

Implementing a Web-Based Knowledge Base for a construction company: Industry-Academia Collaboration

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Abstract

Knowledge Bases (KB) that capture and leverage the knowledge and experiences of employees are popular in many industries. However, in the construction industry, knowledge base implementation has been limited to some applications at the design stage or to project databases during the construction stage. This paper describes a project for implementing a web based knowledge base to help a company transfer construction knowledge from experienced professionals in the field to newly hired professionals. A team of students and faculty in the Honors and Scholars program at University of Cincinnati and construction professionals at the Messer Construction Company developed an application to tap the experience of professionals for internal use of the company. This paper describes the process of conceptualizing, designing, developing, testing and implementing the web based Knowledge base.

1. Introduction

Like most industries, the construction industry has a mix of well-experienced professionals who manage projects and new graduates who have just joined the management team. Due to the diverse locations of construction projects and their rapid pace, experienced and novice professionals working on different projects are not able to communicate well with each other. As a result, the knowledge developed within the construction firm is fragmented at the project level. New graduates working on projects are exposed to the experience of their direct supervisors, with limited exposure to the broader knowledge of other experienced professionals within the firm.

The need for transfer of knowledge within a construction firm becomes even more important as aging professionals with vast amount of experience are ready to retire. Without writing their own books about construction, their valuable experience goes away with them upon their retirement.

Transferring knowledge is not limited to inter-personnel technical knowledge transfer. New employees are usually not familiar with the many company policies that help them with their daily tasks. Their lack of familiarity extends from project policies like hiring subcontractors and processing purchase orders, to personnel policies like personnel evaluation and promotions. These policies are typically different from one firm to another. Although employee training programs are helpful, they are sometimes not

readily available when the employee needs them most. Also, training and policy manuals may not be readily accessible from a project site.

Finally, more often than not, staff members needing technical references spend their time browsing the web and looking for references in the company library. On-line references constitute an important element of information transfer that can help construction workers wherever they are within the company to search for needed information.

Intranets can be effectively used in transferring information within a construction firm. Current intranet applications offer contractors a method to manage construction project information more effectively^[1]. However, intranet knowledge base applications to transfer experiences, although commonly used in other industries, are not widely used in construction. One can only search the Internet for knowledge base software and sample clients using them to see the myriad variety of applications available. In essence, these web-based knowledge base software solutions can be hosted on a server and provide an environment that enables capturing and leveraging the information and experiences of employees.

Although there is a need for knowledge transfer to knowledge base (KB) systems in construction firms, there are many barriers to their application. Some of these barriers are: limited availability of information technology staff time or expertise, the time demand required to maintain the systems, and the initial cost to create the systems. To overcome these barriers, commitments of upper management to embrace innovation of KB technology and making it work are most essential.

2. Knowledge-Base Project Scope.

Considering the limitations cited above, a group of faculty from the Honors Program at the College of Applied Sciences at The University of Cincinnati determined that the College is well positioned to provide Information Technology (IT) expertise to construction firms through the Honors program to develop a construction knowledge base. After all, the college has IT honors students who are eager to implement real-world IT solutions and to learn more about technology. It also has honors Construction Management (CM) students who are eager to learn from experienced construction professionals about construction methods and techniques, and “dos and don’ts” in the construction industry.

The faculty approached Messer Construction Company known for its support not only of innovation but also of the educational process of honors students. Many of the construction management students coop with the company and are hired immediately upon graduation. The company at that time was considering a much simpler concept for the knowledge transfer. The concept was based on providing a support network of experts within the company to provide expertise to all professional staff. The network provides the professionals with consultations in various technological areas of construction.

During the initial exchange information between faculty and executives of Messer, the executives revealed their interest in forming a network of consultants to provide needed information to all professional staff on an as-needed basis. The honors faculty presented the idea of preliminary knowledge transfer through a knowledge base as a foundation for the network. In essence, a professional needing help in a certain area can search the knowledge base first, and then if the needed information is not part of the knowledge database, he or she can contact the expert consultant on the network. The consultants in the network are the same ones who help in providing information in the database. The idea caught-on and a scope of a company-wide knowledge base started evolving. The requirements for the knowledgebase system were evolved in stages, some during the initial discussions and the others during the development stages. Some of the important requirements are: The Knowledge base needs to be online, it should be easily accessible, it should have an intuitive interface, and it can be easily updated without the need for database knowledge. It was also determined that the consultants in the network will be directly involved in the development of the knowledge base including its design. The knowledge base should help all professionals in the company in knowledge acquisition and in troubleshooting construction operations. It should also assist them to search for references.

Almost immediately, a team of three IT Honors students and one faculty started working on the concept and on designing the backend and the interface of the knowledge base. One company executive responsible for Messer IT department joined that team. Meanwhile, the company decided to hire one Honors CM student to coop with the company and to work on the project. The coop's responsibility was to acquire the knowledge needed for the database from the consultant, and to test the system as it was developed. The student was under the direct supervision of the company executive responsible for the project. In applying information technology to a business problem, team diversity is generally the norm, with the primary interactions occurring between the end-user as the content expert and the information systems specialist as the facilitator^[2]

3. Conceptualizing the Knowledge Base Backend and Interface

A student leader with extensive experience in information technology quickly emerged from the Honors IT team. He quickly led the team to making several successful decisions. The first decision was made with respect to the content and project scope of the IT team. The team decided to divide the IT part of the knowledge base project to three components: Backend, Interface, and Documentation. It was decided that each student would be responsible for one component with significant input of the team leader and the rest of the student. The components would be presented to the company for modification and iterations. A reasonable amount of iterations were suggested before a final product was rendered; this was an important step so that the project would not drag-on while the students were completing their coursework.

The original proposal was to develop the knowledge base using series of static web pages for individual modules. Company executives identified over fifty modules from concrete placement and structural steel erection to mechanical and electrical installation modules.

Each module would have the looks of a file containing five tabs that would help in navigation through the module (figure 1). The information provided through the modules depended on the company field operations. The faculty and executives decided that developing a prototype of three modules with standards tabs would be sufficient to test the functionality of the knowledge base. For example, the module on concrete contains information about concrete elements organized under five tabs: Standard Methods, References, Experts, Trick of the Trades, Buying Practices, and Web Links.

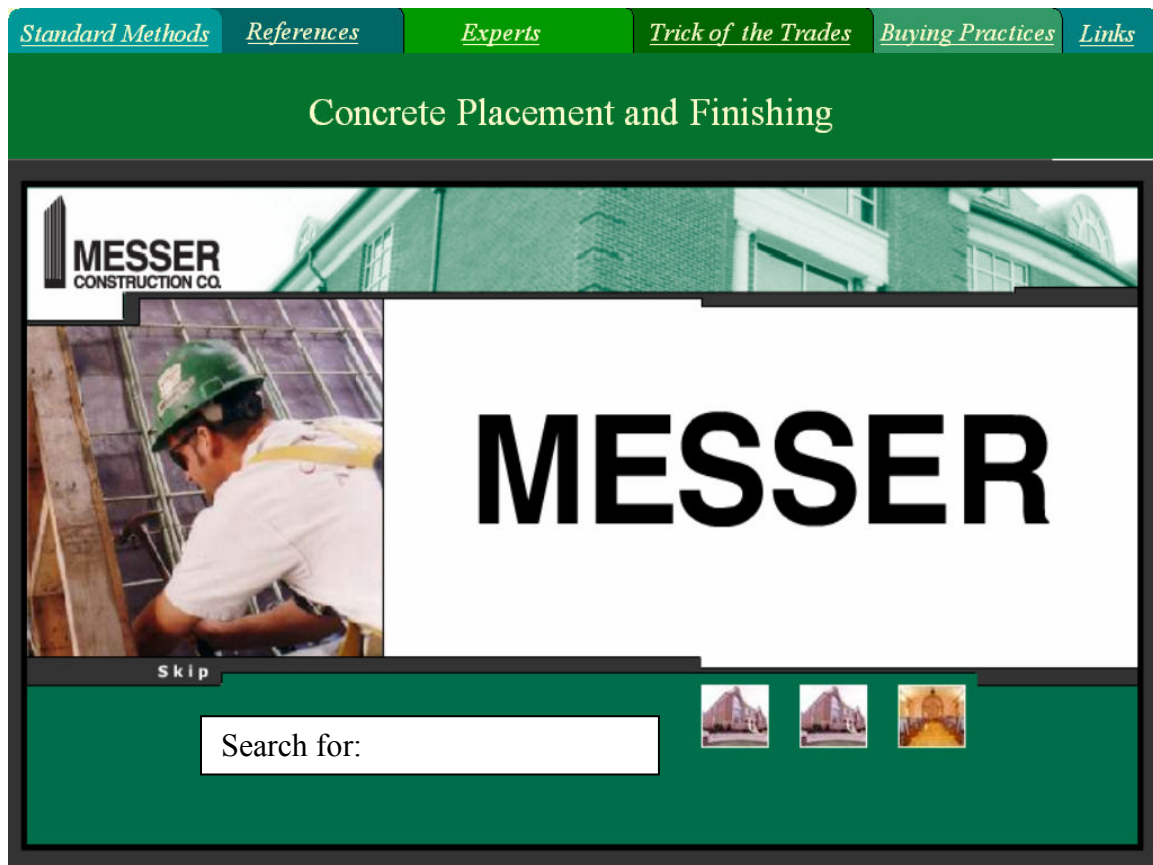


Figure 1: The proposed web page interface for the knowledge Base

Each tab would reveal information important to the user. The Expert tab for example, will have updated information about the professionals who populated the module with information and methods to contact them (email, telephone, facsimile, etc.)

Upon further investigation, the IT team decided that creating a series of static web pages for each module in the knowledge base although feasible, would hinder the scalability, increase the development and maintenance time and limit the future design modification. If the proposed initial design was implemented, it would be necessary that a web page developer be present for adding a new module or updating a module in the knowledge base, which is an expensive proposition for the company.

Therefore, the obvious choice of the IT team was to have a database backend for the web interface. The team decided to design and develop an object-oriented system to overcome the limitations that stem from a static web page design as proposed initially. Messer's technology infrastructure and skill sets were heavily focused on the Microsoft Windows platform, Microsoft Visual Basic 6, Microsoft SQL Server 2000 and Microsoft Internet Information Server. Due to this focus, the decision was made to create the Knowledge Base using these technologies. In addition to these technologies, it was decided to use the native file editor for editing documents (e.g. MS Word for MS Word documents). This gave the administrative user the most control over the documents without forcing the administrative user to learn HTML or any other technologies to post documents to the web. It was also decided to use Microsoft SQL Server's Full Text Indexing^[11] feature to allow easy indexing of all documents submitted to the Knowledge Base. The team decided to use Active Server Pages (ASP) for server-side (back-end) programming and JavaScript for client-side (front-end) programming.

The Knowledge Base project proceeded on two fronts: Developing the IT side with the front-end and backend for the database, and developing a template and tapping the professionals for information to store in the database.

4. Tapping Construction Knowledge from Professionals for Project Development

As indicated earlier, three modules were needed as a prototype for the original development of the knowledge base. Concrete, Masonry, and Roofing were identified as the modules needed to start the project. Three professionals from each area, a total of nine professionals, with extensive practical experience and knowledge in these topics were identified. They were briefed about the project by company executives and knew about the objectives. The faculty presented the professionals with preliminary details of the knowledge base and discussed the knowledge needed to populate it. A model template for information gathering was created and given to the professionals as an example. The nine professionals, in presence of company executives, were asked to develop a template in each of their areas to be used not only in designing the individual module but also to collect information for these modules. After several iterations and modification of the templates by the professionals, the IT team modified the backend design of the database to make it readily available to populate these modules with information.

One Honors CM Student, on coop assignment with the company, started to collect information from the professionals for the three modules. His responsibilities also included interfacing with the IT team to upload the information acquired from the field in the database. The CM-coop, worked on one module at the time, visiting the professionals in their construction sites, audio taping the conversations with the professionals, then returning to the office to sort the information and type it in a systemic manner according to the templates. Once the information was typed, it was uploaded in the knowledge base.

The challenge cited by the honors student in collecting the information was to keep the professionals focused on providing what is needed for the knowledge base without disrupting their flow or thought process. The professionals had so much knowledge to contribute to the knowledge base with little time to do so; but, regardless of the time constraints, the information needed to start the database had to begin somewhere. Another challenge was that data acquisition required several visits to each professional working on projects remote from the office. After acquiring the knowledge (on tape) the student needed get back to the office to type the information using a word processor, then upload it to the database. The entire process required a substantial amount of time. Meanwhile, the coop student was working for only thirteen weeks for the company and another student needed to replace him. Another challenge that was observed by the authors, and cited by both the student and the supervising executive, was that the ability of the inexperienced student to transfer technical information from the tape recorder to word processor was limited sometimes by the technical knowledge of the student and sometimes by his writing skills. This required substantial amount of time from the executive to question and correct the information even before consulting with professionals who originally provided the information.

Transferring the information to the next CM honors coop student was yet another challenge. However the supervising executive, along with the CM student who started the data acquisition, documented a process for future coops to acquire information and populate the database.

The challenges cited above required redirection for the next CM Honors coop student hired for data acquisition. The new student spent a quarter of his time refining the information and cleaning the database of three modules while testing its interface and presenting it to company personnel.

5. Designing Knowledge Base Backend and Interface

The Knowledge Base was designed using an N-Tier architecture approach from its first inception. Use of this architecture for web development offers the reliability and scalability of traditional transaction processing, client/servers' ease of use, and the flexibility of Web interfaces. This architecture uses a consistent "business-object tier" and provide services to the traditionally rich GUIs (such as Win32), and the customer-facing Internet/intranet clients (such as HTML)^[6]. It makes development and maintenance easier while providing a centralization of the code^[9].

5.1 The 3-tier Architecture

The design of the knowledge base has a 3-tier architecture. The different tiers are the user interface tier, the application or business logic tier, and the data tier. The user interface tier is further divided into the end-user interface and the administrative -user interface which share the components of the business logic and the data tiers as shown in Figure 2.

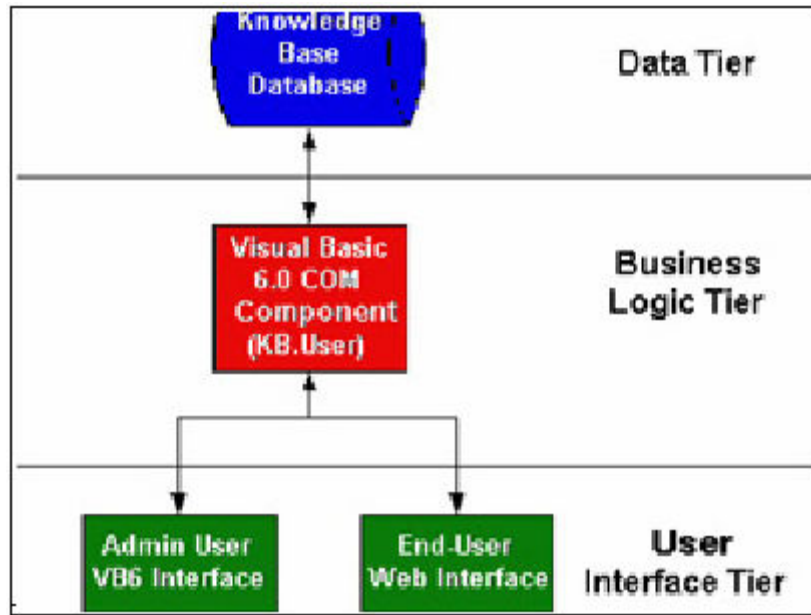


Figure 2: N-Tier Architecture

5.1.1 The user interface tier

The expertise of using a computer varies among the potential users of the knowledge base. It ranges from beginners to experts. So it was important to design a user interface that would be simple and consistent. Consistent screen appearance and interaction styles are very powerful in delivering the content simply, subtly, and directly^[3]. So it was decided to keep the look and feel of the interface simple and the same for all the modules.

The interface layer has two different interfaces. One is the web based end user interface for the users of the knowledge base. The other is the windows-based administrative user interface for the administrator of the knowledge base. It is designed using Microsoft Visual Basic 6.0 and it interfaces to the business logic tier using COM+.

The end user interface

The end-user interface (see Figure 3) is the main interface and is used by construction professionals to search and view documents, images, movies, and other file types. This web interface would be accessed using Microsoft's Internet Explorer.

The presentation structure of the modules and its contents in the user interface needed to be simple and easy to navigate. A familiar structure needed to be implemented^[4]. So a tree structure similar to MS Window's file system in which there is a root container that houses all the folders and files is created. In the knowledge base tree a folder corresponds to a subtopic in the tree. It can contain zero or many files which is any type of file that needed to be stored in the database. It can be an image, an MS Word document, an MS Excel spreadsheet, or any other binary file. To be indexed and

searchable the document must be either an MS Office file, an Adobe PDF file, or a proper IFilter^[10] needs to be installed on the Knowledge Base database server.

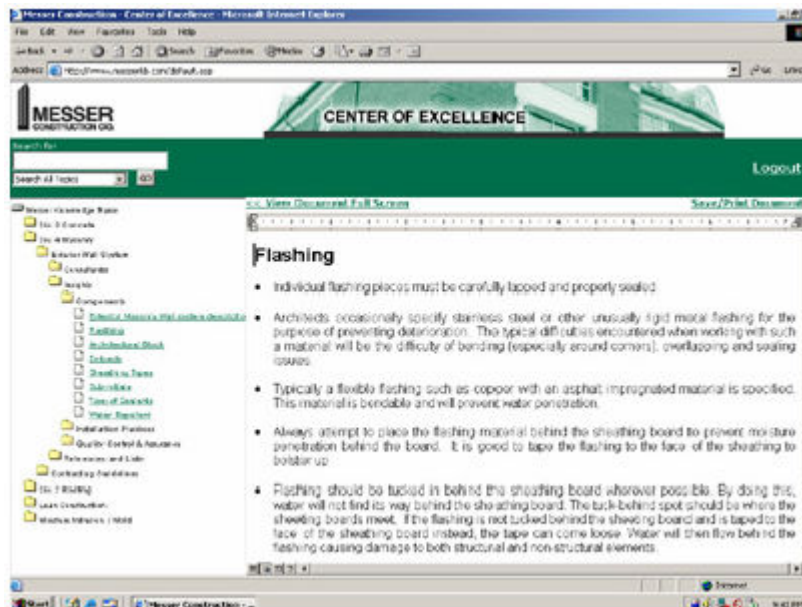


Figure 3: End User Interface

The Knowledge Base tree structure uses cascading style sheets for creating the Window's Explorer like interface and is cached by the web server so that the tree is only created the first time the Knowledge Base is accessed allowing for a much greater response time. The Knowledge Base tree structure that is cached may be updated by an Administrator of the Knowledge Base using the administrative user interface.

Construction professionals may either traverse the Knowledge Base tree looking for subjects of interest, or they may search the Knowledge Base by entering search terms in the Search box. The user is automatically logged in to the end-user interface using Integrated Windows Authentication so that document access can be logged.

The administrative user interface

The administration user interface (see Figure 2) allows an administrator of the Knowledge Base to add, edit, update, and remove users, subtopics, and documents. It also allows the administrator to easily import and export any portion of the Knowledge Base tree along with indexing the newly created documents and refreshing the cached web tree if new documents are added to the tree.

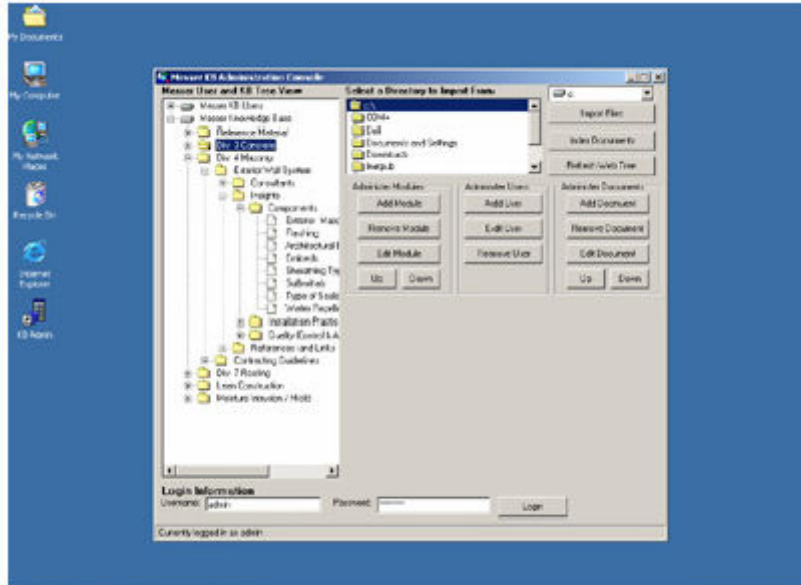


Figure 4: Administrative User Interface

The interface allows easy manipulation of the documents using the program that is associated with the document type as the editor. For example, if a document that was created in Microsoft Word is opened for editing, Microsoft Word is then used as the editor to make changes to the document. The changes are then saved back to the Knowledge Base database and the document is re-indexed. The administration user interface is designed using Microsoft Visual Basic 6.0 and interfaces to the business logic tier using COM+.

5.1.2 Business Logic Tier

The business logic tier is the workhorse of the Knowledge Base. All business logic is stored in this layer of the Knowledge Base which includes creation, editing, and deletion of users, subtopics, and documents. The business logic tier is a Microsoft Visual Basic 6 COM+ application that resides on the application server. In the version that Messer uses for production and development, the business tier was loaded on the same server as the web server. If the application required a better response time or needed to handle more requests, the business tier could be moved to a separate server or even load balanced on multiple applications servers.

5.1.3 Data Tier

The data tier (see Figure 5) is the storage area for the Knowledge Base system. All documents, subtopics, and users are stored in this layer along with access logs and settings of the Knowledge Base. The data tier uses Microsoft SQL Server 2000 Standard Edition as the database server and makes extensive use of Microsoft's Full-Text Indexing. Full-Text Indexing allows all documents stored in the data tier to be indexed and searchable.

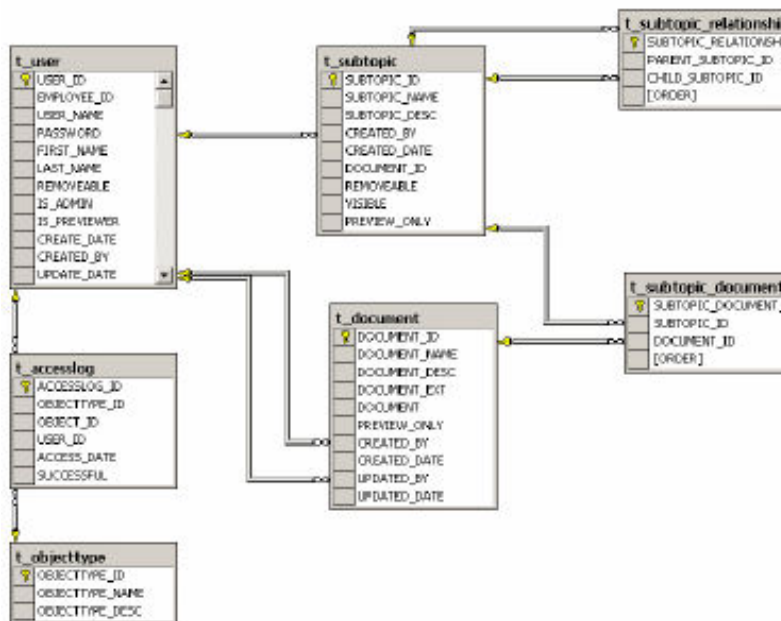


Figure 5: Data Tier Entity Relationship Diagram

6. Testing and Evaluation of the Knowledge-Base

As the rough draft of data of the first three modules was uploaded in the knowledge base, both the IT team and professionals who contributed their knowledge tested its speed and content. Several issues emerged immediately; for example the speed of information retrieval kept degrading with time during which the database was running. Another problem was that the screen display of the information was fixed in size and width; another issue appeared when the search associate with the knowledge base was yielding too many results that rendered the search ineffective. Both the IT team and CM team worked hard on resolving all these problems. Frequently refreshing the cache used by the database as it was displaying the information on the web speeded up the display. Adding an option to expand the screen when a document is displayed helped the visual presentation of the documents and changing the search so that the knowledge base searches for a string of characters as opposed to keywords helped in rendering the search more effective.

While the appearance and speed of the knowledge base was tested, the content was modified with input of the professionals (consultants/experts) who contributed it to the database. Once the information was loaded in an acceptable form, and the knowledge base was running in a functional manner, the system was presented on the intranet to a group of constructors in a satellite office. The presentation yielded several problems that were addressed and feedback was obtained from the staff. Other presentations of the system ensued to a group of professional staff and feedback in form of survey was used to evaluate and modify the database. Most feedback was positive and promising.

Currently, the knowledge base is continuously being populated with more modules and input from professional staff consultants with special expertise. A total of six modules have been completed, and professional staff from the company continuously tests the content of the knowledge as it expands. It should be mentioned that during the development of the system, additional uses for the knowledge base were explored and developed. For example, prior to the development of the system, the company provided every job trailer with the American Concrete Institute (ACI) manuals for standard practices. Currently, the manuals are part of the reference folder in the concrete module. It is available on-line from within the knowledge base providing the users with up-to-date information. A similar approach is being considered for other references and policy manuals.

7. Conclusion

Overall, the project provided an exceptional experience for the Honors student in both the CM and IT programs in the College of Applied Sciences, University of Cincinnati. For the CM students, the project presented an opportunity to learn from experienced professionals about various technical construction operations. In return, it was also a rewarding experience for professionals who shared their knowledge with current and future constructors. For the IT students, the project helped in developing leadership experience for the team leader and IT experience for other students involved in the development of the database. All IT students earned academic credits for their work on the project, while CM students earned real dollars while working on coop assignment for the company.

As a result of this project, the Honors program at the University of Cincinnati, College of Applied Science earned a grant from Messer Construction that was endowed to generate operating fund to start similar projects in the Honors Program.

The benefits for Messer Construction will continue over the years. They range from improved communication among staff, to preserving and transferring valuable experience of field professionals, to just using on-line references in an effective manner and to improve productivity while enhancing communication.

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