Multimedia Web-based Resources for Engineering Education: The Media Design and Assessment Laboratory at UMR

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Abstract

The design, development, and assessment of web-based multimedia learning resources are important aspects of engineering education. The Media Design and Assessment Laboratory at the University of Missouri-Rolla was established to facilitate the interaction between web designers and content providers. It was created under the auspices of the Instructional Software Development Center. This paper will discuss design philosophy in terms of the identification of fundamental concepts, development steps, and assessment implementation within the context of ongoing projects. These projects include modules for an optics curriculum, tutorials for an interdisciplinary course, and interactive software for a basic engineering course.

I. Introduction

The objective of this paper is to discuss the development philosophy of the Media Design and Assessment Laboratory[1] (MDAL) at the University of Missouri-Rolla (UMR). The purpose of the MDAL is to facilitate the interaction between multimedia developers and content providers. The goal of the MDAL is to provide faculty with the classroom-enhancing multimedia tools that will best suit the needs of the students as well as the faculty. The MDAL was formed under the auspices of the Instructional Software Development Center and is supported by several departments and faculty. Some current projects include: the Smart Engineering Website[2], the Applied Optics Laboratory tutorials, PsychConnections[3], basic engineering interactive software, and Blackboard initiation and support for the campus. There are also workshops and a credit class provided by the MDAL staff in web and media design.

The development philosophy is modeled by three primary objectives interrelated as shown in Figure 1. The first objective is the identification of fundamental concepts and the delineation of concept interrelation. During this process the goals of the multimedia-learning tool are developed with the content provider s help and then the concepts are incorporated into manageable modules and related to each other. The second objective is development of the concept modules. Each module should incorporate foundational information, demonstrate potential applications, and link content with other modules. The final objective is the assessment implementation. The assessment is necessary feedback to further improve the modules and to guide the execution of future projects.

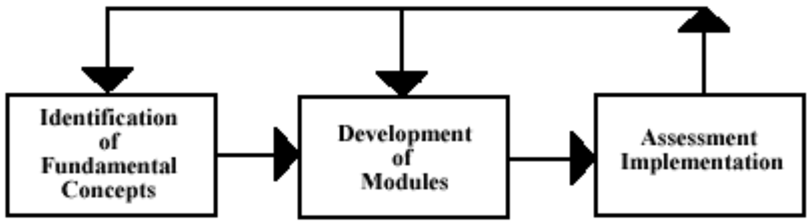

Figure 1 — The interrelationship of the MDAL primary objectives for design development.

This paper will explain in detail each of the primary objectives and illustrate them using examples from projects currently being realized by the MDAL staff. During the identification and interrelation of fundamental concepts content may be organized into modules, which ideally have multiple uses by the engineering educator. The interrelationships and possible alternate uses of modules for a graduate fiber optics class will be illustrated. The development steps for an individual module must incorporate foundational information, demonstrate potential applications, and link content with other modules. The intralinking and interlinking of content in a set of interdisciplinary modules will be described. This endeavor provides an overview of electrical engineering concepts in an elective class and the application of this information to the civil, mechanical and aerospace concepts. Assessment implementation is guided by five fundamental themes: progressive feedback is provided through formative assessment, individual components of learning systems are examined independently, learner difference variables are included in assessment analyses, quantitative and qualitative measurement tools are used, and multiple levels of knowledge are considered. The integration of wireless laptops and interactive software into basic engineering classes with high enrollment will be discussed.

II. Primary Objectives

A. Identification and interrelation of fundamental concepts

The identification and interrelation of the fundamental concepts (see Figure 2) must come from the content provider and must be understood by the media designer. An optimal outcome will not result in the absence of interaction during each step of the development process. This is especially true if the content is simply presented in another form, such as lecture notes, to the media designer as the sole input from the content provider. Most likely the finished product will be inadequate due to the media designers lack of understanding of the material. Student learning will be hindered if the media characteristics do not convey the content provider s intent and emphasis. For instance, the direct transfer of a lecture talking head to the computer screen has been shown to be ineffective.[4] A more interactive experience is necessary. For successful interaction, the content provider should supply context and priorities to the information and the media designer should supply possibilities for meaningful media elements. If the lines of communication are kept open the media resource can effectively exploit the capabilities of the technology and reflect the priorities of the content provider. If the development does not include continual communication, the delivered product may require another complete iterative cycle. The product development may then be discontinued because of time and financial limits.

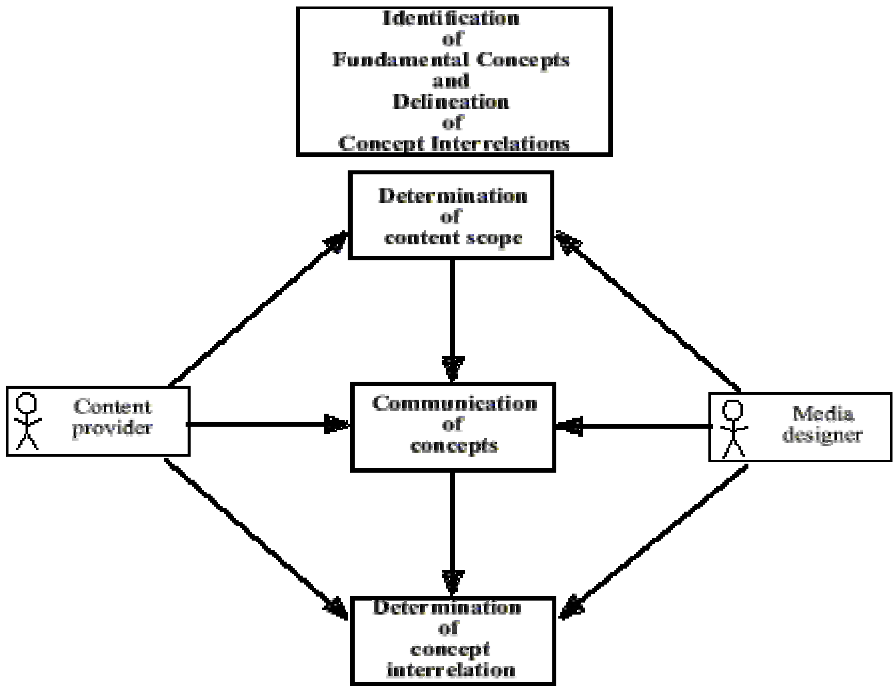

Figure 2 — The identification of fundamental concepts is the first concept in the MDAL development philosophy

During an initial discussion, the intended audience, usage context, and learning goals are clearly stated. The intended audience is usually a college level student with some computer experience. The usage context is the manner in which the modules will be used. The audience may have varying experience in the field of study that will determine the amount and depth of module information. The modules may be used as a classroom supplement or even as a textbook replacement. The learning goals are what the professor expects the student to retain from the modules. These decisions are made at the very beginning to help the content provider consolidate the information that he provides and to insure that the media designer understands what is expected. Once these three decisions are made the content provider and media designer move on to the communication of the class concepts.

To avoid confusion the content provider is asked to provide a detailed outline of the concepts he wishes to include and is asked to discuss the outline with the media designer. The communication of the actual concepts is an especially difficult part of this process. The MDAL does not have representatives from every field, so the developer may not have experience with the concepts. Therefore, it is especially important to have an open line of communication with the content provider to insure that the concepts are presented accurately.

The delineation of concept interrelation involves the development of logical modules and progression. The idea is to have each module completely explain a concept and to refer to other modules for additional information. There should also be a natural progression to the modules that is obvious to the user. Sometimes the content provider wishes to develop modules that can be used for several related classes. In this case the needs of the other class are taken into consideration when dividing the information into the modules. Finally, the content of each module needs to be cross-referenced with the other modules.

Example: The Applied Optics Laboratory Website

The Applied Optics Laboratory Website has just been through this stage of development. The optics professor in the Electrical Engineering Department wishes to create background tutorials to support his classes. The classes are senior electives and advanced graduate courses. The courses, especially the senior elective courses, may have students possessing a considerable range of experience with the concepts. This range is anywhere from undergraduate students with no experience at all to graduate students that only need a review. Both types of classes have a textbook, but the professor wishes to supplement the textbook by consolidating the background information the students should retain so they can review it before coming to class. This is necessary because most of the textbooks in the field assume that the student already has the background knowledge.

The professor has been thinking about creating this website for several semesters now, so he has been organizing the information as he would like it presented. He has been in touch with the head of the MDAL so he has an idea about what media capabilities are available. The information has been divided into three distinct modules. The primary modules have an obvious progression as can be seen in Figure 3. Each primary module has a separate purpose. The *Electromagnetics Review* is considered prerequisite material. The *Optics Overview* is concepts and conventions in optical engineering. The *Plane Wave* module is the mathematical model of wave properties. These are all related in that each needs the other to completely explain all the concepts. For example, if the student does not understand electromagnetics he/she cannot understand the properties of waves. Furthermore, optics cannot be completely explained with out wave properties because light is defined using waves. As can be seen each primary module also has several topics treated as secondary submodules and are also topically progressive.

B. Development steps

The development steps for an individual module must incorporate foundational information, demonstrate potential applications, and link content with other modules as illustrated in Figure 4.

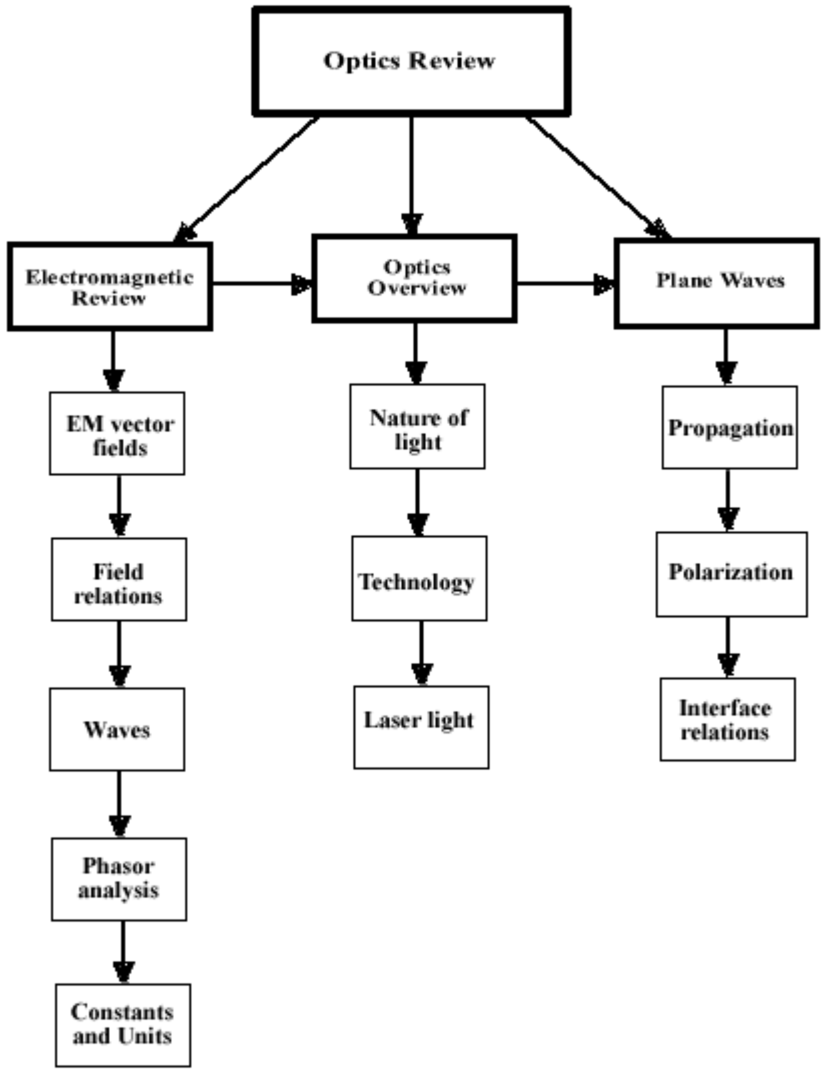

Figure 3 - Diagram indicating Applied Optics Laboratory module layout.

Incorporate foundational information

The first step in incorporating foundational information is to delineate what will be contained inside the module. The intended audience, usage context, and learner variables are taken into account and the outline provided by the content provider is organized according to the modules. The information should begin simple and build inside the module as well as between modules. Each module should be able to stand alone, but by combining them a larger picture is formed.

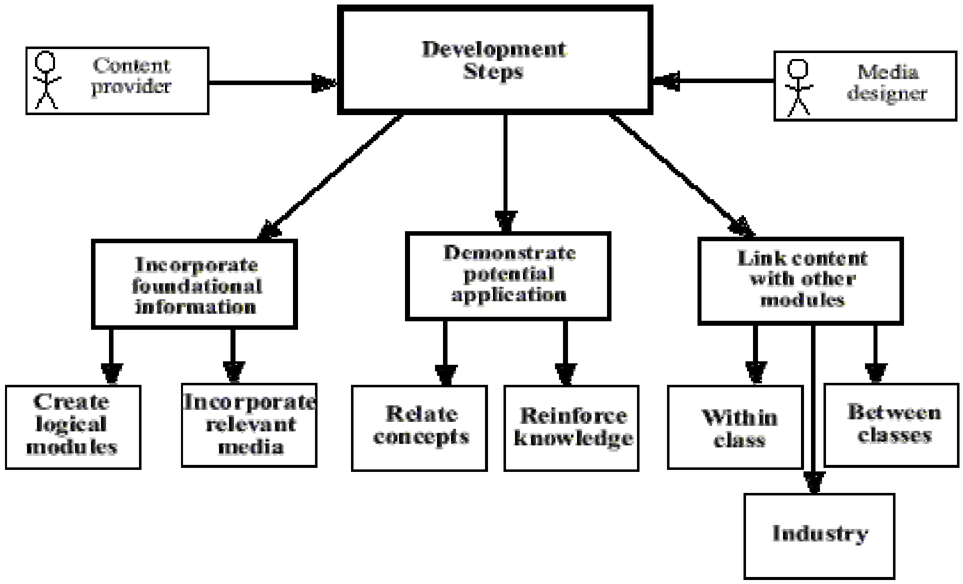

Figure 4 — Development steps for individual modules.

When developing and incorporating relevant media the designer must remember that the objective of the learning modules is to create a positive learning experience for the user. There is a fine line between confusing the user and using complicated media to teach. Many times new media developers tend to create complex designs with too many bells and whistles. To avoid creating modules that do not help the learning process, the development and incorporation of relevant media is a balance of two concepts, simplicity and complexity. These concepts are related to the fundamental concepts and their interrelation as can be seen in Figure 5. Simplicity in the context of media design refers to the usability and consistency. Complexity involves the interactivity, adaptability, and multi-modality.[5]

Usability incorporates all the factors that make the experience for the user simpler and stress free. These factors are especially important in a web based environment because there tend to be technical problems and download time issues. Literature on this subject emphasizes usability in terms of design simplicity. Jacob Nielson is a strong advocate of simplicity. He feels that graphics should not be included unless absolutely essential.[6] This, of course, is an extreme view. Nielson was targeting corporate sites that wanted to convey information quickly and simply. The learning environment is less stringent, but it is important to remember that too much media can cause confusion and detract from the learning process.

Consistency refers to the simplicity of the higher-order design elements of site organization. The advantage of the available media is that complex ideas can be conveyed and linked easily. However, the user then must be able to navigate a more complex environment while learning a complex idea. Giving a novice learner this large amount of freedom may be detrimental to the learning process.[7, 8] Most of the literature on consistency refers to web design, but it can be applied to any multimedia-based medium whether it is on the web or on a CD. A

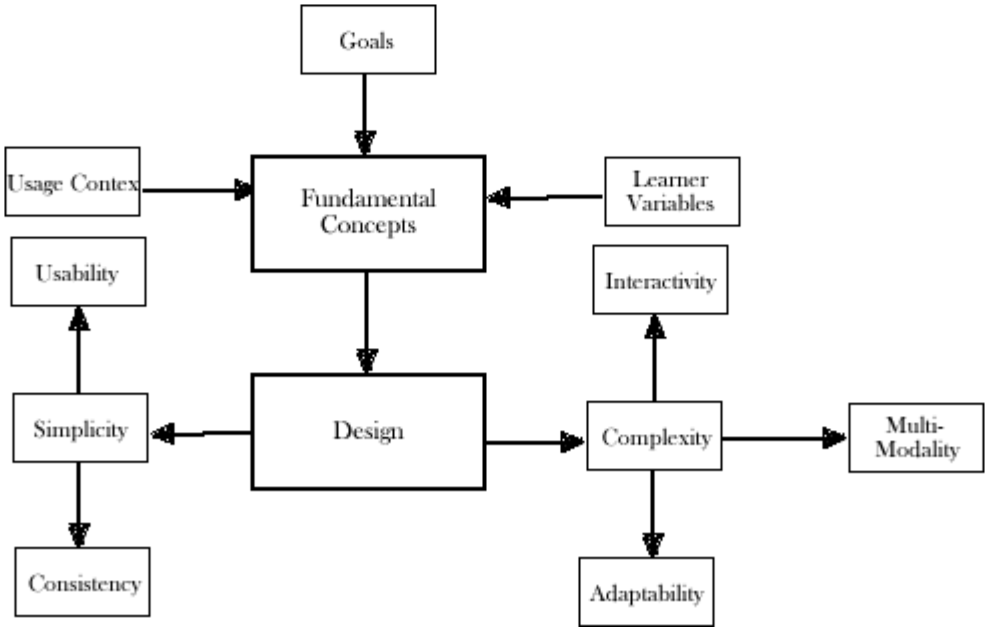

Figure 5 — MDAL philosophy for incorporating relevant media.

clear and systematic organization scheme for the modules is essential to a good learning environment.[9, 10] The progression through the modules should be obvioius,[11] and there should be a well-structured hierarchy.[12, 13] Also, organization should include consistency in the actual design of the pages.[14, 13] The user should be able to tell at a glance where they are in the hierarchy. Also, for the web situation the learner should immediately know that he or she outside of the site.

Interactivity is a very important idea behind effective media design. It has been seen in research that learners retain information most effectively when they actively engage in learning, as opposed to reading or listening.[15] One of the advantages of the new media being developed is that it can potentially facilitate the process of integrating activity into education. By providing links in hypertext the user must make decisions as to his progression through the pages and thus interact rather than passively read. More complex activity can be added by requiring that the user answer questions, locate specific information, research topics and even create their own stories and scenarios.

Multi-modality is a fundamental potential advantage of using media in learning. It is possible to offer the same material in multiple forms such as audio, visual, and textual. According to the cognitive flexibility theory, a popular theory of complex learning, students learn information most effectively when it is experienced in different formats.[16] Further studies indicate that audio can increase the effectiveness learning if it relates to what is being taught.[17] Integrating dynamic multimedia into the learning experience can enhance interest and motivation.[18]

Adaptability refers to the possibility that the information can be tailored to the user. This is becoming a common goal in educational media design. Many designers try to offer examples in more than one media. A potential strength of using the different media is allowing the student to select his preferred format according to learning style. This however, is not implemented often because the time and effort involved in producing the modules is significant enough without having to make multiple formats. Theoretically, once the first modules are produced the formats could be altered in the future to accommodate different learning styles. Also, there is very little support in research to say that the student will benefit from information given in their preferred learning style.[19, 20] There is more support in research for tailoring the media to the user s ability and skill. The student ability is the single most important individual factor in determining user s performance with instructional media.[21, 22,23]

Demonstrate potential application

Demonstrating applications for a concept is important in engineering education. Just teaching the mathematical background does not give a future engineer practical experience that he will need in the work force. Many times the applications will relate several concepts to increase the student s understanding of each. The applications will also serve to reinforce the concepts with real world examples. Therefore it is a goal of the MDAL to include relevant applications or references to applications within the modules.

Linking Modules

The modules should be linked so that the user can easily find the information he needs. This includes links within the class modules, outside the class modules, and to industry where applicable. Links within the class modules should show a logical progression, so the user can easily navigate through the concepts of the class. Links outside the modules should be clearly indicated, so the user can return easily. Examples of these would be links to information that the user has already been exposed to, but may need to review. Links to industry should supplement the application information. The industry information link should be clearly marked as advanced and possibly optional, such as a reference.

Example: Smart Engineering Website

The development steps are illustrated by the Smart Engineering website[2] developed by MDAL designers. The website is used to supplement two interdisciplinary courses. This example is the portion of the website used to supplement the Smart Materials and Sensors class. The goal of the class is to integrate knowledge from several fields to help the students develop interdisciplinary communication skills and awareness. Due to the need to quickly learn some basic concepts in another field there was a need to develop a tool that consolidated the material and allowed the student to view it at his own pace before a lecture.

The component topic in the Smart Materials and Sensors course is sensing in smart structures. Smart structure technology involves the combination of materials, manufacturing, sensing, structural analysis, and other interdisciplinary concepts. This endeavor provides an overview of electrical engineering concepts in an elective class and the application of this information to the civil, mechanical and aerospace concepts. Related to the class was the development of a demonstration highway bridge. The bridge was a field laboratory for the students and documentation of the project was included on the Smart Engineering web page for reference although not directly linked to the class modules. The modules for the class are delineated in Figure 6. The second week will be emphasized in this explanation.

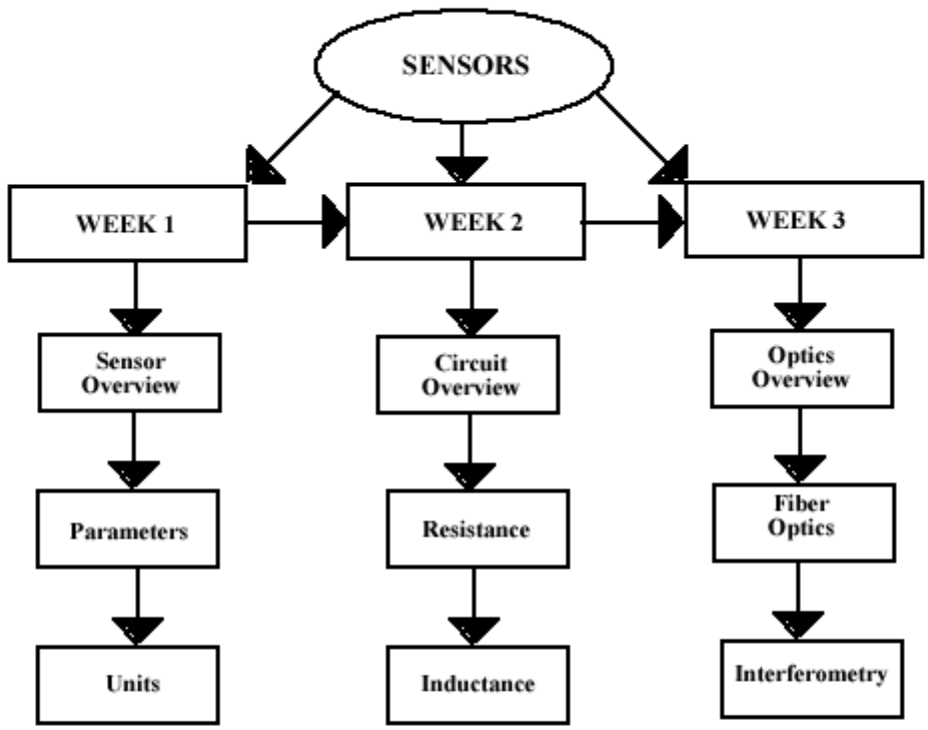

Figure 6 - Delineation of Smart Materials and Sensors class modules.

The material was divided into three weeks of material. The students were to review the week s material before coming to lecture on Monday so that the instructor could use the time to highlight concepts and answer any questions. This allowed the professor to spend more time expanding on the topic instead of allotting an entire lecture for the overview. The weekly modules began with an overview of the main topic of the class and explained it in more depth as they progressed. This was done so that the class could better understand what knowledge they were working toward. This especially helped the students without an electrical engineering background to relate the concepts to those in their own fields.

The topics within the weekly reviews were delineated starting with an overall explanation and supporting that explanation with basic theories. For example, Week 2 begins with a circuits overview. This included definitions of devices and explanations of circuit laws. The next two topics further explain the mathematical background for resistance and inductance concepts and devices. Also, the modules include applications of the previous information. For example, the resistance module explains the use of resistance in strain sensing. This refers not only to the information in the beginning of the module, but the sensing module from the first week. This is an example of the delineation and interrelation of concepts in the modules.

The layout of the Smart Materials and Sensors class website follows the methodology given for media development. Both simplicity and complexity are displayed in an excellent balance. An example module is shown as a screenshot in Figure7.

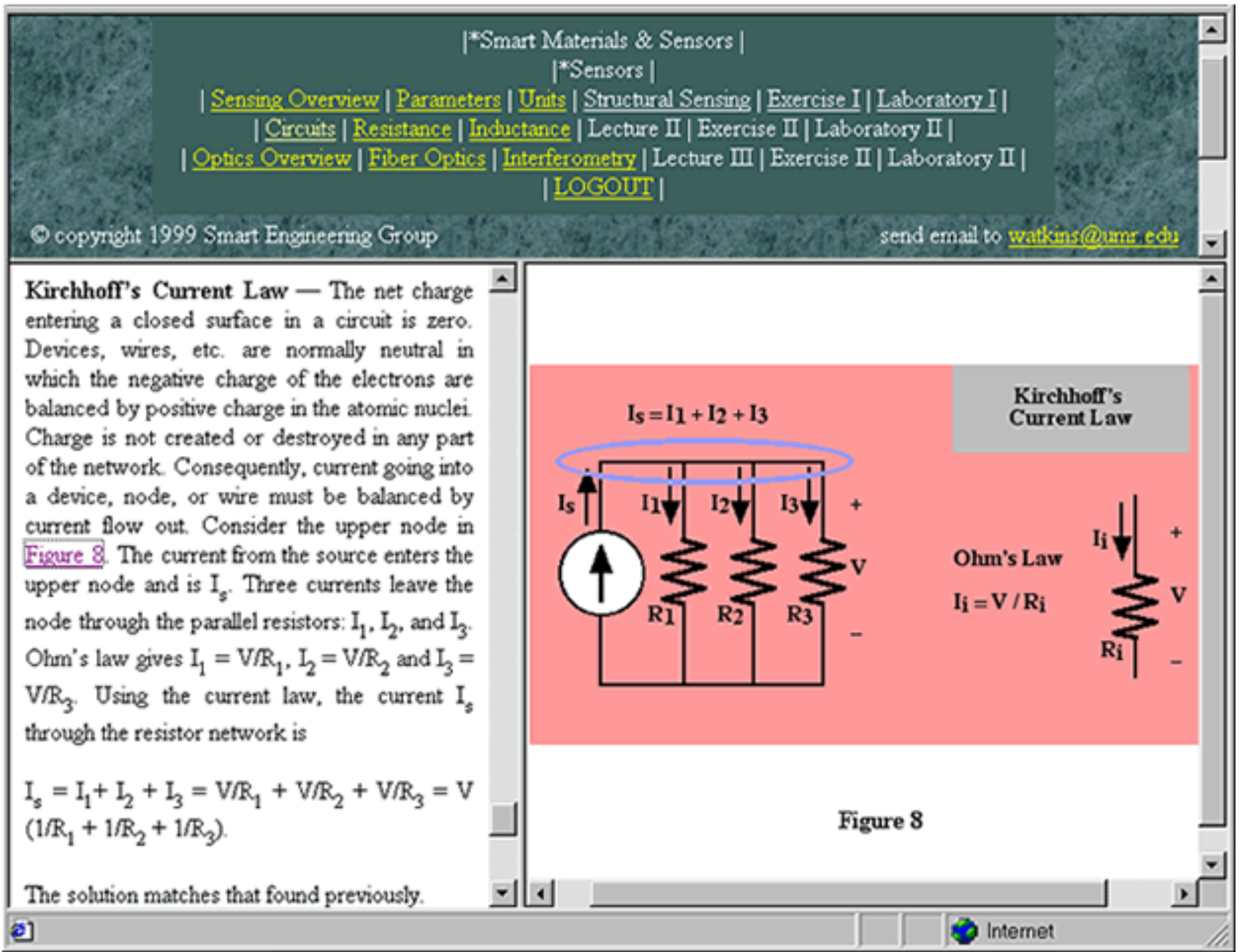

Figure 7 — Screen Shot of Smart Materials and Sensors web site.

The site shows an adequate amount of simplicity for the caliber of student using it. Consistency and usability are illustrated by the similar background for the entire Smart Engineering site including the Smart Materials and Sensors class modules. Also, the menus look similar in that they are hierarchical by line and an asterisk indicates what section and page the user is viewing. The progression of the students was being tracked in this case, so the only active links in the hierarchy were within the modules. The intent was to make sure the student did not leave the modules until they were finished viewing them. The student could, however move between modules easily in case they wished to review a concept. The page layout for the information was the same for each module as well. It consisted of two frames. The one on the left contained text only. The user was able to scroll through the text and click on links to figures. The figures would then appear in the right frame.

Sufficient complexity was also demonstrated by this site. The frames, indicated previously, encouraged the user to interact by clicking on a link to see a figure. This way the user could view the figure of his choice as they scrolled through the text. This also demonstrates the multi-modality. The student sees both a textual explanation as well as a multi-media representation of the text. By allowing the user a choice of text and media the module shows adaptability.

The modules were linked well with supplementary information. There are no outside links because, as explained before, it was necessary to keep the user within the modules. However, the user could easily navigate between modules, which satisfies the linking requirements.

C. Assessment Implementation

The prototype model for assessment at MDAL consists of multiple methodological and measurement components as seen in Figure 8. All of the information gathered in the assessment is used to develop and improve the learning modules created by the MDAL designers.

Learner variables must be taken into account in order to examine the interaction between the learner differences and the experience and retention using media tools. The assessment must take into account the media experiences of the student when analyzing the retention. The more experienced the student is the more complex the tool can be and still cause minimal stress. However, the media could overwhelm an inexperienced student even though he may be able to grasp the concept otherwise. Feedback from both types of students determines how the modules can be adapted to better serve a wide range of students and/or tailor to specific students.

The prototype for the MDAL experimental methodology employs four basic methodologies, applied progressively from formative to summative, as it progresses from design to development to application. Stage 1 includes evaluation of the software and instructional design before the development of the modules begins. The second stage is basic research including studies of a small sampling of students in a controlled environment. These studies focus on specific aspects of the software design and seek more detailed information from the study participants. This level is particularly important because during more applied levels of research it is difficult to use control groups for pragmatic and ethical reasons. It is also difficult to do controlled studies in applied research due to methodological complications.[24] The third stage is level 1 of the applied research. Prototype modules or a series of modules are introduced within the context of a class. The feedback from the students will be used to improve the modules both with regards to design and content before they are introduced as a more permanent

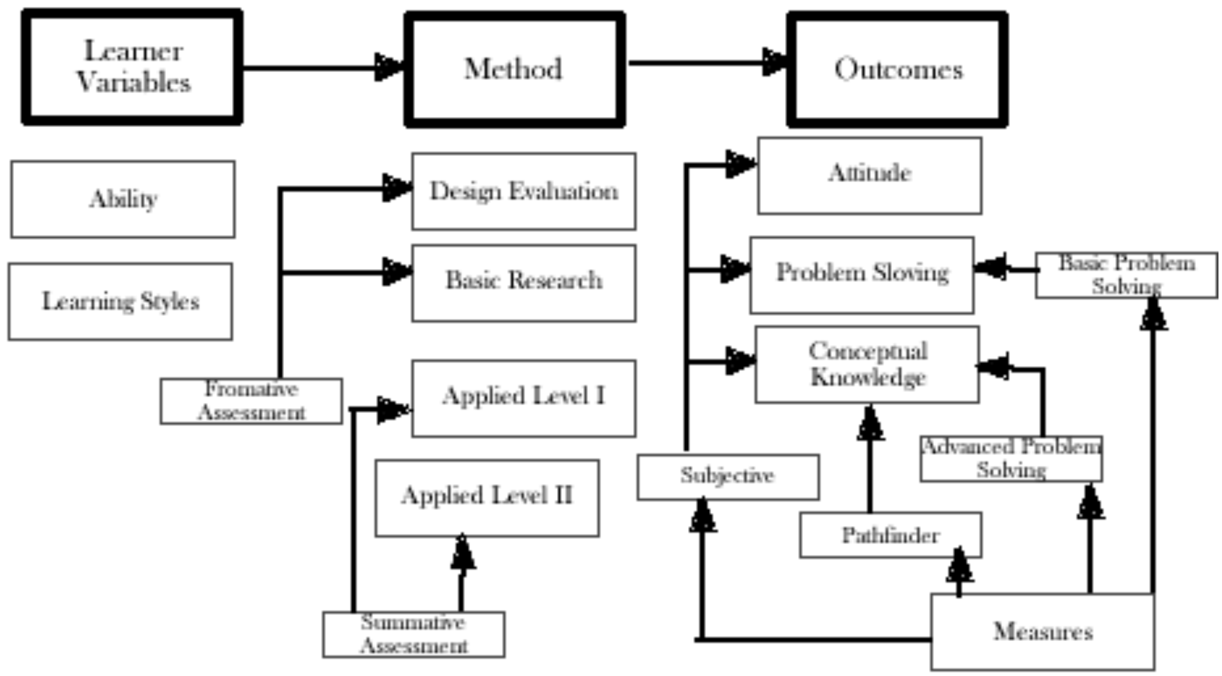

Figure 8 — Assessment prototype for MDAL.

part of the class. The fourth and final stage of assessment is the second level of applied research. This consists of evaluating the media software in the context of several classes to obtain an overall view of the effectiveness.

The outcomes that are considered are learners attitudes, problem solving, and conceptual knowledge. Course satisfaction, motivation, and perception of knowledge gained comprise the variables considered as the attitudes. Problem solving is assessed with regard to the student s ability to do traditional computational problems, as well as, more advanced application problems. Conceptual knowledge is the recognition of structural relationships among course concepts. It also is the ability to apply this structure to novel problems. We assess structural knowledge as a defining characteristic of expertise across science and technology domains.[25, 26]

Example: Integration of Interactive Software

The basic engineering department at UMR wishes to integrate wireless laptops and interactive software in high enrollment classes. This is a very expensive endeavor, so the faculty decided that it was best to assess the potential success of this project. An interactive multimedia program developed by a UMR professor was used as a teaching supplement. An assessment of sections with and without laptops was done for a semester mechanical statics course. The results are not available yet, but the methodology was carried out as follows.

The learner variables including ability and learning styles were investigated. Ability was measured by grade point average. The learning styles were determined by a questionnaire given at the beginning of the semester.

A formative assessment was carried out long before the class began. The developers of the software used similar steps as described for media development in previous sections of this paper. The goal of the software was to supplement the lecture with interactive problems. The context was a media based software program that would be run on computers networked within the university. The learner variables were freshmen to sophomore engineering students with some computer experience, but very little experience in statics. These factors were used to assess the usefulness of the software before bringing it into the classroom.

The summative assessment is an example of the Applied Level 1. The software was used in a classroom environment. A control group was taught using traditional lecture. The laptops were integrated into the lectures of the test group. The outcomes of these two groups were compared as well as individual responses.

The outcomes were measured using several questionnaires. To find subjective information the students were supplied with 12 concepts having to do with mechanical statics. They were then asked to rate their knowledge of, motivation for, and the degree to which they recognized the applicability of each of these concepts both at the beginning of the class and at the end. The similarity of all possible pairs of these concepts was also rated by the student at both in the beginning and end of the course. There were also qualitative/open-ended questions to support the previous questionnaire. To indicate the problem solving abilities and conceptual knowledge the final exam scores were recorded.

The final assessment will involve the comparison of the previous outcomes. Changes in pre and post ratings, as a function of whether or not a laptop was used will be investigated. The similarity of knowledge structure compared to the instructors as a function of class will be evaluated using Schnaveldt s pathfinder approach and the pair similarities ratings. Also, the final exam grades will be compared between the classes with laptops and those without. Finally, The qualitative data will be examined systematically, in an effort to explain the rationale for the quantitative results at a deeper level.

III. Summary

The design, development, and assessment of web-based multimedia learning resources are important aspects of engineering education. The MDAL is implementing several projects that bring content providers and media designer together in a development team. The design philosophy in terms of the identification of fundamental concepts, development steps, and assessment implementation has been outlined within the context of these projects. The projects include: the Applied Optics Laboratory which is a group of tutorials for optics classes, the Smart Engineering Web page which includes a set of tutorials for students with varying experience in the electrical engineering field, and the integration of multimedia in the engineering classroom which involved the use of multimedia software using laptops to enhance an engineering lecture.

The Media Design and Assessment Laboratory has been fulfilling its purpose and goals since June 2000. Content providers and media designers are working together to create multimedia tools that enhance the classroom experience. As these tools are showcased, more educators are realizing that multimedia can benefit both the instructor and the students. The philosophies seen in this paper have been developed through planning, but also trial and error. It is the continuing task of the MDAL to keep refining its philosophies as more empirical data becomes available and new ideas are introduced through experience.

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