73.

Sandhu, J. S. and Wood, T. (1990) Demography and market sector analysis of people with special needs in thirteen European countries: A report on telecommunication usability issues, RACE R1088 TUDOR, Special Needs Research Unit, Newcastle Polytechnic, Newcastle upon Tyne, UK.

Stefanidis, C., Savidis, A., and Akoymianakis, D. (1995) Tools for user interfaces for all. In *Proceedings of the 2nd TIDE Congress,* Paris, France, 26–28 April. IOS Press, Amsterdam, pp. 167–170.

Stewart, D. A. (1996) The unwritten curriculum: Teaching deaf students in the '90s. In *Teaching Science to Students with Disabilities: Experiences and Perceptions of Classroom Teachers and Science Educators*, G. P. Stefanich, K. I. Norman, and J. Egelston-Dodd (eds). The Association for the Education of Teachers in Science, Rochester, NY, pp. 335–342.

Stokoe, W. C. and Battison, R. M. (1981) Sign language, mental health and satisfactory interaction. In *Deafness and Mental Health*, L. K. Stein, E. D. Mindel, and T. Jabaley (eds). Grune and Stratton, New York, pp. 179–194.

Strong, M. (1988) A bilingual approach to the education of young deaf children: ASL. In *Language Learning and Deafness*, M. Strong (ed). Cambridge University Press, New York.

Sutton, C. (1992) *Words, Science and Learning*. Open University Press, Buckingham, Philadelphia.

Vanderheiden, G. C. (1994) Application software design guidelines: Increasing the accessibility of application software to people with disabilities and other users. Trace R&R Center, Dept. of Industrial Engineering, University of Wisconsin-Madison, http://trace.wisc.edu/docs/software_guidelines/software.htm.

Yore, L. D. (2000) Enhancing science literacy for all students with embedded reading instructions and writing-to-learn activities. *Journal of Deaf Studies and Deaf Education*, **5**(1), 105–122.