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Lifelong Learning with Digital Compendia

Dennis Paul Valenzeno, PhD[*], Thomas Brennan, PhD[†], Francis Gasparro, PhD[‡], Christopher Lambert, Ph.D[§], Kendric Smith, PhD[**] , [*]University of Kansas Medical Center, [†]Dickinson College, [‡]Thomas Jefferson University, [§]Connecticut College, [**]Stanford University

Abstract **-** The Digital Compendium is a new concept in education, and is described here for the science of photobiology, a Digital Photobiology Compendium (DPC). Medical school is the start of a lifelong learning endeavor. Increasingly computer- and web-based resources will facilitate this process. Yet there are currently few resources that span the range of knowledge from student through practicing professional. To this end we are developing a technologically advanced, scientifically up-to-date learning tool, with the initial effort in the field of photobiology. Photobiology is a young interdisciplinary field that is growing in importance because of its relevance to laser/light therapies and the biological consequences of increased UV radiation due to ozone depletion. The DPC will be web-based, consisting of a matrix of more than 100 instructional modules in all subdisciplines of photobiology. The modules will be mutually compatible to allow the user (learner or instructor) to connect a set of modules in a user-defined *Work*. Standard *Works* will also be predefined. The matrix will include modules suitable for learners at various levels from advanced undergraduate through practicing professional.

Key words **-** Internet, web-based, digital compendium, photobiology, CAI

Introduction

Medical education is a life-long process that only begins in medical school. It continues through residency and a lifetime of medical practice.[1] The modern physician must be aware of and motivated to use the broad range of medical information available as a result of modern information technology.

Surveys show that an increasing number of physicians are using the Internet. Although the percentage is still small, less than 10%, it is growing each year. [2] The impact on medical education, if well managed, can be revolutionary. Not surprisingly, the great bulk of instruction in medical schools is still classroom-based and clinic/hospital-based. This process has been augmented by a proliferation of web pages used in support of formal courses and clerkships. [3] Most often, web pages are being added as an afterthought, an adjunct to supplement traditional instruction. They are often viewed as “super” textbooks, textbooks that can show animations, videos and sound. From a cognitive science perspective, this view of medical education is flawed. According to Reese [4], “Computers are a supplement that can enhance the effectiveness of all instructional techniques. However, their use must be integral to the instruction rather than simply being added on to existing courses.”

Here we describe a web-based educational system that is designed to be learner centered, to invite the learner with highly interactive experiences, and to be useable for a lifetime. This system is referred to as a Digital Compendium. It consists of a set of interactive web-based modules that can be assembled into different *Works* to serve learners at multiple levels. The key feature of this Digital Compendium that sets it apart from other sets of learning modules is the integration of the modules, their organization into a matrix, as described below, and the ability to custom-assemble these modules in different orders.

As an illustrative example, we describe the first Digital Compendium that is currently under development in the field of photobiology, the Digital Photobiology Compendium (DPC). This area was chosen because it is a young interdisciplinary field of science of intense current interest for physicians. It is growing in importance because of its relevance to laser/light therapies in medicine[5], such as photodynamic therapy for malignancies[6] or macular degeneration [7,8], and the medical consequences of increased UV radiation due to ozone depletion.[9] To produce the DPC we have assembled an outstanding core of content specialists who are well-recognized experts in the field. These experts produced some of the more recent leading textbooks and lab manual in photobiology, are well versed in modern computer/web implementations and have the stature to attract the additional content experts that will be required to produce the full complement of modules.

Project Design and the Matrix Concept

The DPC will be a set of interactive computer-based modules that can be assembled into different *Works* to serve learners at multiple levels. Modules will be useable in preset sequences in addition to custom sequencing by individual instructors for use with a particular class or set of learners. All modules will be new, not yet copyrighted, material developed expressly for the project.

The project can be viewed as a *matrix* of modules (below). The matrix consists of 13 rows and several columns. Rows correspond to subdisciplines of photobiology as defined in *The Science of Photobiology.*[10] The columns are ordered such that the most elementary modules are at the left. Each module will be an interactive experience for the user including audio, video, animations and simulations.

A collection of modules in the first column labeled Basic Text, constitutes an undergraduate level Basic Text like *The Science of Photobiology.*[10] The second column constitutes a Lab Manual. The third column constitutes a History of photobiology. On the other hand, a collection of the modules in the first row, labeled Photophysics, constitutes an in-depth digital monograph in photophysics. Similarly, each of the rows contains modules that constitute digital monographs in that particular field. Some may be shorter than others, depending on the robustness of the sub-discipline.

Unifying concepts will be applied to all *Works* constructed from the matrix. There will be a similar "look and feel" to the web-based presentations. Similar tools will be incorporated to allow searching of text, access to a glossary of photobiological terms and linking to modules related to, but outside the scope of, the Work that the user has accessed. Prerequisites for each module will be indicated and links will be provided to the prerequisite modules.

The Development Team

DPC developers are being recruited worldwide. Selection of developers is directed by a set of core planners headed by the Project Director. In consultation with a small Advisory Committee, the Director first selects the Editors who will be responsible for the first 3 columns of the matrix, the Compendium Editors.

The Compendium Editors recruit Module Developers for the modules that they oversee. They ensure the consistency and compatibility of these modules including style, content and technical aspects. They work with the Monograph Editors (below) to ensure that their modules are also suitable for the digital monographs defined by each row of the matrix.

Thirteen Monograph Editors direct the development of modules constituting digital monographs for each row of the matrix. Their responsibilities are similar to those of the Compendium Editors with whom they coordinate efforts.

Approximately 100 Module Developers will write and interact with a programmer to develop highly interactive, but technically feasible modules. Module Developers will develop learning modules in compliance with the DPC guidelines, which they will help establish, with oversight by the relevant Monograph and/or Compendium Editor.

Technical and Content Guidelines

Early in the development process guidelines need to be defined to specify both technical and content attributes that will apply to all modules. This is to ensure their mutual compatibility. These guidelines will produce the similar "look and feel" for all modules from basic to advanced and will prescribe dynamic interactive modules, anticipating reasonable improvements in bandwidth during the development of the project. Guidelines are critical to the goal of creating modules that can be custom-assembled in different sequences. Custom sequencing will also be aided by requiring that developers provide careful identification of prerequisites for each module.

As new Editors and Module Developers are recruited to the project, they will be provided with the guidelines for module development and will be encouraged to interact with other Editors and Module Developers. This will be facilitated through annual meetings and through the Developers' Web Site containing development materials and focused discussion groups. This site, Figure 2, is active (http://www.POL-US.net/DPC/development) and features are being added to the site to aid communication among all those involved in DPC development.

	Basic Text	**Lab Manual**	**History**	**Detailed #1**	**Detailed #2**	**Detailed #3**	**etc. ⇒**
Photophysics	basic photophys	photophys experiments	photophys history	advanced photophys	advanced photophys	*etc.*	*etc.*
Photochemistry	basic photochem	photochem experiments	photochem history	advanced photochem	advanced photochem	*etc.*	*etc.*
Photosensitization	basic photosens	photosens experiments	photosens history	advanced photosens	*etc.*	*etc.*	
Ultraviolet effects	basic UV effects	UV effects experiments	UV effects history	*etc.*			
Environmental	basic environm	environm experiments	environm history	*etc.*			
Photomedicine	basic photomed	photomed experiments	photomed history	*etc.*			
Circadian rhythms	basic circ rhyth	circ rhyth experiments	*etc.*				
Photoreception	basic photorecep	photorecep experiments	*etc.*				
Vision	basic vision	vision experiments	*etc.*				
Photomorphogenesis	basic photomorph	photomorph experiments	*etc.*				
Photomovement	basic photomove	*etc.*					
Photosynthesis	basic photosynth	*etc.*					
Bioluminescence	basic biolum	*etc.*					

Figure 1 The DPC Matrix. The rows in the matrix represent subdisciplines of the field of photobiology. The columns designate similar themes within each subdiscipline. The "Detailed" columns indicate advanced material suitable for graduate and/or postgraduate instruction.

Compendium Development

The modules in the first 3 columns of the matrix, Basic Text, Lab Manual and History, will be developed first. Plans for each module and working drafts will be posted at the Developers' Web Site to encourage formative discussions during development. Modules will be placed on the DPC Instructional Web Site as they are completed. There is no need to wait for other modules to be completed. Revisions, based on the evaluations described below, or on new understandings of photobiological concepts, will be made, as needed.

The advanced modules not included in the first 3 columns of the matrix will be developed later under the direction of the Monograph Editors. Development will occur as described in the preceding paragraph, taking into account the lessons learned during development of the initial modules.

Computer/Web Implementation

The Developers' Web Site will be enhanced to facilitate communication among all developers through online discussion groups, extending to voice chat, as developers become capable of this technology. Focused discussion groups will be available for the core developers, for each of the Compendium Editors, for each Monograph Editor and as needed for other uses. Additional new features will include links to relevant educational resources, search capabilities, tools (with examples) to make it easier for Module Developers to incorporate interactive components in their modules, and help screens. The list of terms to be included in the glossary will also reside at the Developers' Web Site. Editors or Module Developers

Figure 2. The DPC Developers' Web Site includes information about the project, modules currently under development and tools to facilitate development and communication among DPC developers.

may propose additional terms, modify definitions of existing terms or recommend deletion of terms. There will be provision for comments and/or opinions regarding each proposal. Final decisions will be the responsibility of the Program Director.

As modules are completed they will be posted on the second DPC web site, the DPC Instructional Web Site which will be implemented by the programmer. This is the site where instructors and learners will go to build custom *Works* or to access *Works*, either custom or standard. Under the direction of the Program Director the programmer will provide the programming necessary for the assembly of custom and standard *Works*, for discussion groups associated with each module and each *Work*, for the pop-up glossary and for global search capabilities. There will be *extensive help screens* to guide instructors and learners, and a premium will be placed on making these intuitive and easy to use.

Test Group

To evaluate the utility and effectiveness of the DPC a group of learners will use the DPC in established undergraduate, graduate and postdoctoral level courses of study. The enthusiasm for and acceptance of the digital compendium concept is indicated by the ease with which the test group was assembled. The recruiting process involved two e-mailings separated by 3 months to the Photobiology Listserve. This listserve consists of 141 participants and is maintained at Bowling Green University as part of Photobiology Online (http://www.POL-US.net and http://www.POL-Europe.net). As a result of these mailings, a test group of 534 students at 25 institutions worldwide will use and evaluate the DPC. The group is composed of 408 undergraduate students, 118 graduate students and 8 postdoctoral fellows. The geographical distribution is given in Table 1.

	School	Location	Undergrad	Grad	Postdoc	Total
1	Arizona State	AZ	25			25
2	Bowling Green State University	OH		38		63
	Bowling Green State University	OH	100			163
3	College of Charleston	SC	25			188
4	Connecticut College	CT	5			193
5	Dickinson College	PA	32			225
6	La Sierra University	CA	90			315
7	NIEHS	NC	2		2	319
8	St. Mary's College of MD	MD	10			329
9	University of Nebraska	NE		5		334
10	University of Texas, Houston	TX		9		343
11	University of Utah	UT		3		346
12	Royal Military College	ON, Canada	6			352
13	Universitat Ramon Llull	Spain		12		364
14	University of Hyderabad	India		12		376
15	University of Padova	Italy		10		386
16	University of Granada	Spain	6	8		400
17	Stanford University	CA	25			425
18	University of Westminster	United Kingdom	6			431
19	Centr. Research Inst. Chem.	Hungary		4		435
20	Bar Ilan University	Israel	15	15		465
21	Limburgs University Centrum	Belgium	27			492
22	University of Wisconsin	WI			6	498
23	University of MD, Baltimore Co.	MD	3	2		503
24	Florida International University	FL	6			509
25	University of Puerto Rico	PR	25			534
	TOTALS		408	118	8	

Table 1 Institutions and approximate number of students who will use and evaluate the DPC. Undergrad = undergraduate students, Grad = graduate students and Postdoc = postdoctoral fellows.

Our primary evaluation task is to determine if the DPC is effective in imparting knowledge of photobiology to learners, and if it does so better than previous methods. Assessment of learning with the DPC will consist of both formative and summative components. Formative components will include ongoing feedback among module developers, instructors and learners through online discussion groups and by special sessions at the annual developer's meetings to which learners and instructors will be invited.

Summative evaluation will be based on pre- and post-tests built into each module to assess gain in student knowledge (paired t-tests). They will assess knowledge gained during the time that the DPC module is being used. We will also compare the scores on instructor-generated tests for classes using the DPC vs. classes taught before the advent of the DPC.

Use and Evaluation

In addition we will evaluate the DPC with respect to:

1. The usage of the DPC including how often and by whom it is used and how it is being used.
2. The opinions of learners, instructors and developers who use the DPC.
3. The progress of dissemination of the DPC and what avenues are most successful for dissemination.

In addition we will use a logbook to track milestones and problems associated with the DPC, including how they were resolved and the process that led to resolution, for the benefit of future implementations of the Digital Compendium concept.

Discussion

Writing with a cognitive science perspective, Reese [4] identifies four characteristics of the best computer-based learning applications. Such applications make it possible for students to learn the material at their own time and pace and in the order that makes the most sense to them. These applications incorporate approaches and materials that appeal to a variety of cognitive strengths and learning styles and use the unique capabilities of the computer. These characteristics describe many of the strengths of the Digital Compendium approach. Learners (students or professionals) can learn at their own pace, accessing the DPC on the web as needed. The learner or the instructor can construct custom *Works* that are tailored to individual backgrounds and learning needs. The variety of visual and textual material, particularly interactive elements will appeal to a variety of cognitive strengths and learning styles. And finally a seminal principle of Digital Compendia is that they capitalize on the unique capabilities of computers and the web from the start of the project, not as an afterthought.

To our knowledge there have been no previous efforts to construct a work like a digital compendium that unites, in a common format and presentation style, an exposition of a field of science from the level of undergraduate student through practicing professional scientist. Some publishers offer the option of customizing textbooks to exclude or include selected chapters, or offer custom collections of books chapters, articles, reviews and an instructor's own material. They will obtain copyright, collect, bind and sell this to students (*e.g.*, http://www.custombook.com/cb/). However, these materials have not been designed to be mutually compatible. They are a piecemeal approach to custom learning tools.

The current project differs from these in that new material, the modules, will be developed in a way that will make them mutually compatible. Authors of advanced modules will be aware of the material available in the introductory modules and will indicate prerequisites. All modules will use a similar format, have similar tools available and refer to the same glossary. Instead of a collection of dissimilar materials, these will be a coordinated set that will allow users to return throughout their professional careers to add new knowledge from a familiar, convenient and authoritative source.

The Digital Compendium concept can readily be generalized to other medical sciences. For example, medical physiology is often divided into subdisciplines that include general physiology, cardiovascular physiology, respiratory physiology, renal physiology, gastrointestinal physiology and endocrine physiology. Each of these can become a row in the matrix. The first column of the matrix would then become a basic "textbook" that could be suitable for first year medical students. Rows could be monographs useable for more detailed study. Organization of the Digital Photobiology Compendium has been greatly facilitated by the cooperation of the American Society for Photobiology, especially the opportunity for organizers to meet at the annual scientific meetings of that society. We would anticipate that development of Digital Compendia in other areas would similarly benefit from strong support from relevant scientific societies, and would benefit the societies by providing a forum to focus educational efforts.

As medical educators we strive to graduate physicians who have not only mastered a body of knowledge, but ones who are prepared and motivated to maintain their skills and knowledge throughout their careers. Facilitating this maintenance by providing continuity in educational tools is one way that we can accomplish our objectives more fully.

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Address Correspondence to:

Dennis Paul Valenzeno
Department of Molecular and Integrative Physiology
University of Kansas Medical Center
3901 Rainbow Boulevard
Kansas City, KS 66160-7401
dvalenze@kumc.edu