DELIVERING DATABASE KNOWLEDGE WITH WEB-BASED LABS

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ABSTRACT
This paper describes the design of web-based labs that are used in database-related courses to teach students practical skills. Topics of the database courses cover a variety of areas including modeling, design, query language, and applications. Labs are necessary to enhance the teaching of these topics effectively. Traditionally, all labs are implemented in desktop-based environment where students have to install heavy client software to access database servers. In order to release students from that burden, we have implemented web-based labs to support database related courses, from which students and teachers can practice and learn database topics via Internet access. This paper explains the database topics covered, labs, alternative delivery mechanisms as well as the benefits and problems involved in switching to web-based labs for a variety of database courses.

INTRODUCTION

In general, database courses are technology dependent. Database courses rely on the use of a software environment to help students understand fundamental principles. In introductory courses, general data modeling and basic database design concepts can be presented solely in the classroom. However, in application courses, it is essential for students to see live databases and be able to directly examine tables, constraints, and design implementation. Manipulating data in a live database assists them in understanding what data integrity really means. In addition, the database query language, just like any other programming languages, can be learned more effectively by using it, not merely by reading lines of code from textbooks (Brown and Lu 2001, Ramakrishnan and Nwosu 2003, Sadiq et al. 2004). A good database environment will allow students to examine and interact with a live database typically via rich client tools.

Technologies in industry evolve constantly. It is beneficial to expose students to leading software environments to reduce their potential "technology shock" after they graduate and join the workforce. A trend in information systems is delivery through web technologies. Many leading software vendors are striving to deliver their products via a web platform to reduce the technical burden on users. In turn, it is possible for us to implement web-based labs to enhance student learning in database courses. The Web, with its easy access and flexibility, has become a common platform for the delivery of educational courses. Efforts to use Web delivery have been reported in various teaching areas. Complex lab instructions can be delivered via web (Breimer et al. 2011). Web-based database labs were developed to assist students learning in a different context in data modeling (Kung and Tung 2010), database querying (Brown and Lu 2001, Ramakrishnan and Nwosu 2003, Sadiq et al. 2004), as well as web interface programming (Moore et al. 2002, Schaeffer and Olson 2011). Efficiency and simplicity are, in our minds, a priority in delivering database knowledge with web-based labs.

DATABASE TOPIC COVERAGE

Database courses cover a variety of topic areas including data modeling, design, query language, database application, data warehousing, database administration, and database security. We offer database classes for undergraduate and graduate students via both on-line and on-ground classes. Theoretical and practical applications are blended in the courses.

Our undergraduate entry-level database course introduces concepts of data modeling, database design, and structured query language (SQL). Subsequent advanced courses cover topics ranging from transaction management, database performance tuning, distributed database, and business intelligence, to database administration. More specialized courses such as web databases, databases in web services, data warehousing and data mining, are also offered in different programs and at different levels, as depicted in figure 1.

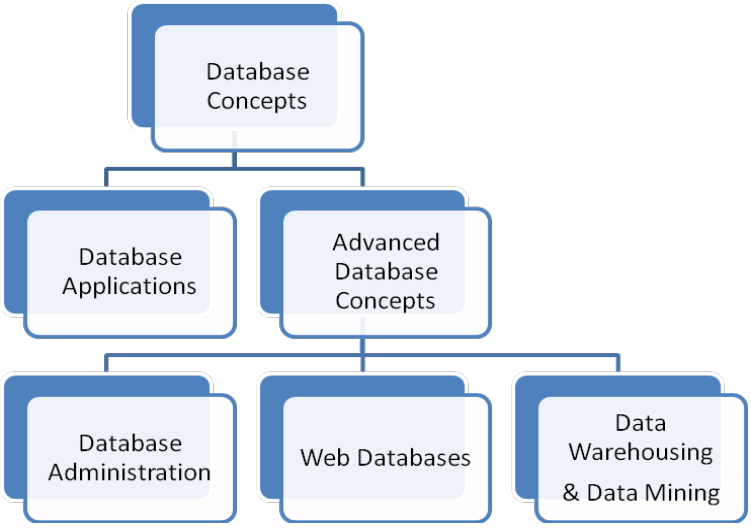

Figure 1. Database Topic Coverage

Although most of these topics need labs to support student learning, different topics have different lab requirements, as listed on Table 1.

REQUIREMENTS ON LABS

During data modeling and database design, Entity relationship diagram (ERD) and normalization are examined and the need for labs are minimal. However, students practice both data definition language (DDL) and data manipulation language (DML) to master the SQL query language. SQL allows students to create database objects and perform data management tasks. In addition, procedural SQL knowledge is gained through database objects such as stored procedures, functions, and triggers. All of these language components can be experienced directly by working with a live database during labs.

Modern databases are server-oriented in nature and managed by database management systems (DBMS). To access the server, users interact with server objects through various client environments. In a typical SQL client environment, a single query statement can be edited and executed so the result will be displayed in the result pane. In addition, the query can be examined to analyze its performance impact.

On the database application level, the lab requirements shift. End users of a data-driven application interact with database data via an application interface. The design goal of labs for this stage is to help students understand on how database design impacts user interface design, and how the application interacts with database objects, including querying data, manipulating data, invoking procedures, and implementing business logic. Data-driven applications with a professional interface and security are needed. Interface components such as navigation, web pages, tabs, and security should be available and easy to build for an experience similar to industry.

Table 1. Requirements on Labs

TOPIC COVERED	LABS REQUIRED
Data modeling and database design	ERD
SQL	Execution of single SQL statements and script files
Procedural SQL	Procedures, functions, and triggers
Database applications	Database integrated applications
Data warehousing	Data warehouse objects queries
Database administration	Security, performance, transaction management, and data dictionary
Application programming	Data-driven web applications programming
Web database and web services	Server and client interaction

Advanced topics, such as data warehousing, require students to access special databases to help them understand key concepts. A data warehouse's dimension model, the star schema, differs from the relational model typically used in operational databases. Student learning is supplemented by querying a data warehouse and examining fact and dimension tables.

However, not all database-related classes require database-centric labs. In classes such as web databases the focus is on programming the web client and interacting with databases rather than the underlying database design. Therefore, the labs for these classes require suitable application programming environment but little to no DDL and few administrative features.

LAB DESIGN OPTIONS

Labs for database classes can be designed in various ways. Database server and client are the major components of many labs. As another alternative, the DBMS can be built in single, all-inclusive files, such as Microsoft Access, where the installation and access process is extremely easy. For practicing simple SQL query, Microsoft Access is enough. However, issues with the single file environment are obvious. It lacks the support for procedural SQL programming. With its limited capability in handling multiuser transactions, the single-file approach falls behind other leading industry technologies.

An environment that is integrated with the database and, at the same time, provides client server architecture is needed to serve a broader range of courses. Most integrated development

environments (IDE) from major vendors use a workbench metaphor to support rich-development tasks. Examples of workbench environments include Microsoft Visual Studio, IBM Data Studio, and Oracle SQL Developer. Workbench environments are very powerful in labs, especially for coding and debugging. However, the workbench environment normally requires a heavy client be installed, which causes difficulties for students in installation and configuration, particularly in online courses.

Some IDEs provide a declarative way to formulate SQL queries and even user interface forms. Examples include drop-and-drag query builder tools where the user selects tables and attributes so the query builder can formulate the SQL statement. The declarative approach builds on the non-procedural aspects of simple SQL statements. A declarative environment is efficient and effective for prototyping purposes. It is especially helpful in some courses where students focus on problem solving and query results, instead of the details of writing the SQL statement.

With its popularity and easy access, the Internet is becoming a platform for IDEs. IBM web query has extended its SQL query builder to a web-based environment so a web browser can be used as a client to access the database and build SQL statements declaratively. The declarative approach also has been extended to the area of building web application pages. Oracle Application Express (APEX) is a web-based environment that provides capabilities for not only SQL manipulation, but also web application development with complete declarative approaches. Oracle APEX has enabled us to successfully deliver web-based labs for some of our database-related classes.

IMPLEMENTATIONS

Oracle APEX is a comprehensive browser-based SQL and application development environment. It supports scripts and single statements in SQL. The workshop and application IDE enable students to build projects using the web browser as the sole client for developing, deploying, and running web applications.

LABS WITH SQL WORKSHOP

To support database design classes, labs are designed to guide students' lab activities. A database account is created for each student which is tied to a workspace account that student can access via the Internet. The SQL workshop, as shown in Figure 2, is the primary tool for concept classes.

Figure 2. SQL Workshop Interface

The object browser enables students to view, browse, and manage all database objects. For example viewing a table structure displays constraints, such as primary key, foreign key, and checks. Further, this same visual interface may be used to update the underlying DDL. SQL Commands runs single SQL statements, while SQL Scripts run many statements at a time. Within the SQL workshop, students can access all database objects under their designated account and practice SQL without disturbing the workspaces of other students. Such safety encourages students to explore database capabilities in more depth.

LABS WITH APPLICATION BUILDER

To support database application classes, labs are implemented to teach student how to implement web applications that interact to database. The APEX application builder is an environment to build web applications with Oracle as the underlying backend database. It assembles an HTML interface on top of database objects such as tables and views, as shown in Figure 3.

To build a data-driven web page, students need to apply the SQL knowledge learned in the concepts class and specify SQL statements in web pages to access data. In the entire process, they do not need to spend time on programming web interface itself due to the declarative approach in building pages. In this way, they can focus on data manipulation, rather than interface programming. The focus of the labs in database applications should not be on programming web interfaces regardless of programming language such as .NET or Java. It should be on database manipulation, how database design affects end users and how data are protected by data integrity constraints.

Figure 3. Application Home

LABS FOR DATA WAREHOUSING

Data warehousing labs are implemented to provide students experience in data warehouse design and querying. Differences exist between operational database and data warehouse. The table design for the star schema can be examined through the web-based object browser. Items of interest include the depth and width of both dimension and fact tables. Possible attribute hierarchies for aggregation in a dimension can be accessed by querying the data dictionary enabling students practice traversing a hierarchy such as region → country → state/province → city.

With the SQL skills learned in the concepts class, students can perform basic analytical queries to answer typical business questions. Practice in drilling down and rolling up along dimension hierarchies can be performed to obtain data at different levels of granularity. To better answer business queries, standard SQL has been enhanced with analytical functions to facilitate analytical processing. As a fundamental part of data warehousing, aggregate and analytical functions make complex querying and reporting easier and faster. All analytical queries can be performed in the lab over internet against a data warehouse server.

Some features that can enhance performance in data warehousing, such as implementation of indexes and partitions, are also available for students via the object browser. In addition, the technical metadata of the data warehouse is provided in data dictionaries to help students understand the data warehouse model and perform queries.

Web-enabled OLAP is another important data warehousing topic that benefits from a lab (Wang et al., 2011). As a rapid web application tool for database, APEX offers built-in features such as user interface themes, navigational controls, form handlers, and interactive reports. These features can be included in full-fledged web-enabled OLAP applications so students can use their web browser to experience OLAP's interactive features. Interactive reporting with interactive drill-down, filtering, dynamic customization, and interactive charting can all be built into the application. Figure 4 shows an example of the web OLAP interface for interactive drilling.

Geography	Product	Time	Sales	% Chg Pr Period	% Chg Pr Year	Ytd
South America	Portable Music and Video	CY2007	$1,668,735	-	-	$1,668,735
North America	Portable Music and Video	CY2007	$3,795,936	-	-	$3,795,936
Oceania	Portable Music and Video	CY2007	$11,587	-	-	$11,587
Europe	Portable Music and Video	CY2007	$2,274,220	-	-	$2,274,220
Africa	Portable Music and Video	CY2007	$647,626	-	-	$647,626
Asia	Portable Music and Video	CY2007	$6,704,484	-	-	$6,704,484
South America	Portable Music and Video	CY2008	$1,777,808	6.5	6.5	$1,777,808
North America	Portable Music and Video	CY2008	$4,055,191	6.8	6.8	$4,055,191

Figure 4. OLAP with Drill Down Enabled

The department, in coordination with the university IT department, hosts the server at the university, improving access. This approach provides a wider range of flexibility in experimenting and tuning the server, and adding more services in future than vendor-hosted implantation (Wang et al. 2010). The web-access provides a significant advantage and client software is no longer needed for students in web-based labs. Student can focus more on course content when using a web-browser. This is especially valuable when taking into consideration the range of hardware and operating systems used by the students. The web-interface makes it unnecessary to install any local software. As a result, students in online distance education courses no longer experience many of the installation and configuration problems found in the past. Now that they can complete all labs via the web interface, their focus and effort remains on database topics rather than logistical difficulties.

SCOPE AND ISSUES

During the implementation and transition of courses to the web-based environment we noted significant benefits and experienced a variety of issues. Technology innovation over the Internet makes it possible for us to implement web-based labs to enhance education. Its true pedagogical value needs to be assessed from different perspectives (Zalewski 2008). An analysis of this approach to delivering database labs is organized around the following questions:

1. In which situations is it useful to implement web-based labs for delivering database knowledge?
2. What are the benefits of the web-based labs for delivering database knowledge?
3. What are the disadvantages of web-based labs for delivering database knowledge?
4. What is the pedagogical value of web-based labs for delivering database knowledge?

The analysis and response to the four questions regarding web-based labs for database courses are summarized below.

The scope for the web-based lab environment is designed for database-centered courses. In these labs, students focus on database manipulation and interaction with minimal effort on programming the user interface. Lab activities involve querying with SQL, viewing database objects, building declaratively data-driven applications development. However, not all database-related topics can be covered by web-based environment. Teaching design and modeling is an area that does not require web access. The application generated from the environment is good for prototyping but not for replacing programming web pages. It is not our intension to replace or eliminate labs with other programming languages for any programming classes.

Applications can only be built on top of the Oracle database because Oracle APEX is integrated with the database. The connection between the web client and database server is embedded. Connections to other types of DBMS are not supported. In order to implement applications with programming languages such as ASP.NET or Java, connection strings are required and drivers needed to be installed. Therefore the APEX environment was not adopted in several web programming classes where focus is on using programming languages like ASP.NET. For the same reason, the APEX development environment is not suitable for classes on web services, where the focus is on a traditional client and server architecture.

Web-based labs for delivering database knowledge are useful when:

- A course teaches database-centric knowledge.
- A course uses SQL and procedural SQL development.
- A course does not focus on detailed user interface implementation.
- Course does not require integrating other programming languages into the application such as ASP.NET or Java for database-driven application development.

Benefits of the web-based access to a DBMS and web-based declarative web application environment include:

- Significantly reduced student and instructor time troubleshooting installation and configuration of DBMS and associated connectivity.
- Location transparency for distance students now that they have the same access and performance regardless of location.
- Access transparency for students despite differences in their personal computing resources.
- Class time and attention to database knowledge increases.

Since the APEX environment was relatively new, issues existed in the areas of faculty training, lab preparation, and learning curve. The installation and configuration included several challenges. For example, it was easy to install and configure a web server that is embedded in the database server. However, it became apparent that the embedded web server did not readily support a large number of concurrent users. We recommend implementing a standalone web server instead of using the embedded web server. This configuration now successfully supports the web traffic needed to support our courses.

The disadvantages of web-based webs for delivering database knowledge are:

- Initial learning curve for instructors and students.
- Initial installation and configuration challenges that may require additional resources.
- Investment in developing detailed course materials if adopted early in the product lifecycle.

The findings above were distilled from more than 3 years of experience implementing web-based labs across a variety of undergraduate and graduate courses. The benefits of delivering database labs via a web interface were found to outweigh the difficulties encountered along the way. In summary, the pedagogical value of web-based labs for delivering database knowledge includes:

- More time devoted to learning databases.
- Less time spent on technical support issues generated by the wide variety hardware, operating systems and software used by students.
- A lab delivery platform and learning environment that can be shared across multiple courses in different teaching areas.
- Students experience in accessing the database more closely resembles everyday users of the application.
- Students experience some of the benefits of distributed systems, particularly delivered via the Internet.

CONCLUSION

In conclusion, the web-based database labs have effectively supported most of our database related classes. The labs reduced the need for students to install heavy client environment in order to access database server and experience database applications. However, it doesn't mean this is the only way to support the lab environment. The web-based database labs should be used in conjunction with other lab format to reach best teaching and learning objectives.

REFERENCES

Breimer, E., Cotler, J., and Yoder, R. (2011). Towards an Innovative Web-Based Lab Delivery System for a Management Information Systems Course. Information Systems Education Journal, 9(4), 27-36.

Brown, J. and Lu, J. (2001). Designing Better Online Teaching Material. Proceedings of the 32nd SIGCSE Technical Symposium on Computer Science Education, 352-356.

Kung, H. and Tung, H. (2010). A Web-Based Tool for Teaching Data Modeling. Journal of Computing Sciences in Colleges, Vol. 26 No. 2, 231-237.

Moore, M., Binkerd, C., and Fant, S. (2002). Teaching Web-Based Database Application Development: An Inexpensive Approach. Journal of Computing Sciences in Colleges, Vol. 17 No. 4, 58-63.

Ramakrishnan, S. and Nwosu, E. (2003). DBMS Course: Web Based Database Administration Tool and Class Projects. Proceedings of the 34th SIGCSE Technical Symposium on Computer Science Education, Vol. 35 No. 1, 16-20.

Sadiq, S., Orlowska, M., Sadiq, W., and Lin, J. (2004). SQLator – An Online SQL Learning Workbench. Proceedings of the 9th Annual SIGCSE Conference on Innovation and Technology in Computer Science Education, 223-227.

Schaeffer, D. M. and Olson, P. C. (2011). Adding the Web to Database Class. Journal of Computing Sciences in Colleges, Vol. 26 No. 3, 98-101.

Wang, J., Kourik, J. L., and Maher, P. E. (2010). Introducing Leading IT Technologies into Curricula via vendor-Hosted Services. Journal of Business and Education Leadership, Vol. 2, No. 1, 96-105.

Wang, J., Kourik, J. L., and Maher, P. E. (2011). Web-Enabled Online Analytical Processing for Intelligent Business Decision-Making. Proceedings of 10th Wuhan International Conference on E-Business – Information Technology and Information Systems, 592-597.

Zalewski, J. (2008). Web-based Laboratories: How Does That Affect Pedagogy? Thoughts for a Panel Discussion, Proceedings of the International Multi-conference on Computer Science and Information Technology, 761 – 762.