A Case Study: Development of Interactive Multi-Media Courseware in Dentistry

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Abstract: This article details a project undertaken at the School of Dentistry at the Université de Montréal concerning the development of multi-media computer-based instruction for clinical and anatomical subjects in dentistry. Under the direction of Dr. Arto Demirjian. six courses were developed on Macintosh and PC platforms in three languages (English. French and Spanish) and packaged on CD-ROM. The courses, produced between January 1992 and December 1993, are intended primarily for dentistry students but are also being marketed as a vehicle for continuing professional education of practicing dentists. The article describes the contents and design features of the various courses, outlines the human and technical resources which were implicated in their development and production and relates the approaches which were taken to promote their use.

Résumé: Cet article décrit un projet entrepris par la Faculté de médecine dentaire de l'Université de Montréal. Il s'agit de la mise en place d'un programme d'enseignement multimédia informatise pour les études cliniques et anatomiques du domaine dentaire. Sous la direction du Dr. Arto Demirjian, ce projet de six cours a été mis au point en trois langues (française, anglaise et espagnole) pour les systèmes Macintosh et PC, sur progiciel CD-ROM. Les cours, développés entre janvier 1992 et décembre 1993, s'adressent d'abord aux étudiants en médecine dentaire mais ils sont également adaptes à la formation professionnelle continue des dentistes praticiens. Cet article donne un aperçu du contenu et des caractéristiques de conception des différents cours, il présente les ressources techniques et humaines qui ont contribue à leur élaboration et à leur production, et relate les démarches entreprises pour la promotion et l'utilisation de ceux-ci.

INTRODUCTION

A two year research project in multi-media courseware development was undertaken at the Faculty of Dentistry of the Université de Montréal, from January 1992 until December 1993, under the direction of Dr. Arto Demirjian, professor of anatomy.

Funding for this project allowed us to assemble a diversified team of human resources, and provide up-to-date equipment and software, for both Macintosh and PC/Compatible platforms. The development team involved

several people with different backgrounds, providing a wide variety of re-sources: content expert, designer, programmers and medical illustrator.

The courseware developed was intended primarily as a learning tool for undergraduate students at different stages of the dentistry program. How-ever, it was also envisaged that it would serve as a continuing education tool for dentists who are practicing their profession. Some, of the courseware is already in use by students and it is being evaluated in different parts of the world, mainly in the United States, but also in Canada, Europe, Australia and South America.

In this report we are going todescribe the courseware, then address the context in which the project was completed, the methods employed to achieve the goals, and finally the promotion and diffusion of our work.

COURSEWARE

The following courses, presented in a chronological order of production, are the tangible results of our efforts. Each successive module was treated as an opportunity to design and test new interfaces and evaluate various refinements concerning the interactive features.

Anatomy & Anaesthesia of the Mandibular Nerve (AAMN)

Written for dentists, professionals and students alike, this course, the first to be produced during the project, describes the anatomy and anaesthesia of the mandibular nerve as well as other anatomical structures in the area. It contains three chapters of theoretical information (Osteology, Dissection and Clinic) and a Quiz section.

The original version was developed prior to this project, by Dr. Demijian and Richard Tanguay, with the authoring software SuperCard. That initial version served as a prototype for the development of a second one, created with Macromedia's Director software. Basically, the object was to improve the interface and graphic design, while the content was mostly left untouched.

The content comprises more than 100 photographs, diagrams and medical illustrations. The standard screen layout (Figure 1) presents an image on the left, accompanied by a descriptive text on the right. The text contains highlighted words that double as buttons. When clicked on, these button activate the corresponding structure in the image, in a particular manner, through animation or highlighting.

A location and access map of the contents is always available through the use of a Where Am I?" button (Figure 2). This brings up a flowchart of the different sections of the document with the present location of the user highlighted. The user can also access any part of the content by clicking on the corresponding section of the flowchart.

The Quiz section was originally one module consisting of multiple choice questions. It was modified by adding a second module, an anatomical puzzle
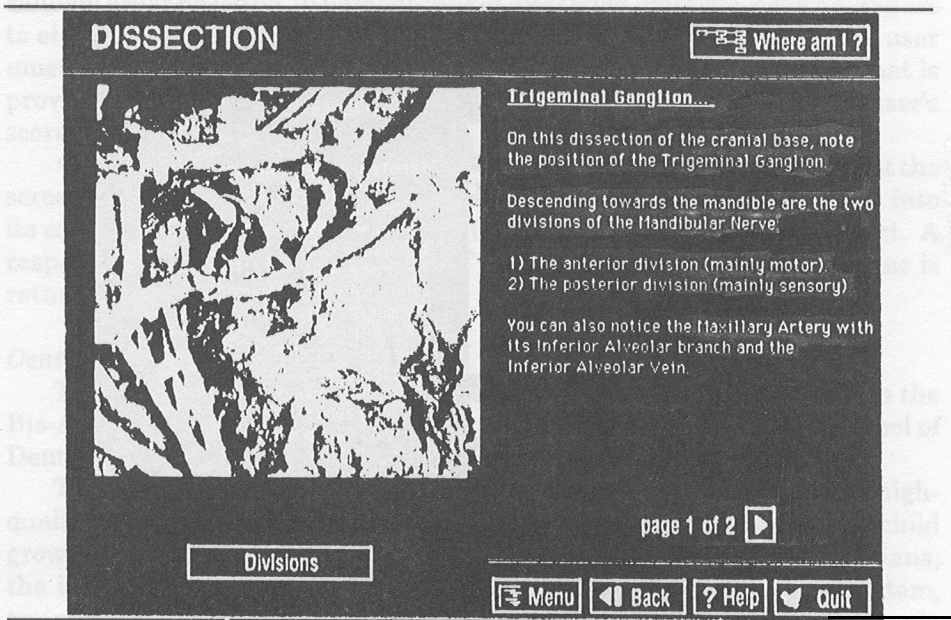
FIGURE 1.
AAMN — Typical Screen Layout

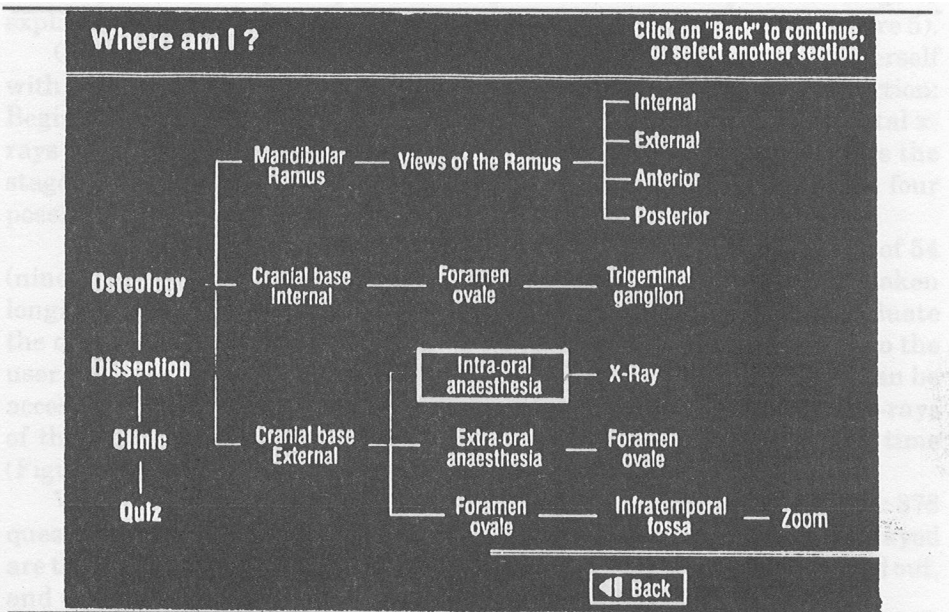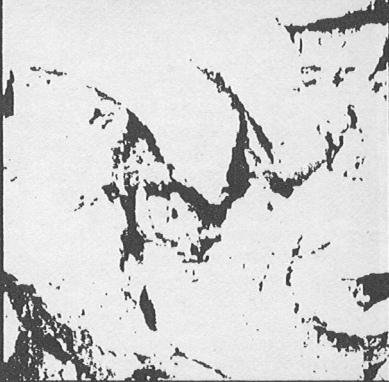**FIGURE 2.**
AAMN   Access and Location Map

FIGURE 3.

AAMN — Multiple Choice Questionnaire

FIGURE 4.

AAMN — Puzzle

of the cranial bones. The two modules work as follows:

⍰ The multiple choice questionnaire (Figure 3) presents 68 questions in random order based on 10 photographs of dissection material, each having six to eight different anatomical structures highlighted in some way. The user must identify each of these structures from a list of possible answers that is provided. After two incorrect tries the correct answer is provided. The user's score is compiled and displayed in the bottom part of the screen.

⍰ The puzzle (Figure 4), presents the bones of a skull dispersed about the screen. The object is to reassemble the skull by putting each bone back into its correct position. The software verifies if the chosen position is correct. A response is then given accordingly. If the position is not correct, the bone is returned to its original position.

Dental Development

This interactive tutorial for the evaluation of Dental Age is based on the Bio-Age tutorial/database package, a product also developed at the School of Dentistry prior to this project.

The new Dental Development package was designed to offer a high-quality presentation of the findings of a 25 year research project on child growth and development. Aimed at dentists, orthodontists and pediatricians, the information given is divided into five sections: the Demirjian System, training modules for beginner and advanced users, a bibliography, a sample of longitudinal x-rays, and a clinical evaluation utility for practical application of the Demirjian System.

The section entitled "Demirjian System" presents the Dental Age Evaluation System developed by Dr. Demirjian. Each developmental stage is explained and illustrated with x-rays, photographs and diagrams (Figure 5).

Once the user has assimilated the theory, s/he can test himself or herself with the two self-assessment modules provided in the Training section: Beginner and Advanced. In both cases, the user is presented with dental X-rays on which specific teeth are pointed out. The object is to determine the stage of dental development reached by those teeth, out of three to four possibilities displayed in the lower part of the screen.

In the Beginner's module, the user chooses one dental x-ray out of 54 (nine x-rays for each of six patients, three boys and three girls, taken longitudinally from age six to 14) (Figure 6). Then he or she has to evaluate the dental age of the specified tooth. The information made available to the user includes the gender and age of the patient. The correct answer can be accessed through the use of a "Solution" button. The user can view all x-rays of the patient at the same time, and change x-ray or patient at any time (Figure 7).

With the Advanced module, the difficulty level was raised as follows: 378 questions are available in random order, and the only information displayed are the gender and age of the patient, the x-ray on which a tooth is pointed out, and the possible answers.
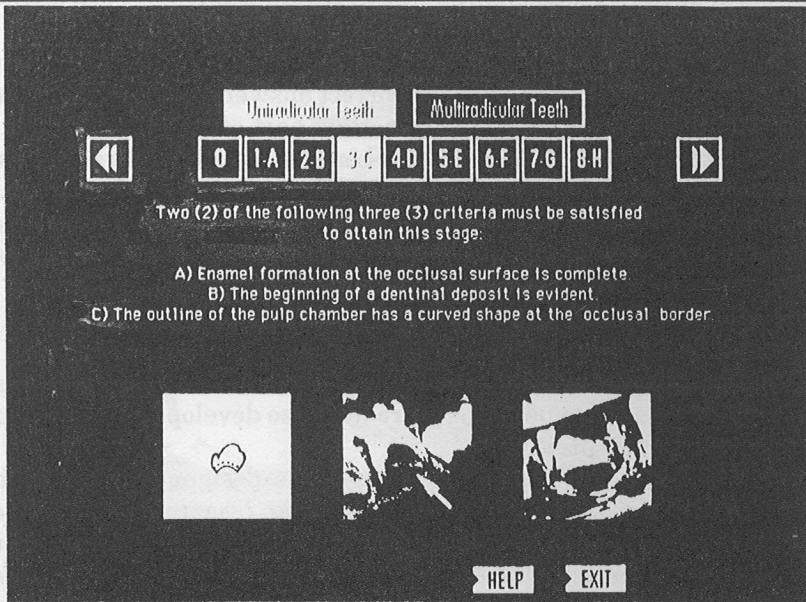
FIGURE 5.
AAMN — The Demirjian System

FIGURE 6.
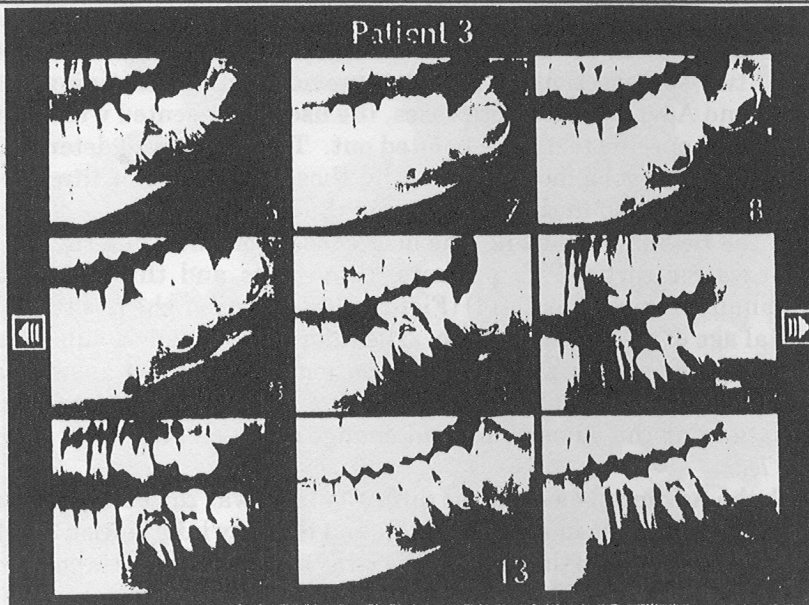*AAMN   — Dental Development   X-ray Selection in the Self-Evaluation Section*

FIGURE 7.

Dental Development - Beginner's Module in the Self-Evaluation Section

The Bibliography section contains over 800 pages of text, tables and graphs, which represents the main body of literature published by Dr. Demirjian and others on the subject of dental development. Articles can be selected through an index or via abstracts, and are presented in scrollable fields (Figure 8), with their accompanying tables and graphs. There is a print function to generate hard copies. An external function (XFCN) was developed for that purpose since the authoring software used (namely Macromedia's Director) did not offer an elegant way to accomplish this task. When necessary, external functions like these are developed for both Macintosh (XFCN) and PC/Compatible (DLL Dynamic Linked Library) platforms.

The Sample X-Bays section shows a longitudinal collection of dental x-rays taken from the same patient from one and one-half to nineteen years of age. The images displayed were digitized with x-ray scanners, to present the user with the finest quality possible.

Finally, in the last section, the Clinical Evaluation, two calculation tools are made available as practical applications of the theory. These enable the users to calculate the dental age and maturity score of a patient, provided that x-rays of that patient are available. External functions were specifically developed for those tools, for both Macintosh and PC/compatible platforms.

FIGURE 8.

Dental Development — Browsing Through Articles in the Bibliography Section
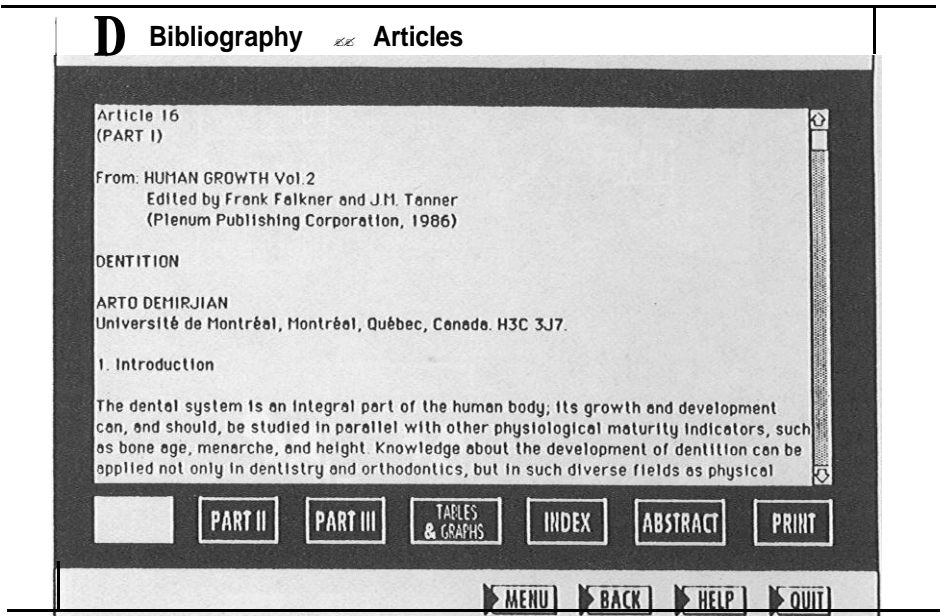
Anatomical Puzzles

The anatomical puzzle of the cranial bones, originally designed as part of the AAMN courseware, was supplemented with a hand/wrist area puzzle and questionnaire, to form a stand-alone instructional game, to offer different, fun and challenging ways to learn.

As previously described in the puzzle of the cranial bones, with the hand/wrist puzzle the user is asked to place the previously dispersed bones in their correct configuration. The software verifies if each bone is properly placed, and reacts accordingly. However, with the hand/wrist area, a puzzle and a questionnaire are offered as two different methods of learning:

✍ The puzzle asks the student to position the bones of each of the three groups — Phalanges, Metacarpals and Carpals · in their correct locations (Figure 9). While similar to the puzzle on the cranial bones, this puzzle does not verify if the bones are dropped in their correct location. Instead, an outline is made available to facilitate the positioning of each bone. The user can hide or show that outline in order to modify the difficulty level.

✍ With the questionnaire, on the other hand, hand and wrist bones are displayed correctly assembled, and the student is asked to click on specific bones, one after the other, randomly, until there is none left (Figure 10). The user is given three chances   correctly identify each bone, before the correct answer is revealed. The score is compiled and displayed on the left side of the screen.

FIGURE 9.
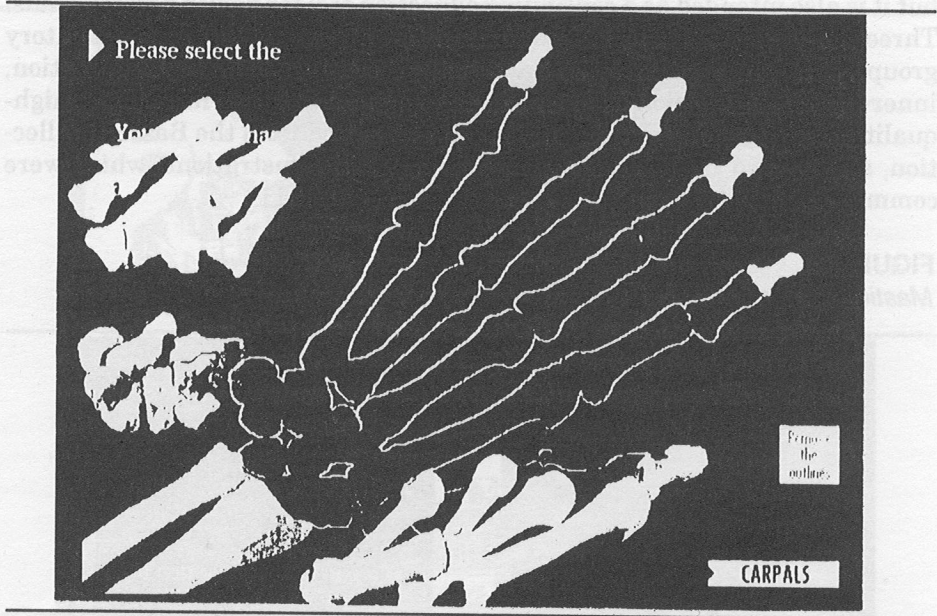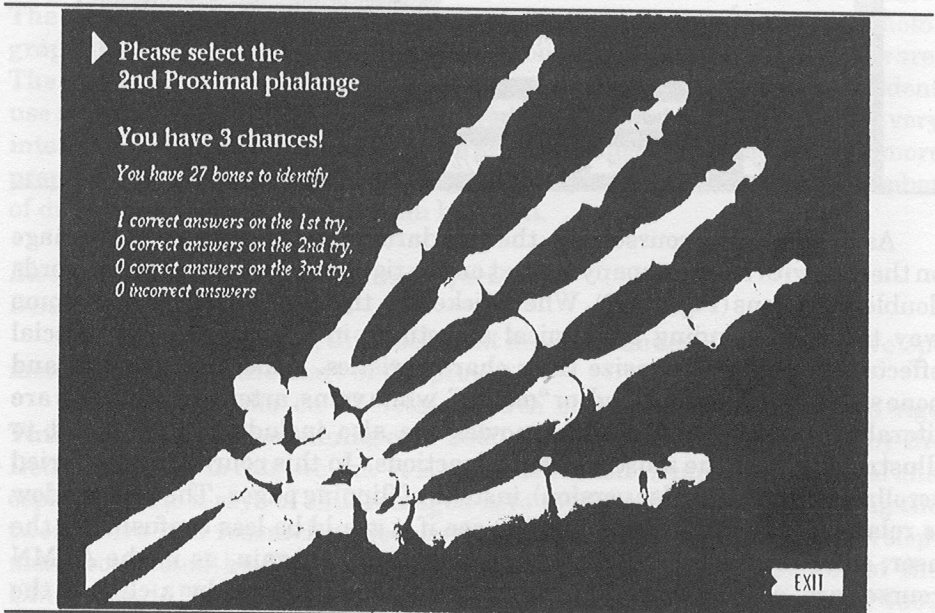*Anatomical   Puzzles   —   Hand   Puzzle*

FIGURE 10.
*Anatomical Puzzles — Hand Questionnaire*

Masticatory Muscles

This courseware was prepared for first year medical and dental students, but it is also intended as a continuing education tool for health professionals. Three groups of muscles, the infra-hyoid, the supra-hyoid and the Masticatory group per se, are defined and an explanation of their origin, insertion, innervation and function is given. The contents of the course includes 21 high-quality dissection photographs (most were obtained from the Bassett Collection, at Stanford University) and several medical illustrations, which were commissioned specifically for this document (Figure 11).

FIGURE 11.

Masticatory Muscles — Typical Screen layout with Medical Illustration
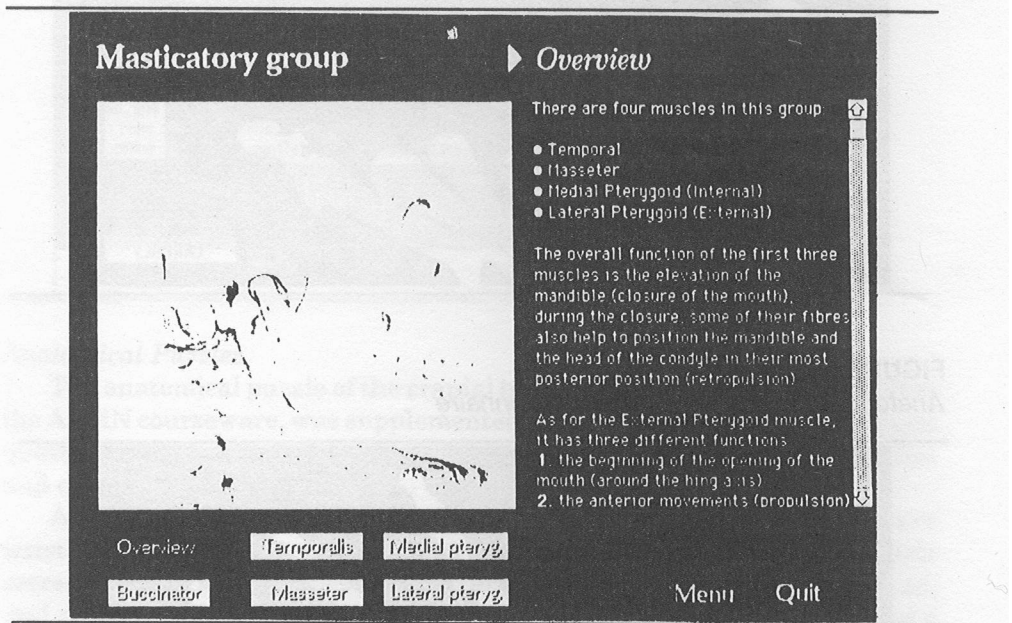
As in the AAMN courseware, the standard screen layout shows an image on the left, with an accompanying text on the right in which highlighted words double as buttons (Figure 12). When clicked on, those buttons identify in some way the corresponding anatomical structures in the image, with special effects created to emphasize their characteristics. Basically, muscles and bone structures are animated, or "moved", while veins, arteries and nerves are literally "highlighted". Digital movies are also included at one point to illustrate some of the muscle group's functions. In this courseware, we tried scrollable text fields (Mac version), instead of flipping pages. The text window is relatively small and we wanted to see if it would be less confusing to the user, since there would be fewer screen changes. Again, as in the AAMN courseware, a location and access map is made available by a click of the mouse.

FIGURE 12.

Masticatory Muscles — *Typical Screen Layout with Dissection Material*
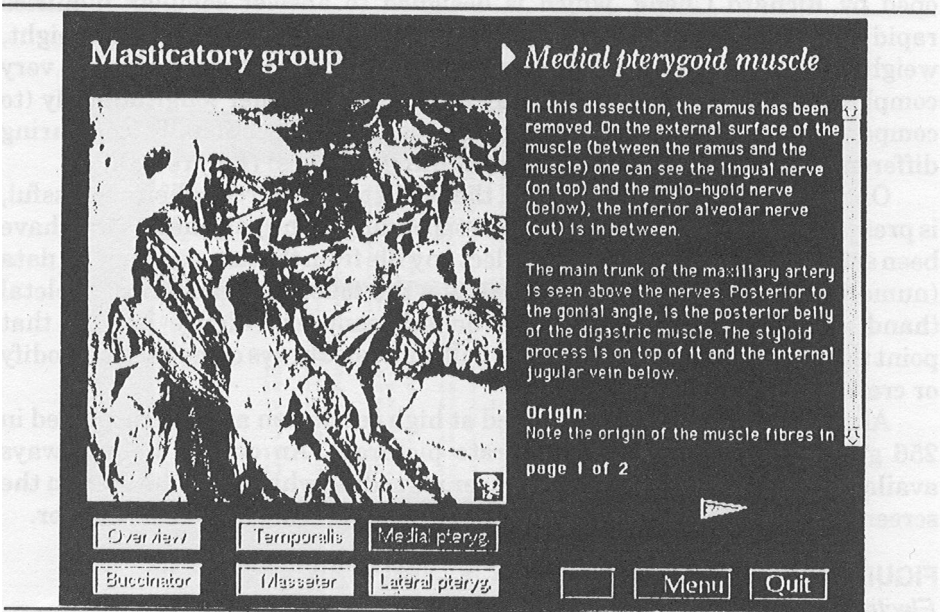
The Quiz section was divided into two modules: one with multiple choice items, and the other with short answer questions. These questionnaires were developed with Macromedia's Authorware Professional authoring software. The first module, a multiple choice questionnaire based on dissection photographs, is basically the same as the questionnaire in the AAMN courseware. The second one, requesting short answers, was designed to have the student use the keyboard to enter responses to randomly asked questions. While very interesting, we found that this kind of self-assessment tool implies a lot more preparation, and is longer to develop and test, because of the larger number of different good answers that can be given.

Electronic Encyclopedia on Maxillo-facial, Dental and Skeletal Growth

Due to its complexity, this document has been under continuous development from almost the start of the project.

The Encyclopedia on Skeletal Growth supersedes the Biological Age Tutorial/Database (containing over 2000 x-rays) which was developed by Dr. Demijian prior to this project. It is a new collection of hand/wrist, dental and cephalometric x-rays of children aged zero to nineteen, acquired during the twenty-five year research project on the subject of child growth and development conducted by Dr. Demirjian at the Human Growth Center of the de Montreal, referred to earlier. This collection contains over 4000

x-rays (providing over 450 MB of data).

The Encyclopedia is based on a custom built relational database, developed by Richard Cheng, which is designed to answer complex inquiries rapidly. Multiple parameters (dental, skeletal, chronological age, height, weight and sex) may be combined together to create either simple or very complex search requests, which may be completed either longitudinally (to compare growth of children at different ages) or cross-sectionally (comparing different children of the same age or at different ages) (Figure 13).

Once a query has been launched, the result of the search, when successful, is presented to the user as a list of files responding to the parameters that have been set (Figure 14). The user can select any file from the list, and view its data (numerical and visual) by clicking on one the following categories: skeletal (hand-wrist area), cephalometric or dental (panorex) (Figure 15). At that point the user can change category at will, and can always come back to modify or create a new search request.

All the x-rays have been digitized at high resolution and are displayed in 256 grays, to provide highly accurate pictures. An on-line help (always available) is provided to inform the user regarding what he or she sees on the screen: the different parameters, their definition, what they are used for.

FIGURE 13.
Electronic Encyclopedia   Selection of Search Parameters

FIGURE 14.
Electronic Encyclopedia — Search Results and Subject Selection

FIGURE 15.
Electronic Encyclopedia — Visualization of Subject's Data and X-rays

The Temporo-mandibular Joint (TMJ)

This document is currently under development. It is being produced with Macromedia's Director on the Macintosh to be played back on both Macintosh and PC/Compatible platforms. This courseware is being developed with all the positive aspects of the previous documents, plus new options (Figure 16). The newest feature provides monitoring of user access throughout the courseware. The information collected is recorded to external files under a user specified personal code. This allows the user to view what he or she has seen and, by the same token, know what he or she has yet to see. The Access and Location map, always available, will display this information through flowcharts of the different sections of the document. Those sections will be marked in the following manner: what is underlined will show the user where he or she is, what is italicized will show what he or she has seen, and what is bold will show what is left to see (Figure 17). This user code will also be used to record "bookmarks" inserted by the user at specific locations for later reference. The user will also be able to take notes, which will be recorded externally either for later reference or to be printed.

Review Questions are provided in the Main Menu as an advisement strategy to the user. The user has the choice of reviewing the questions with or without answers. If the questions cannot be answered correctly, it is assumed that the user will go back to the corresponding chapters for review.

FIGURE 16.
TMJ — Typical Screen Layout
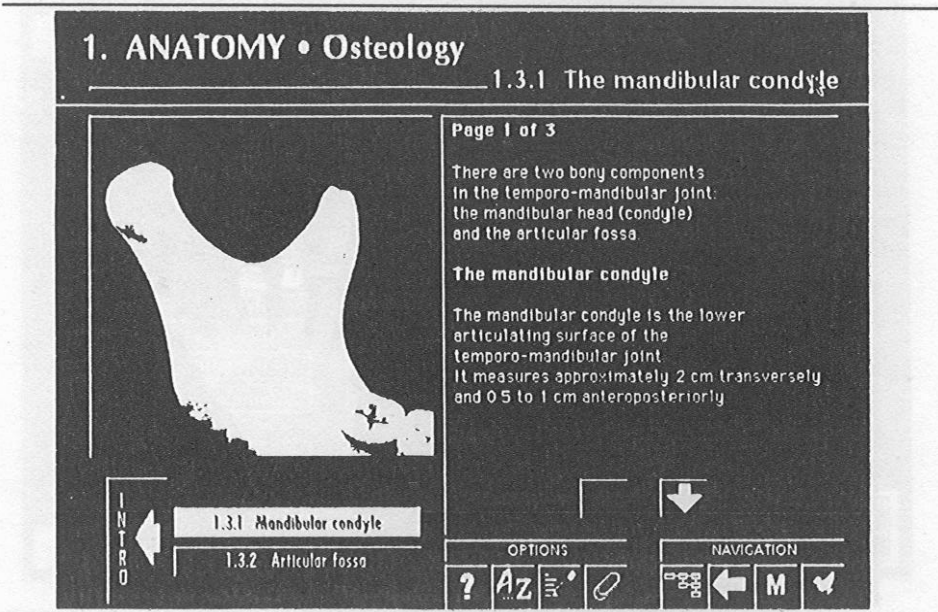
FIGURE 17.
TMJ -Access and Location Map
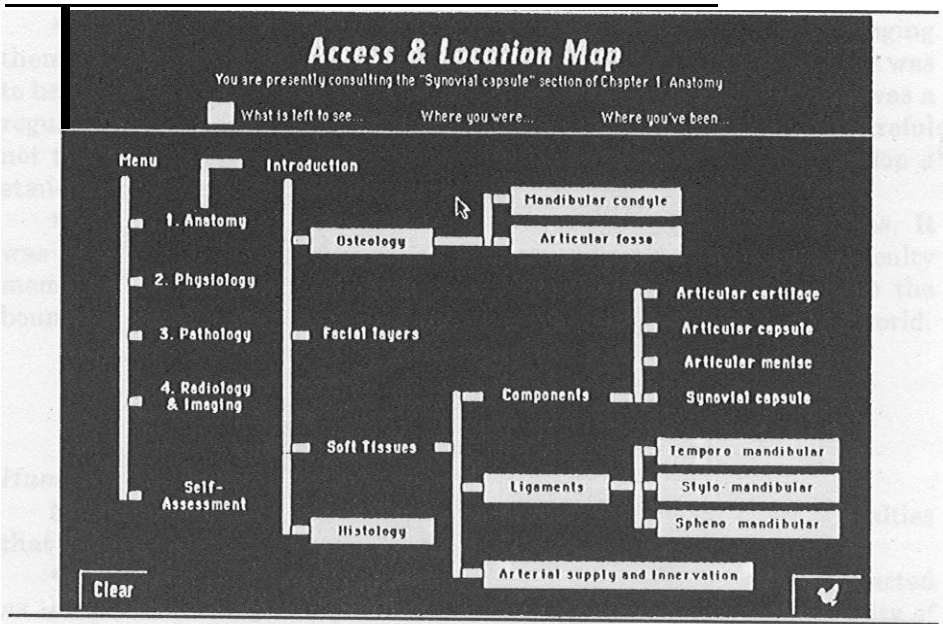
Different types of quizzes are provided in the Self-assessment section to test the knowledge acquired in the tutorial. Two content questionnaires, one Multiple Choice (Figure 18) and the other requiring Short Answers (Figure 19) are provided. There is also one visual Multiple Choice questionnaire, based on dissection room material and x-ray images. A FileMakerPro template has been created to produce the questions and answers included in the questionnaires. Once they are completed, external files are exported which are then read by the self-assessment module. This particular facility allows easier management of quiz material, and facilitates the modification of the contents of the questionnaires as desired.

OBJECTIVES

As a research and development project, the primary objectives were as follows:

 ☚ To design and develop computerized teaching or learning tools. Subject-matter was selected from Dr. Demijian's own teaching and research material, and prepared to be developed into computerized documents.

 ☚ To search for, test, select and evaluate the different tools necessary produce high quality documents. Keeping in mind that a wide variety of media can be used to communicate information, whether visual or audio, still

FIGURE 19.

TMJ — Mu/tip/e   Choice Questionnaire in the Se/f-Assessment Section

FIGURE 19.

TMJ — Short Answer Questionnaire in the Self-Assessement Section

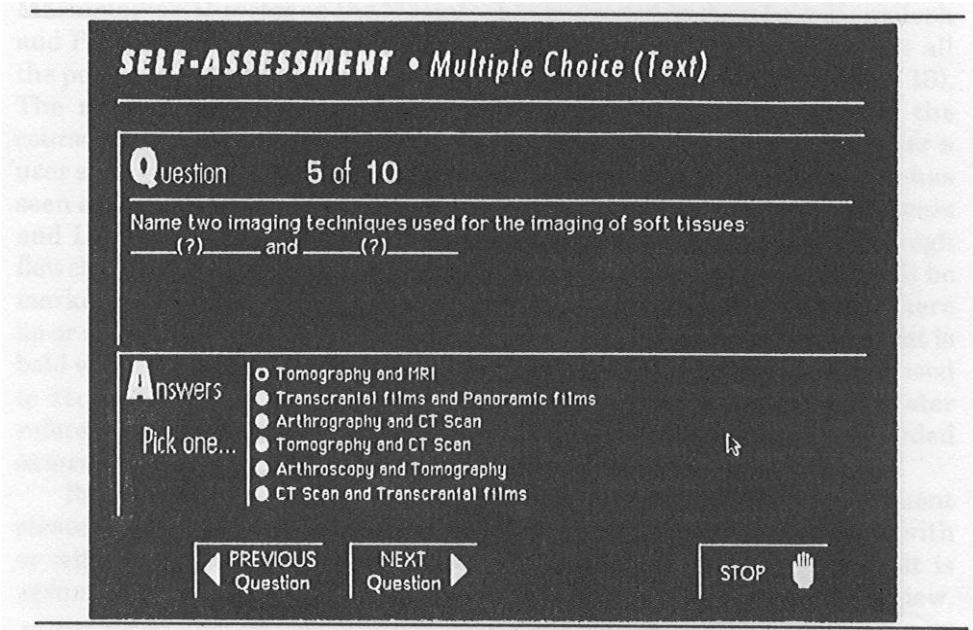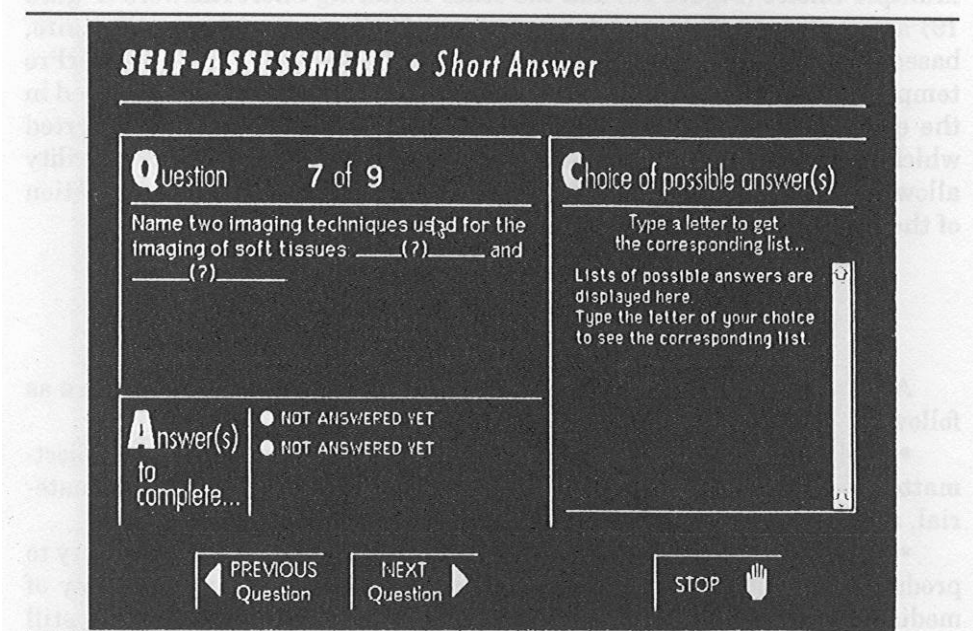or animated, textual or graphic, we needed to find the appropriate hardware and software to capture and incorporate the necessary media into the courseware in an efficient manner.

☞ To assess the implications of producing such tools, as well as managing them, in terms of human and technological resources. Even if this project was to be terminated at a known point in time, we wanted to work as if it was a regular activity of a permanent service inside the faculty. We had to be careful not to get caught by the "one shot deal" syndrome, in order to develop a standard and practical procedure to produce interactive documents.

☞ To promote technology-based learning inside Dentistry Programs. It was important to expose people to our work; not only students and faculty members within our own environment but also individuals outside the boundaries of the school, in other learning environments around the world.

RESOURCES

Human Resources

Many people were involved in the course of this project, with specialties that complemented one another.

☞ *Project Director and Content Expert.* He managed the project, and acted as the primary content expert. A professor of Anatomy at the Faculty of Dentistry of the Universite de Montreal, he thought out, defined, and wrote the content of the courseware. Other experts were also consulted when necessary.

☞ *Multi-media Specialist.* An industrial designer by training, his tasks were: provide support to the expert for the preliminary gathering and organization of the information; evaluate the human and technical resources needed; conduct instructional, interactive and navigational design; conduct analysis for the scripting on the Macintosh platform; interface design; production of the Macintosh versions; supervision of the production for the PC versions. In parallel to the actual production of the courseware, he managed the Macintosh network and the production of support material, such as the user's booklet, brochures, and disk labels. He also participated actively in public events to promote the courseware at conferences and expositions.

☞ *Authoring Programmer.* Responsible for the production of the PC versions of the courseware, using Toolbook and Authorware Professional.

☞ *Programmer.* Responsible for the production of the Electronic Encyclopedia on Maxillo-facial, Dental and Skeletal Growth including the development of the relational database with db Vista, and the front-end for the PC version with Toolbook.

☞ *Medical Illustrator.* Responsible for the production of medical illustrations of subjects difficult or impossible to photograph.

☞ *Scanning Technicians.* To digitize the x-rays (over 5000) to be included in the Electronic Encyclopedia, we required the services of the equivalent of

one full time technician for a year and a half.

  ≺ ***Programming Consultant.*** Some part of the courseware development required the services of a programming consultant, mainly to develop and produce external functions for the Macintosh versions (XFCN), and to assist in their development for the PC versions (DLL).

  ≺ ***Translators.*** Having taken care of the English and French translations ourselves, we required the services of two Spanish speaking dentistry students to produce the Spanish versions of three courses. Their work was of course verified and adjusted by Spanish speaking content experts.

  ≺ ***Technical Support.*** Using new technologies one inevitably must rely on various sources of technical support including hotlines provided by software developers and hardware manufacturers, after sales support services from the dealers, and exchange of information through the Internet network.

Technological Resources

  Having to develop for both Macintosh & PC/Compatible platforms, we organized and structured the department to maximize the exchange and transfer of information among people and workstations.

  An ethernet network was first implemented to link all workstations. Two file servers were included on the network: one dedicated for Macintosh development, the other linking all platforms (Macintosh, PC/Compatible and UNIX). Considering the large number of documents that would be created and manipulated, a backup scheme was organized to prevent any loss of data.

  Through the development stages, many different configurations of workstations were used to ensure compatibility between courseware and hardware: various peripherals, accessories, and various CPU performance and clock speed (MHz) were integrated. On the Macintosh side, we used a IIsi as the lower end, up to the Quadra 900 for higher performance. As for the PC/ Compatible platform, it ranged from an aging IBM 386 running at 20 MHz, to more recent 486 models running at up to 66 MHz. Many peripherals were intentionally acquired from different manufacturers to diversify the stations' configurations, thus giving us more chance to experiment and to detect and address any incompatibility of platforms with our documents.

  As with most multi-media documents, our courseware needed to incorporate various types of information presented in as many different media: artwork, photographs, slides, x-rays, video, sounds. The following peripherals were used to acquire that information: reflective and transparency scanners, slide scanners (Figure 20), 35mm digital camera, 8mm S-VHS video camera, microphones, CD-ROM players.

  Once a unit of courseware was finally completed, meaning that the English, French and Spanish versions of both Mac and PC platforms were finished and verified, all documents were written to a compact disk (Figure 21), in hybrid format, tested, and if necessary, sent to a production plant for mass reproduction.

FIGURE 20.
Hardware (Scanners) for Capturing Visual Material
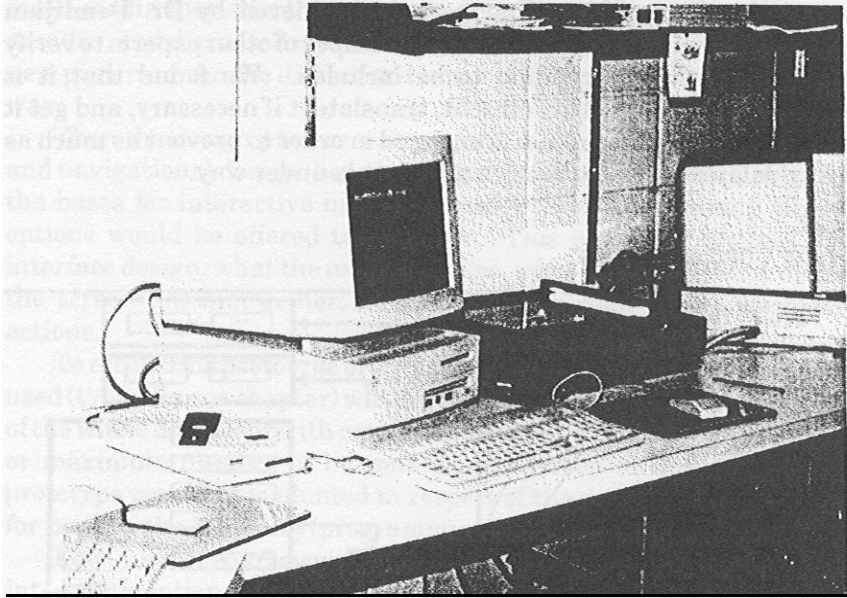
FIGURE 21.
Compact Disk Writer
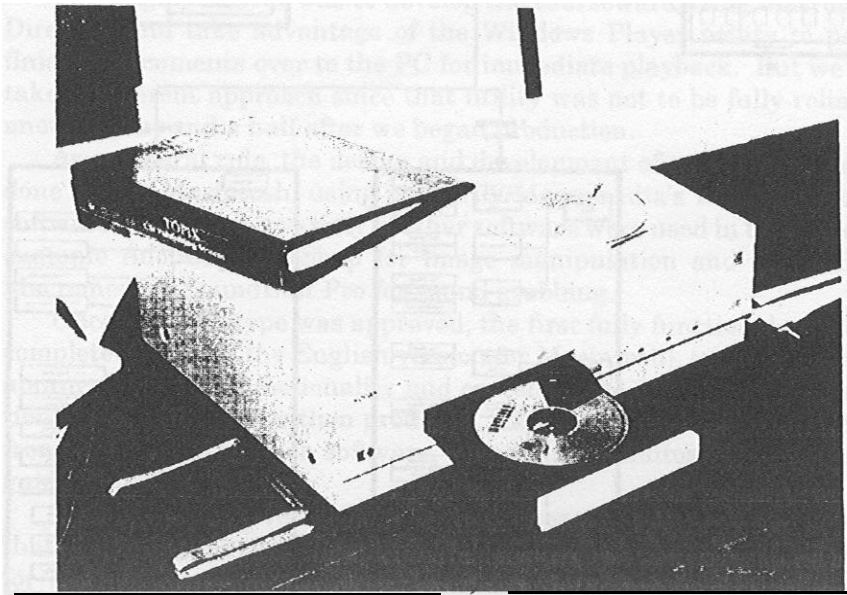
DEVELOPMENT, DESIGN & PRODUCTION

The first step taken was to define, structure and prepare the content of the courseware-to-be (Figure 22). That part was achieved by Dr. Demirjian himself, the content expert, with the occasional input of other experts to verify the correctness of the information to be included. We found that it is important to finalize the written content, translate it if necessary, and get it approved before the design process is engaged in order to prevent as much as possible any delay in production once a project is under way.

FIGURE 22.
Sample Now Chart of Comfort
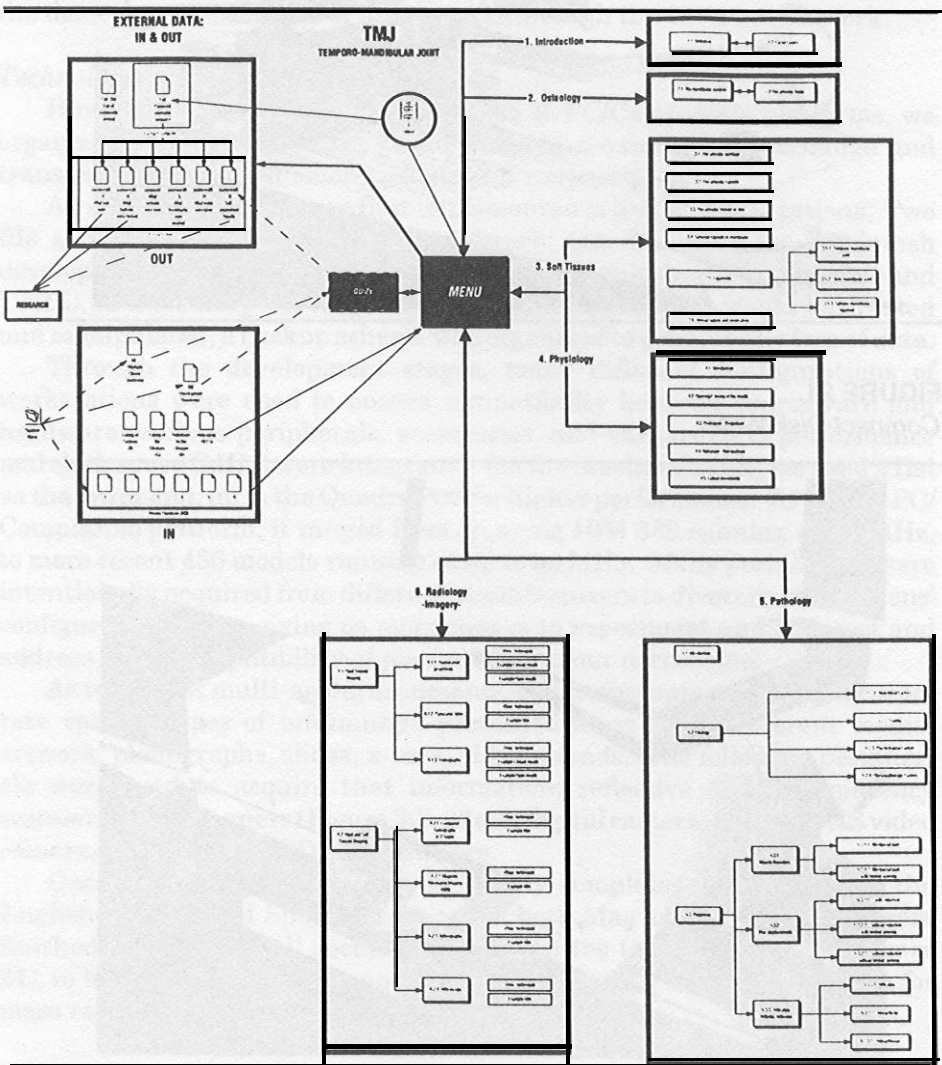
Once approved, the content was given on paper to the multi-media specialist. Private tutoring sessions were provided for him so that he could assimilate as much as possible the nature of the material. The expert and the multi-media specialist then evaluated existing media such as slides, artwork or video, and discussed new media to be obtained, like medical illustrations, new pictures from the dissection room, or 3-D models to be animated in some way.

Then the design process was put into motion, starting with information and navigational design (based on the information flowchart), which defined the bases for interactive navigation, as well as determining what kind of options would be offered to the user. This naturally brought about the interface design: what the user would see, what would the items displayed on the screen tell him or her, how those items would react upon the user's actions.

To create this prototype of the courseware, a small part of the content was used (typically one chapter) which provided typical situations representative of the whole document with respect to, for example, maximum length of titles, or maximum number of buttons on the screen at the same time. That prototype was then evaluated in respect of the design objectives, and tested for bugs in the scripting (programming).

Each unit of courseware was used as a new opportunity to test various interactive options and interfaces, to try out different production approaches (hardware and software) and to determine the best way to produce multi-platform, multi-language courseware.

Tools

The original intent was to develop the courseware using Macromedia's Director, and take advantage of the Windows Player utility to port the finished documents over to the PC for immediate playback. But we had to take a different approach since that utility was not to be fully reliable for another year and a half after we began production.

As a general rule, the design and development of each courseware was done on the Macintosh, using primarily Macromedia's Director authoring software. Of course, a variety of other software were used in the process, for example Adobe's PhotoShop for image manipulation and retouching, or Macromedia's SoundEdit Pro for sound grabbing.

Once the prototype was approved, the first fully functional version was completed (usually the English version for Macintosh), tested, verified and approved as to its functionality and content. The other versions (translations) for the Mac were then produced, while the PC versions were created from scratch with other software, using the Macintosh documents as a guideline.

To create the PC versions, we had to choose another authoring software that would come as close as possible to Director's performance, while waiting for Macromedia to improve their Windows Player utility. We first used

Toolbook, but its lack of visual or special effects kept us on the lookout for another solution. Then we tried Authorware, because of its cross-platform transferability. The original documents were developed with Authorware for the Macintosh, then transferred to the PC and re-opened with Authorware for Windows. The transfer results were good, but we were dissatisfied with Authorware's overall speed, its restricted scripting environment, and its lack of visual effects (again we were comparing it to the Director version on the Macintosh). It's positive aspect was its built-in functions and variables which prove to be very useful when creating a document to be used as an evaluation tool, like a self-assessment, questionnaire or quiz. But since it was possible to achieve the same thing with Director, we were still not fully satisfied.

When Macromedia released a reliable version of the Windows Player in September 1993, we re-oriented our strategy toward developing a Mac version transferable over to the PC, for immediate playback. It meant changing some design aspects, because of minor incompatibilities between platforms, but we felt it was worth it because the overall result was very acceptable, and there were important savings in production time.

Finally, these efforts brought us to emphasize the use of Director first to design and develop the prototype, then to use it with the Player software (for both Mac & PC) to produce the tutorial part of the courseware. At the same time we retained Authorware as a tool to develop the self-evaluation modules, again for both platforms.

Promotion

Once we had some documents to work with, we started promoting the idea of using these as learning tools in the curriculum, using different approaches.

✍ Dr. Demirjian started using the courseware in the classroom as part of his teaching material. The documents are displayed to the class with a Macintosh IIci, equipped with an overhead projector and a color LCD projection panel.

✍ We also designed a kiosk, to be installed in the corridors of the Faculty of Dentistry, so that students and faculty members could be exposed to our work and access it whenever they felt like it. That kiosk is also used to demonstrate its possibilities in special events taking place in Montreal, like conventions and expositions (Figure 23).

✍ A few computers (Macs & PC's), were also made available to students to use these documents in a more comfortable setting, with technical support for the unfamiliar users.

✍ Having access to the Internet network gave us the opportunity to make our work known all over the world. Demonstration packages were made available to anybody using the network, for them to download and evaluate. The network even turned out to be one of the best ways to promote our documents right here in Montreal!

✍ Finally we produced a brochure, or catalogue, of our documents with all the necessary descriptive and technical information. This catalogue is distrib-

FIGURE 23.
Interactive Kiosk
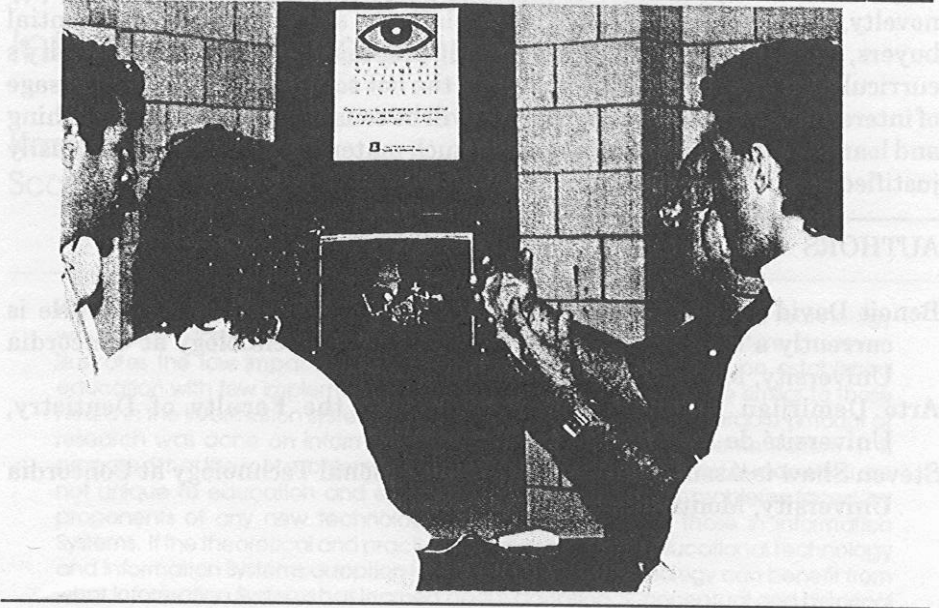
uted to individuals, students and professionals, universities, and libraries, all over the world.

Conclusion

This experience has proven to be very positive from a research and development point of view. The expectations were largely surpassed, due mainly to the fact that new possibilities were constantly uncovered as we progressed through each new project, allowing us to experiment further.

Though vary well received by undergraduate students, it took a long time to get some basic recognition from other faculty members, administrators, and practicing health professionals. And it will surely take more time to see some kind of real implementation in the curriculum ofundergraduate studies as well as for continuing education. That time frame will depend mostly on how many experts will come forward and invest themselves to produce new subject-matter for development of more titles.

Once a critical mass of titles is available, both on fundamental and clinical aspects, we expect interest in using multi-media instructional materials will increase. At the moment, production of such computer-based materials in the field of dentistry owes much to the commitment and vision of a relatively small number of developers. It is not yet market driven.

Even with the involvement of well-established specialized people in the marketing field, we found that commercial distribution of such materials is very difficult. Several factors are probably responsible, such as the product's novelty, its specialized aspect, the relatively small number of potential buyers, and the difficulty of integrating the material with other faculty's curricula. We look forward to a point in the not so distant future when usage of interactive multi-media courseware will be considered a standard teaching and learning strategy. Development of such material will then be more easily justified.

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