Robert Carrigan,
Chairmen of the Chairmen's Committee

Ron Milton,
Vice-Chairman of the Chairmen's Committee

Dan Morrow,
Chief Historian

MEDICINAL CHEMISTRY VIRTUAL LIBRARY

2005 COMPUTERWORLD HONORS CASE STUDY

Education & Academia

A University Library introduces the concepts of Medicinal Chemistry and Drug Discovery through visualization and interaction with drug molecules, biochemical pathways and related topics, serving to outline and visualize the connection between various drug classes and integrating different disciplines and subjects that a pharmacist should be acquainted with. **[20055361]**

SUMMARY

The Library introduces the concepts of Medicinal Chemistry and Drug Discovery through visualization and interaction with drug molecules, biochemical pathways and related topics. The library also serves to outline and visualize the connection between various drug classes and integrating different disciplines and subjects that a pharmacist should be acquainted with.

APPLICATION

In the last decade, pharmaceutical education has undergone major changes with the introduction of the Doctor of Pharmacy (Pharm. D.) degree and with the demand for educational accountability in higher education in general. Medicinal Chemistry is one of the disciplines that are considered as the foundation of Pharmacy. In its core, Medicinal Chemistry is an interdisciplinary field that requires the collective knowledge of various related topics, which highlights the need for a tool to connect and integrate these disciplines. In addition, tools to help students visualize how drug molecules act and how changes in chemical structures could affect their activities and properties are important especially as drug molecules act in a three dimensional fashion. Finally, a pharmacist's primary job, in most cases is interacting with patients and with information. Tools to help him/her practice and understand such interactions are vital in her/his education.

As part of the educational strategy of the College of Pharmacy, University of Michigan, the Medicinal Chemistry Virtual Library was created as a web-based teaching tool. The website is designed to include an online textbook composed of the lecture notes used by the faculty teaching the Medicinal Chemistry courses, a number of mini-libraries including chemical structures of all clinically available drugs with their generic and trade names and a linked sound byte that helps students with pronunciation of the names of these drugs. Other mini-libraries include biochemical pathways and physiological processes. These resources are available in two formats, a static format and an interactive format. The former enables linking, integrating and connecting all the material and drug classes together, while the latter is the major interactive tool that enables students to visualize the different concepts and processes.

Another important set of components of the Virtual Library are tools that encourage and help students practice critical and creative thinking. These include various assignments that encourage critical thinking, real time chat between students and faculty, discussion threads (initiated for the most part by students) and interactive practice sheets. Students are also required to participate in the design of the Library by creating their own drug-related websites within the Library, encouraging them to use creative thinking abilities, and to utilize group work, an important skill especially for pharmacists who are required to work within groups of health-care professionals.

The evaluation of these tools, their effectiveness and utilization by the students through pretests, practice tests and extracurricular activities is an integral part of the Library. These tools are designed to introduce and apply various aspects of critical thinking and assess student development throughout the different courses.

The Virtual Library also provides the faculty and the students with a wealth of information, particularly with the mini-libraries and other resources. In this way, the students are able to strive for better learning habits, and the faculty are better equipped to introduce novel teaching methods. These methods include active learning, emphasis on critical thinking, and assessment-based teaching throughout the courses.

Our future plans include adding a molecular modeling component to the Virtual Library and administering an outreaching survey to evaluate its impact and identify other areas that may add to its usefulness. Our educational strategy is to extend the creation of this Virtual Library to all disciplines within the College of Pharmacy, including Graduate programs. In the future, we plan on assessing the possibility of using these tools for distant learning and making these tools available for general use by other educational institutions.

For a demonstration of some of the images from the Virtual Library, go to:
http://sitemaker.umich.edu/mbeleh/files/images.html

For a tour of the Virtual Library, go to: http://sitemaker.umich.edu/mbeleh/files/tour.swf

BENEFITS

Achieving the expected benefits of the Virtual Library was put to test through a variety of assessment models. These models include:

• Assessment surveys (online and written forms) that are administered to all students taking the courses. These surveys are given in a three step format: prior to taking the course and exposure to the Virtual Library, through one-third of the semester when limited exposure is usually achieved, and at the end of the semester, after the students have fully utilized the Library and related components.

• Questionnaires distributed among the faculty exposed to the Library.

• A comparative look back at the quality of learning achieved by students who did not have the opportunity of using the Virtual Library, and those who have had full use of the Library.

• A comprehensive survey is planned to include current students, recently graduating students, faculty and alumni that will address, among other things, the usefulness of the Medicinal Chemistry Virtual Library. The start of this study is tentatively set for the Spring of 2005 and is expected to last about a year.

Looking at the first assessment tool (students' surveys), several aspects have been addressed. Students were asked to evaluate the usefulness of specific tools such as chat rooms, discussion threads and similar tools. Such tools are designed to introduce interactions between students and faculty, better understanding of the material and utilize critical thinking and problem solving skills. Prior to using these tools, only about 60% thought that these elements could be useful. At the end of the semester over 80% felt that these goals have been fully achieved. Those who did not have a positive response indicated that they did not like the setting of these elements and provided comments on how to better improve these tools. These comments have been taken into account in order to improve these elements.

Tools designed to teach and practice critical thinking also showed a favorable response, with 94% of the students indicating these tools had great educational value and helped them in a constructive way to better understand the material and apply the concepts of critical thinking. Almost all students (over 98%) felt that overall the course helped them understand and apply critical thinking within their coursework and beyond.

Components designed to assist students in learning and practicing creative thinking, a very difficult concept in an area such as Medicinal Chemistry, also fared well in students' responses. Prior to exposure to these components, only 60% indicated that creative thinking exercises could be useful and achievable at this level in the subject at hand. Only 40% felt that group work had any additional values and most students expressed strong opinions against group work. After students had limited exposure to these components, 85% felt that it was a burden and would not add to the educational values of the course. The turn-around after fully utilizing these components was dramatic; with 70% of students indicating that this component added to their overall learning experience and recognized the importance of creative thinking as pharmacists and Pharmacy students.

Taking a closer look at the negative responses, about half of these responders were negative because their group did not work together well, and they were frustrated by the attitude of other group members. A group of these negative responders felt these exercises were too time-consuming within the realm of all the classes they take. These concerns have been taken into consideration, and efforts have been underway to overcome these difficulties.

Finally, we took a look at the overall use of the Virtual Library and its added benefits in connecting the information, interacting with the material and visualizing the concepts and Medicinal Chemistry of the drugs. The survey conducted before exposure to the project indicated that only 60% of students thought that the Library will be of any use to them and most of those responses just thought that the lecture notes will be their main use. In the end of the semester survey, 92% said they utilized the Medicinal Chemistry Virtual Library and found it greatly improved their understanding of the material presented. They especially liked the interactive material, the availability of a different resource for studying and most importantly the ability to visualize many of the concepts discussed, that they would have otherwise just memorized with no true understanding.

The written responses were extremely positive. These responses clearly showed that the Library has a positive impact on students' learning, understanding and ability to utilize critical and creative thinking. In addition, it afforded students a rare chance to see how all the information they learn is interconnected.

From the perspective of the faculty, its benefits were obvious as a very useful tool to connect the various courses and a great tool for both the faculty and the students. It enables the faculty to rely heavily on active learning and critical thinking and affords them the chance to introduce novel teaching methods in their courses.

Evaluating and comparing the performance of students utilizing the Library showed improvement in several critical areas. An expected improvement in their understanding of the material, and their ability to use critical and creative thinking was apparent. This improvement was obvious in two sets of comparisons. The first is comparing their performance at the start of the semester before they completely utilize the Library to their performance towards the end of the semester when they have been fully exposed to the Library. The second is comparing students from classes that were never exposed to the Library to those who did. In both cases, there

is a very favorable comparison to those students utilizing the Library.
This last point is remarkable when considering that the activities afforded by the Virtual Library required the use of Classroom time that would have otherwise been utilized in introducing more material. Therefore, the quantity of information delivered to classes not exposed to the Virtual Library is more than to those who utilize the Library. However, upon evaluation of their understanding of the material and retaining information, it was clear that the latter group had a better overall understanding and retaining of the material.
Another benefit for the use of the Medicinal Chemistry Virtual Library is its assessment component. This component enables faculty and instructors to identify weaknesses in the class and address them in a timely fashion. It also allows them to locate students struggling with the course material or approach, and to help these students get back on track. One of the beauties of this benefit is that it may identify a problem that the student is not aware of. It also allows for individual attention rather than the prevalent look at an average of the class. Finally, faculty can also assess their own teaching approach and make any changes as they proceed through a given course.
As the Virtual Library adds on other features such as molecular modeling, the visualization and interaction benefits will increase. And as this project expands to all disciplines within the College of Pharmacy these benefits are expected to be extended and magnified. It would allow for further integration between disciplines and inclusion of more information. As a comprehensive tool for the College of Pharmacy, it would allow students to better time-manage the use of the libraries. The benefits of use of these tools in distant learning and public use would be another dimension.

IMPORTANCE

As Medicinal Chemistry in particular and Pharmaceutical and Clinical Sciences in general are in their core interdisciplinary fields, we need in many cases innovative tools, teaching methods and assessment techniques as well as collaborations to achieve our stated educational goals. To address these issues, we formulated an educational strategy that required:
• Curricular reforms to better prepare students for the evolving changes in the professional practice and to achieve better coordination of these courses together.
• Re-evaluate teaching methodologies to implement these changes along with critical thinking and active learning in the educational process, and ultimately enhance the learning process.
• Assessment of the educational outcomes as defined by the faculty involved in the teaching process.
To achieve these changes, we defined four steps as starting points for educational reform:
• Changes in both the content and methods of teaching in a way to enable students to better understand and visualize the concepts, and connect various material, drugs, disease states and patients' cases evaluation.
• Integration of all courses within a disciplinary sequence and better coordination between courses from different disciplines within the Pharm. D. curriculum.
• Implementing concepts of critical thinking and active learning.
• Use of web-based teaching to achieve the first three steps.
Our two-phase plan included bringing together the faculty to layout this plan, discuss the aforementioned issues, introduce the vision of the faculty in regard to the educational process and come out with a working document for how these changes will occur. In this phase I, we started working on preliminary changes to the curricular content and setting up the web-based resources. The second phase involved more sophisticated and elaborate processes that include the creation of the Medicinal Chemistry Virtual Library that enables us to use a hands-on approach in teaching Medicinal Chemistry and rely heavily on active learning including student-led discussions, assessment-based teaching, and using concepts of critical and creative thinking.
The importance of this project stems from its ability to act as a tool to help us achieve all the aforementioned goals and beyond. It enables the integration of all the courses within the Medicinal Chemistry sequence and allows us to coordinate with all other disciplines within the College of Pharmacy. It also provides the faculty with resources they would need to introduce innovative teaching techniques, whether it is through the different mini-libraries within the Medicinal Chemistry Virtual Library, the practice sheets or the critical and creative thinking exercises, just to name a few examples. The Medicinal Chemistry Virtual Library provides students with an opportunity to visualize the various concepts discussed in class and interact with the material presented, in ways that were not available prior to the introduction of the Library. It helps students better understand the material discussed and gives them the resources that helps them achieve the educational outcomes of each course.
The Library is an essential tool in introducing the concepts of critical and creative thinking, and provides students with the opportunity to practice such concepts. It is one of the few spots in the curriculum where students are able to showcase their creative thinking.
The use of the Library enables instructors to use a more hands-on approach in teaching and to rely on active learning and assessment-based teaching, two techniques that have proved to improve the quality and depth of learning.
It also allows for a great deal of interaction between students and faculty on a regular base, both in one-on-one capacity (for example within the chat feature and some of the activities) and an overall interaction (for

example within the discussion threads and other activities).
Finally, one of the most important aspects of the different activities that lie within the Medicinal Chemistry Virtual Library is its inherent capacity to act as an assessment tool for both students and faculty. It truly has enabled students to self-evaluate themselves as they proceed through their courses and enabled faculty to assess students' development and their own teaching techniques and to achieve their educational outcomes.

ORIGINALITY

When we set out to create the Medicinal Chemistry Virtual Library, we envisioned the project to emulate the Internet at large, from the sense that it can be expanded indefinitely by addition of features and information, integrating and linking all the components together and making it easy for participants to add to the Library. We also envisioned the Library to have an individual taste, where each student would be able to utilize components he/she feels appropriate, and faculty to use and add only to components they feel are important to their teaching and educational outcomes.
We believe that the Medicinal Chemistry Virtual Library is unique in both its approach and content. It has tremendous depth and breadth in both its content and reach. The depth of the Library is illustrated by the variety of resources, tools and activities it contains and by the ease of expanding its content. More importantly is the depth of the information provided and its impact on the educational outcomes. The ability of the Library to teach and provide practice for such concepts as critical and creative thinking and active learning brings forth a depth to the educational purpose that would be difficult to achieve otherwise. The Library's inherent component of assessment adds another dimension to the education process, in particular the self assessment of students.
The breadth of the Library is obvious when the amount of information is considered. It provides a connecting point for every drug clinically available in the United States, its medicinal chemistry, mechanism of action, structure activity relationship just to name a few. Many other concepts are included with applications of all these concepts within the realm of these drugs. As the Library expands to include other disciplines within the College of Pharmacy, this aspect of the project will be even more evident, and will play a crucial role in providing an added dimension to achieve the educational goals.
The Medicinal Chemistry Virtual Library includes much more than course syllabi or home pages; it provides complete lecture notes organized as an online textbook, a number of mini-libraries including chemical structures of drugs with a linked sound byte for their pronunciation, biochemical pathways and physiological processes, in both a static format and an interactive format. In addition, it includes tools that encourage students to practice critical and creative thinking through various assignments, real time chat between students and faculty, discussion threads and self designed websites by the students.
An added element is the originality in our approach to delivering the information via the Medicinal Chemistry Virtual Library. The heavy reliance on higher levels of thought as well as the active participation of the students in the educational process is an important component of the Library. The ease with which information can be changed or activities added (including by students) makes the Medicinal Chemistry Virtual Library a truly interactive media. The constant interaction that the student gets with the material, with related courses, with other content and with the instructors is a unique approach.

SUCCESS

Although the Medicinal Chemistry Virtual Library is still early in its inception, it has been very successful. Its success has prompted interest in expanding its concept as well as its structure into other disciplines within the College of Pharmacy, which will only add to its success. The addition of such Libraries from the different disciplines as envisioned from the beginning, will transform this tool into a comprehensive entity that will act to connect the various educational aspect that a pharmacy student would need, to help us produce well-informed and prepared pharmacists.
In our surveys that evaluate the usefulness of the Medicinal Chemistry Virtual Library as an educational tool for students, it was clear that most students (94%) found that it added to the educational process, both when looking at the outcomes as well as their overall understanding of the material presented. As one of the students commented: "We got a chance to test and apply what we've learned and realize what we needed to learn. The library's tools were also helpful in understanding the overall big picture".
In addition, it was very helpful in addressing the need for learning and practicing critical as well as creative thinking (98%), as indicated by a student: "Yes-the tools forced me to use critical thinking skills and although it was hard at first, I thoroughly enjoyed it because it taught me ways of thinking that no other course has taught me previously".
It was successful (70%) in advancing group work and its importance in the preparation of a pharmacist who has to work within a healthcare group. One student wrote: "It really made us work together, and also get a better understanding for our drugs". The only negative aspect of this portion of the Library was that some groups did not work well together, a problem that we are attempting to fix in order to improve on the success of that component.

Although the Library is somewhat overwhelming at the start, students got used to its structure quite quickly and fully utilized it; “At the start of the semester I was overwhelmed by the amount of information on the website and didn't know where to go to obtain information. At the end of the semester I rely heavily on the website and know where it is I need to go”.

The usefulness of the components that helped students visualize the concepts of the course material as well as realize the connections to other material taken at the College is tremendous (92%). One comment: “This class is the most well prepared class I ever took. The resources and tools within the Library to help learn were abundant. Without the different ways in which the same ideas were reinforced, I don't believe I would have done as well”.

As for the components that help with interactions between students and instructors, participation was slightly lower than all the other components, but was still successful (80%).

These overall numbers were much higher than expected as the Library was designed with multiple components with the thought that students would only utilize parts of the Library that they feel would be useful for them. It turns out that most students fully utilized every component of the Library.

Faculty responses were also very positive. Those who have already participated in the project to varying degree found it useful without exception. Others who have been exposed to the Library are extremely interested in utilizing a similar idea in their area. As we work with those instructors to create a web of Libraries from different disciplines, we envision added growth and added success to the project.

Student performance was greatly enhanced by the use of the Virtual Library in two ways; the first was in their overall understanding of the material and their ability to really connect the information provided with related topics they were exposed to. They were able to truly apply the information to case studies and real life situations and analyze problems presented to them. The second was their performance on exams, assignments and other assessment tools. Upon comparison between students from classes that were never exposed to the Library and those who fully utilized it, the result was always in favor of the latter group in any set that was compared. This is remarkable when you consider that the former group was generally given a higher quantity of information than the latter due to the time spent in many of the activities that the Library provides and the activities afforded by active learning which was possible due to the Library. One of the most apparent values had to do with the information retained from one section to another and one course to another.

Some other comments from the students that show the degree of success of the Library: “I think this class was a model of what other courses should be. I have a greater sense of how important the molecular structure of a molecule is. I though it was tough, but I got a lot out of the class”.

“The class afforded me a great learning experience. Thank you =)”

“The approach to teaching material was excellent and should be implemented by all professors throughout the College of Pharmacy!”

“I really enjoyed this class. I would like to mention that all the work really paid off. Not only did I feel happy about my exam scores, but I did really well in my pharmacology class because of how much I learned in this class”.

Not to be overlooked as a success story is the inherent ability of the Library to be utilized as an assessment tool. Faculty are able to assess the students as they progressed within a course and pick up any struggling student. They are also able to discover any problem with their delivery of the material. Students found it very useful as a self-evaluating tool that allowed them to look at their progress and seek help if needed. As students commented: “I really feel that I have improved how I was studying, and what I knew was expected... this has really helped me do better”, and “I really like the library tools. They give me an idea of where I am with the material and what I really understand” and finally “The tools within the library allowed me to gauge my studying and how much I knew. They also showed me areas I needed to focus on and areas that I was strong in”.

DIFFICULTY

The Medicinal Chemistry Virtual Library has been a wonderful project that has tremendously added to the academic success of the Medicinal Chemistry education at the College of Pharmacy. As with any other project it does face some difficulties. Time is an issue for all participants. Students may feel overwhelmed with the amount of time they would like to devote to this tool, when they consider their overall course workload. It sometimes becomes an extremely hard task to try and balance their time. From their comments they feel it adds so much to their learning experience that they sometimes feel that they are spending too much time on these tools. Here is what one student wrote: “At first, I was kind of frustrated that this class seemed so work and time-intensive, but I started to appreciate it more as the semester progressed. If this were the only class I had to take and focus on, I would probably find it very fulfilling. It's just hard to put in as much and get out as much from the class when we have so many other core classes at the same time”.

Time is also an issue for faculty as they have to cut down on their class time to introduce some of the concepts that the Library enforces and in some cases to include other teaching techniques such as active learning. Juggling the need for introducing the information the students need from the course and these novel approaches and higher thought processes is sometimes challenging.

Time is also a factor for those faculty who are extremely interested in creating their own Libraries from other disciplines. The good news is that the Medicinal Chemistry Virtual Library could be duplicated and the tools are easily adjusted to suit other disciplines. The bad news is that placing the material online is still a time-consuming process and evaluating, adjusting and using the Library is another challenge. The creation of the Libraries might be solved by hiring technician who could help in that regard, but the evaluation and actual use of the Libraries is always going to be a concern, which could potentially limit faculty participation.

The time issue also arises when looking at this tool as a continuous assessment tool for both faculty and students. The need to spend a lot of time on reviewing and understanding these tools and taking steps to make the required adjustments can be very challenging.

Another challenge lies with the change in the teaching approach, where there is a need to change how students are assessed and tested. Education of faculty on how to best utilize these tools and introduce novel teaching methods is also a concern. This process could be very challenging for some instructors.

Assessing the project success has always been a difficult challenge. Although we feel we have been successful so far in implementing ways to assess the usefulness of the Library, and its weaknesses and strengths, we still strive to find other approaches for these assessments.

As with many online projects, intellectual property is a concern. Faculty are in many cases reluctant to allow the use of their work for the general public. With our ultimate goal to make these libraries available online to all educational institutes and actually to the general public, this will become a serious challenge that has to be dealt with.

One of the strengths of the Library also provides a challenge. In its conception, the Library was designed to be modeled after the Internet at large, with potentially an infinite number of tools and information. This can create a problem logistically for students and faculty on how best to utilize this tool.

Despite these challenges, we feel that this project is extremely successful and will grow and become the cornerstone of Pharmaceutical Education at the College of Pharmacy, University of Michigan and possibly beyond in the years to come.