12-17-2010

Visualization for Verification Driven Learning in Database Studies

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Visualization for Verification Driven Learning in Database Studies

A Thesis

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
requirements for the degree of

Master of Science
In
Computer Science

by
Aditya Reddy Kallem
B.E., Osmania University, India, 2008
December, 2010

ACKNOWLEDGEMENT

I would like to thank Dr. Shengru Tu for guiding me throughout my thesis. Without his help, I could not finish this thesis.

I would like to thank Dr. Adlai DePano and Dr. Christopher Taylor to be part of my defense committee members.

Lastly, I would like to thank all my friends and my parents who gave me so much love and encouragement.

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Abstract

This thesis aims at developing a data visualization tool to enhance database learning based on the Verification Driven Learning (VDL) model. The goal of the VDL model is to present abstract concepts in the contexts of real-world systems to students in the early stages of computer science program. In this project, a personnel/training management system has been turned into a learning platform by adding a number of features for visualization and quizzing. We have implemented various tactics to visualize the data manipulation and data retrieval operations in database, as well as the message contents in data messaging channels. The results of our development have been utilized in eight learning cases illustrating the applications of our visualization tool. Each of these learning cases were made by systematically implanting bugs in a functioning component; the students are assigned to identify the bugs and at the same time to learn the structure of the software system active

Keywords: Verification Driven Learning, Database, Visualization, Meta data

1. Introduction

One of the efforts of computer science education community is the push for presenting abstract computer science concepts in the context of familiar real-world applications [1]. However, real-world working software systems are very complex to implement. Developing such working software systems requires thorough understanding of many concepts which can take years of learning. Therefore, students often do not see their learning directly related to the real world until they complete many computer science courses which take couple of years. Such a prolong process can make students lose their interest in the computer science program.

The objective of Verification Driven Learning (VDL) is to bind the students to real-world challenges. By facilitating students doing the verification activities, we can let students see their future roles in real-world projects. Students will realize their learning of computation is relevant to the real world.

In a general VDL process, the students go through a series of activities listed below.

1) The students begin the process by reading the functional description of the subject system. A simplified version of the functional requirements specification of the subject system can serve this purpose well.

2) The students execute the program and interact with the system as a user. The purpose is for the students to get familiar to the subject system.

3) The students are assigned to verify the system's functionalities by comparing the features and capabilities experienced in Step 2 against the document read in Step 1. If needed, the students can go back to Step 1 (to review the document) or go back to Step 2 (to try out more features).

4) The students are quizzed with multiple-choice questions which challenge the students about “what’s wrong”. Answering these questions requires a comprehension of the problem. At the same time, the multiple-choice questions illustrate examples of concise, hit-the-point language style for describing problems.

5) The students are asked to find the bug. The objective is for the students to locate the planted bug through critical thinking. In order to help the students to achieve their goals, a collection of facilities are provided including system structure diagrams, data flow observers (e.g., a message viewer), illustrations of component structure drill down. For some complex components with a planted bug, an animation that points out the problematic code is prepared.

A *verification-driven learning case* should consist of the following elements.

1) a working system,

2) the justification of the system’s existence and background information,

3) the simplified requirements specification of the system,

4) the description of the functionality of the system including intuitive explanation of the business rules and solution logic,

5) test cases (pairs of input data and expected output),

6) decomposition of the system is prepared and presented to the students as subsystems, components and objects; each has its functionality specification and user’s guide,

7) the specifications of interfaces between components and objects,

8) intuitive user interfaces for students to interact with the components and objects, or to examine messages

A database is a collection of organized data which is accessed depending on the requirement of the organizations. A database always serves as the backend of applications to store the information that has been collected by the frontend clients. Database is an elective course in many computer science curriculums. Due to the strong demanding from the job market, most computer science students take one or more database courses in their studies. Traditionally, relational database learning starts from the foundation in mathematics – relational algebra and relational calculus. While the foundation is essential for a thorough study, students often need help in grasping the abstract concepts.

As part of our research on the VDL model [2], this project aims at enhancing the VDL model with data visualization tools for database learning. For example, the dynamic visual tool is used to identify and verify database results. The output of a query is highlighted in the table visually by the dynamic visual tool. We will visually present the operations performed on a database in order to make easy to understand the logic that is being executed in the database. The visualization is to bring real-world problems and solutions to the classrooms. All the database operations ranging from SELECT statements to INSERT and DELETE operations are performed in examples from the database in working software systems.

2. Background

Based on the concepts of VDL, a module for database is developed which is a FLASH/JavaFX file that can be integrated and reused in any Web application. This FLASH/JavaFX file can visually interpret the queries applied to a database. It takes the query as an input parameter and visually shows the way this query is applied onto the database. Every data that is retrieved/inserted/updated/deleted is represented in this FLASH/JavFX file discretely.
The prime components of this FLASH/JavaFX module are the Query Parser and the ability of FLASH/JavaFX to visually represent the dynamic content in an appealing manner.

2.1 Query Parser

The queries that are used by working software systems are basically very complex and very difficult to understand. Consider a simple SELECT statement which is supposed to retrieve an employee's name that works in a particular company, for this query to return results it needs to access two tables i.e. employee & company and apply the conditions company name and employee name on respective tables, In another example consider the SELECT statement to retrieve the names of employee's in a branch in descending order of their salary, in this case we need to query the location table, employee table and sort it in descending order. The aforementioned operations are very simple and can be used only for demonstration purposes but In a working software systems the resulting queries are very complex which includes JOINs, multiple tables, multiple conditions and sorting of database values. In order to effectively show each of the database operations performed by the working software systems, we need an efficient and dynamic module which can break down the database operations thoroughly and provide enough meta data to FLASH/JavaFX so that the FLASH/JavaFX can visually interpret the Database operations. This is where we need a Query Parser which can understand the query and retrieve the required meta data from the query and the database.

2.2 Adobe Flash

An Adobe generated FLASH file can be readily integrated into any Web application. And since the FLASH file is already compiled, the Web server just needs to load the FLASH file to the clients. The purpose of FLASH is to show the communication messages between the key components of working software systems i.e. the communication between the client, server, database, Web-services, etc. The FLASH essentially shows the key values that are being passed from one component to other component. Since we implant bugs in the system to make the students learn about database queries, these incorrect values are shown in the communication which helps the students understand that the bugs are implanted in the Database component. This communication messages module is a basically a FLASH file showing the structure of the working software systems. And the dataflow between these components are dynamically shown in the FLASH animation in which an envelope carries the messages between all the key components.

There are two key components used to build such a dynamic FLASH file which can show the communication between components,

1) Tweened Animation and
2) Action Script

1) Tweened Animation:

We can create two types of tweened animation in flash i.e. motion tweening and shape tweening, between which we have made an effective use of motion tween. The motion tween was used to define the animated motion of the communication messages among different components of the learning system. But the dynamic messages which were passed in the communications were completely controlled by Action Script, which is the second key component.

2) Action Script:

The Action Script language adds the complex interactivity, playback control and data display in the application. Action Script includes a large library of built-in classes that allows us to create such a visually application. Flash includes more than one version of Action Script to meet the need to different kinds of application, but in this application we have made use of Action Script 3.0 which thoroughly follows the rules of object oriented programming style. Action Script 3.0 executes extremely fast which makes it a perfect choice for complex operations and data manipulations.

The Action Script is the major component which played a crucial role in animated communication messages. The messages in the animated communication messages were dynamically updated by Action Script.

2.3 JavaFX

JavaFX is an expressive rich client platform for creating and delivering rich Internet experiences across many devices and platforms. JavaFX is fully integrated with the Java Runtime and takes advantage of the performance and ubiquity of Oracle's Java Runtime Environment that is installed on literally billions of devices worldwide. In addition, JavaFX fosters a productive and collaborative developer-designer workflow. The JavaFX platform contains an essential set of tools and technologies that enable developers and designers to collaborate, create, and deploy applications with expressive content to browsers and desktops. In addition, mobile application developers can use built-in emulators to preview applications for mobile and television devices using the JavaFX platform.

Initially the modules of VDL program were developed using Adobe's Flash due to its industry standards. But later we switched the development environment to JavaFX because the developer tools were readily available from Oracles Java Environment for deployment of products on to the client interfaces without having to deal with the pricing and the licensing options. JavaFX provides an environment which is comparably as good as Adobes developer environment.

The main advantage of JavaFX over Adobe is the scripting language that is used to develop the interactive applications.

3. Visualization Design for Database Studies

The visualization of tables and operations performed in databases is to help the students to better understand the working process of a database. We have designed a visualization model to address the issue. The primary techniques employed in our thesis to help the students are:

a) Highlight the critical data items to capture the students attention ,

b) Provide the complete table schema beyond the selected columns to help the students get a better idea about the table.

3.1 Visualization of Data Retrieved from Databases

A common way to retrieve data from a database is to use the SELECT statement on a table in the database. This data retrieved is displayed to the user in the order the SELECT statement prescribed.

Example 1:

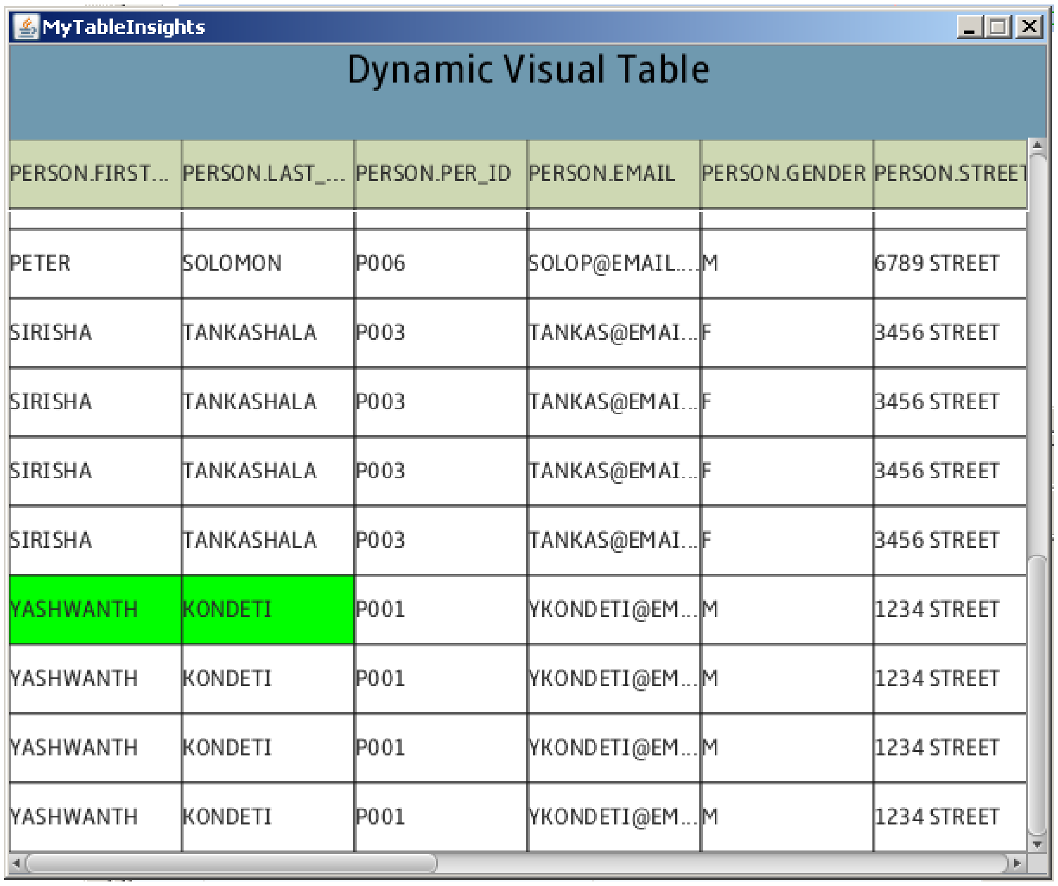
Consider a SELECT statement which retrieves employee names of a company. For this SELECT statement, we need to retrieve the rows from the person and the job tables by performing a join and then filter the results by applying the WHERE conditional statement which extracts the employee names working in a specific company.

```
SELECT
person.first_name, person.last_name
FROM  person, job
WHERE person.job_code = job.job_code AND job.comp_id = ‘MICROSOFT’
ORDER BY first_name
```

The above query retrieves the first names and the last names of all the employees from the person table who are working in the company “MICROSOFT”. This simple query will be a challenge for a beginner student. In this scenario, our goal is to present the user not only the values of “first_name” and the “last_name” columns but also the table structure, the remaining fields in the table, and the way the data is organized in the query result. If the aforementioned details about a table are readily available, even a beginner student will be able to get a proper understanding of the way data is organized in the database and also the sequence in which the query accesses the data in the table.

To effectively present this information to the user we have designed a module which visually shows the table structure, table fields and complete data that is currently organized in the table.

The following image shows a sample snapshot of visualization of data retrieved from database,



PERSON.FIRST...	PERSON.LAST_...	PERSON.PER_ID	PERSON.EMAIL	PERSON.GENDER	PERSON.STREET
PETER	SOLOMON	P006	SOLOP@EMAIL....	M	6789 STREET
SIRISHA	TANKASHALA	P003	TANKAS@EMAI...	F	3456 STREET
SIRISHA	TANKASHALA	P003	TANKAS@EMAI...	F	3456 STREET
SIRISHA	TANKASHALA	P003	TANKAS@EMAI...	F	3456 STREET
SIRISHA	TANKASHALA	P003	TANKAS@EMAI...	F	3456 STREET
YASHWANTH	KONDETI	P001	YKONDETI@EM...	M	1234 STREET
YASHWANTH	KONDETI	P001	YKONDETI@EM...	M	1234 STREET
YASHWANTH	KONDETI	P001	YKONDETI@EM...	M	1234 STREET
YASHWANTH	KONDETI	P001	YKONDETI@EM...	M	1234 STREET

Figure 1

The highlighted data represents the data that is requested by the SELECT statement

3.2 Visualization of Data Manipulation in Databases

Manipulation of data in database becomes confusing if the user doesn’t have a clear idea about the database schema. Our visualization will help students in understanding three types of data manipulation operations: INSERT, UPDATE and DELETE.

The insertion operation is very intuitive. However, if the table contains certain constraints such as “primary key”, “unique key”, “not null”, then the student might have problem if the new row violates some constraint

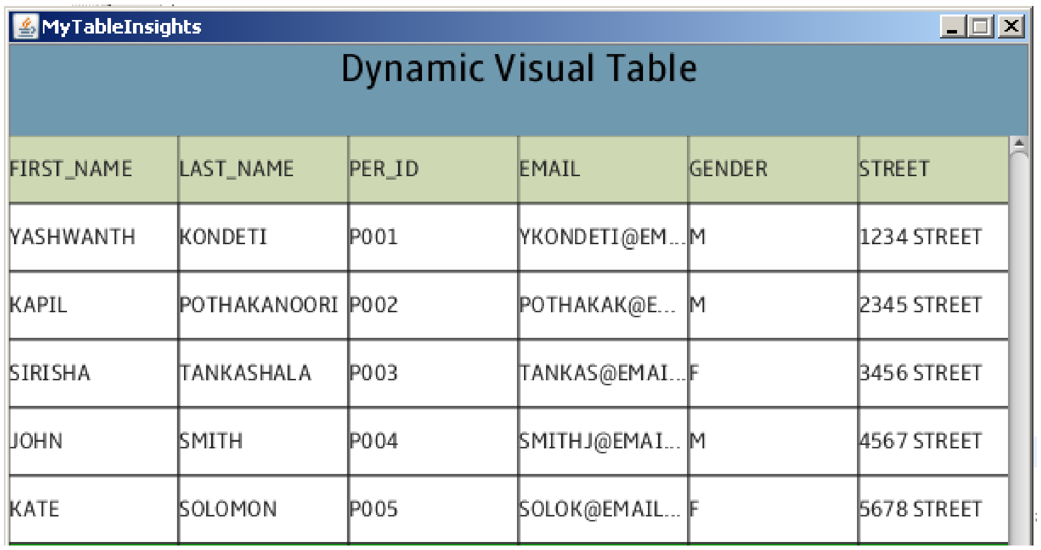
Example 2:

Consider the following statement which inserts a new row into the “person” table.

```
INSERT INTO person
VALUES ('PETER', 'SOLOMON', 'P001', 'SOLOP@EMAIL.COM', 'M', '6789 STREET ',
'MEMPHIS', 'TN', 'J006')
```

The person table has PRIMARY KEY constraint on the per_id field. Therefore, the new row’s “per_id” column’s value has to be a unique key in the person table. Thus, assuring uniqueness of the per_id value is the key criterion for successful insertion. To address these common issues, we have visually interpreted the table and supported viewing all the rows and the columns. With this information, the student will be able to understand a rejection decision and make considerable changes to the query on the fly.

When the students execute the above statement, the database returns execution failure result and the dynamic visual tool provides the following information for the students to reason out the failure of execution of the above statement.



MyTableInsights

Dynamic Visual Table

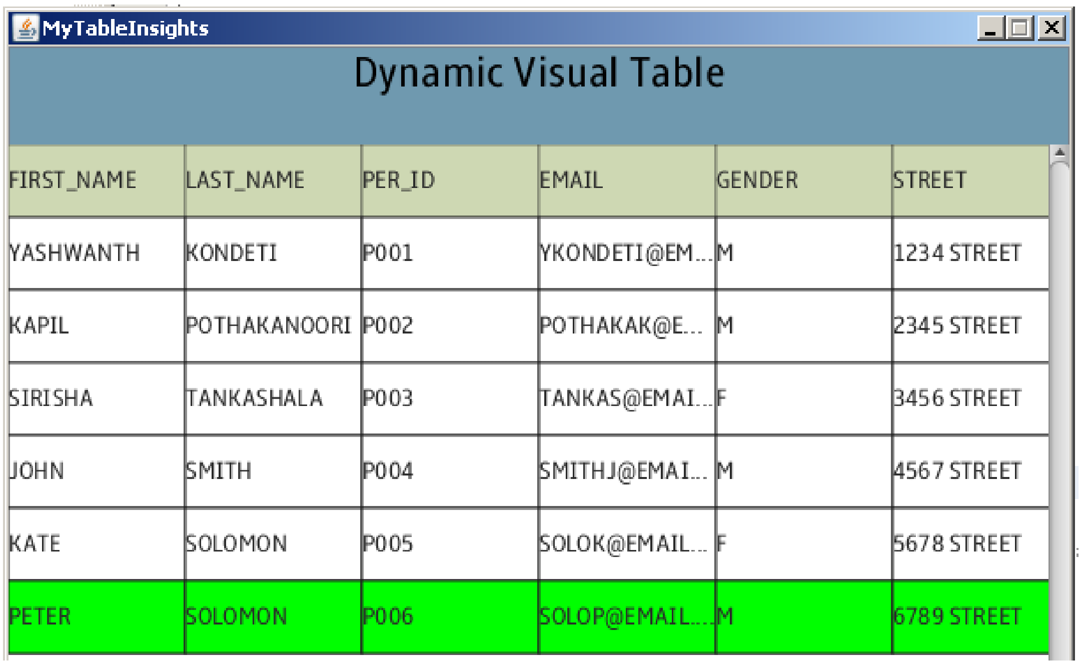
FIRST_NAME	LAST_NAME	PER_ID	EMAIL	GENDER	STREET
YASHWANTH	KONDETI	P001	YKONDETI@EM...	M	1234 STREET
KAPIL	POTHAKANOORI	P002	POTHAKAK@E...	M	2345 STREET
SIRISHA	TANKASHALA	P003	TANKAS@EMAI...	F	3456 STREET
JOHN	SMITH	P004	SMITHJ@EMAI...	M	4567 STREET
KATE	SOLOMON	P005	SOLOK@EMAIL...	F	5678 STREET

Figure 2

By examining the above information it is clear that the “per_id” value in the new row that we are trying to insert is already present in the table. Therefore, we need to verify the “per_id” values from the database and provide a new value for the new row we are trying to insert. After making the following required modification to the values of the INSERT statement we re-execute the INSERT statement to insert the new row.

```
INSERT INTO person
VALUES ('PETER', 'SOLOMON', 'P006', 'SOLOP@EMAIL.COM', 'M', '6789 STREET ',
'MEMPHIS', 'TN', 'J006')
```

The execution of the above statement will result a success notification from the database and following information is displayed by the visual tool. The highlighted row clearly identifies the newly inserted row in the table.



FIRST_NAME	LAST_NAME	PER_ID	EMAIL	GENDER	STREET
YASHWANTH	KONDETI	P001	YKONDETI@EM...	M	1234 STREET
KAPIL	POTHAKANOORI	P002	POTHAKAK@E...	M	2345 STREET
SIRISHA	TANKASHALA	P003	TANKAS@EMAI...	F	3456 STREET
JOHN	SMITH	P004	SMITHJ@EMAI...	M	4567 STREET
KATE	SOLOMON	P005	SOLOK@EMAIL...	F	5678 STREET
PETER	SOLOMON	P006	SOLOP@EMAIL...	M	6789 STREET

Figure 3

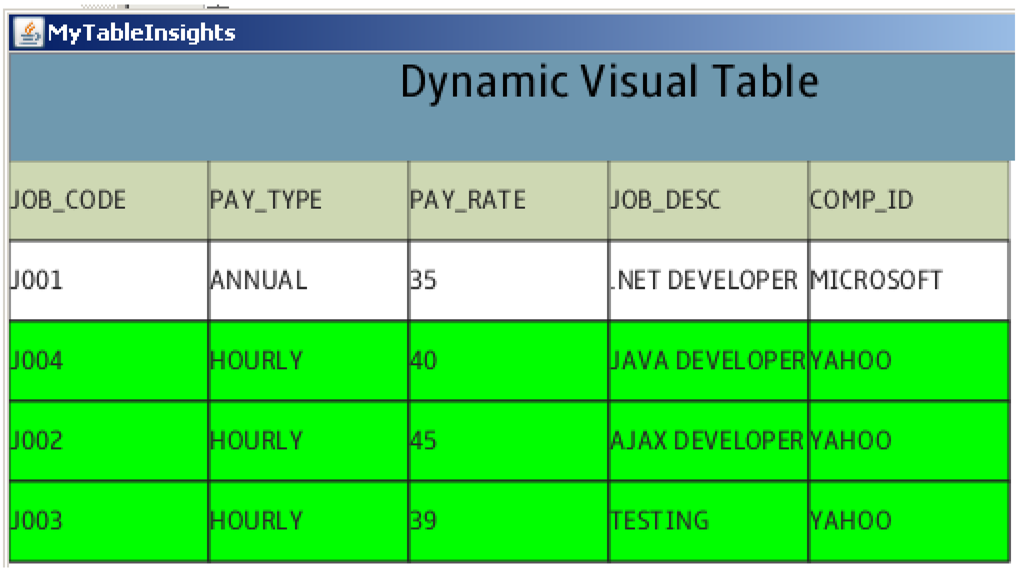
Example 3:

Now, we consider the UPDATE operation. The SQL statement in this example updates the pay_type field of a job in a company. Here we use the UPDATE statement which requires the table name, the column name, and the row selection criteria.

```
UPDATE job
SET pay_type=’HOURLY’
WHERE comp_id = ‘YAHOO’
```

This query update all the rows in the table which satisfy the row selection criteria and sends back a success notification. Our goal is to visually interpret the data manipulation operations that are performed on the table by the UPDATE statement. To achieve this goal we display the complete table with all the records and highlight all the updated data in the specified column which makes it easy for the user to identify the updated data among other records.

The following snapshot shows the representation of data that has been updated in the table.



Dynamic Visual Table

JOB_CODE	PAY_TYPE	PAY_RATE	JOB_DESC	COMP_ID
J001	ANNUAL	35	.NET DEVELOPER	MICROSOFT
J004	HOURLY	40	JAVA DEVELOPER	YAHOO
J002	HOURLY	45	AJAX DEVELOPER	YAHOO
J003	HOURLY	39	TESTING	YAHOO

Figure 4

The highlighted data clearly identifies the data that has been updated by the query.

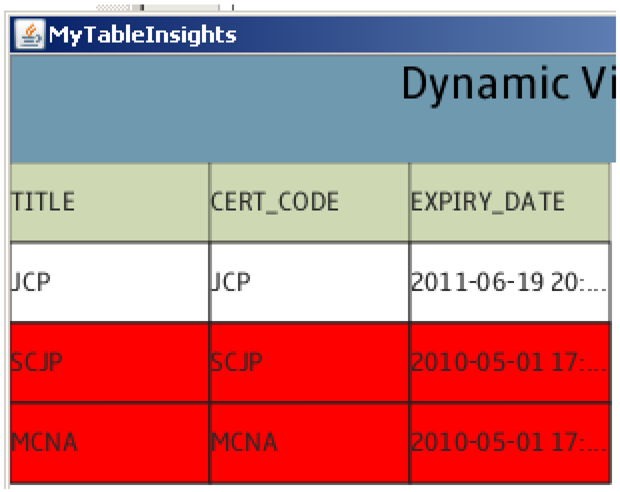
A DELETE statement can be applied on a table to delete obsolete or unwanted data from the table. If the student is unaware of the required constraints to delete the obsolete data then a disastrous result can happen.

Example 4:

Consider the following delete statement which deletes all the expired certificates from the certificate table.

DELETE certificate WHERE expiry_date < ’08-18-10’

This query deletes all the records whose expiration dates are earlier than 08-18-10. In order to interpret this operation visually we highlight all the deleted records in the table and these deleted records are shown along with the remaining records in the table. This makes it easy for the student to understand the records which are deleted. The following snapshot shows the visual representation of data that has been deleted in the table. The highlighted data clearly identifies the data that has been deleted by the query.



TITLE	CERT_CODE	EXPIRY_DATE
JCP	JCP	2011-06-19 20:...
SCJP	SCJP	2010-05-01 17:...
MCNA	MCNA	2010-05-01 17:...

Figure 5

3.3 Visualization of Communication Messages

In addition to the visual tool showing the query results, we have also developed an animation component to visualize the messages in communication channels. The animation component is to help students explore the message contents communicated between components in a system.

Databases typically serve as the back end of information systems. In modern database applications, users' requests and query results are passing through multiple components in multiple tiers by messages. For a learner, viewing the contents of the messages can often assist his/her analysis in critical thinking. We have designed a module specifically for this purpose. This module can carry out animations that dynamically display the contents of the selected message and reflect any changes.

In order to achieve this goal we have designed a FLASH based module which visually represents the working software system structure and dynamically updates the messages that are used for communication between the applications.

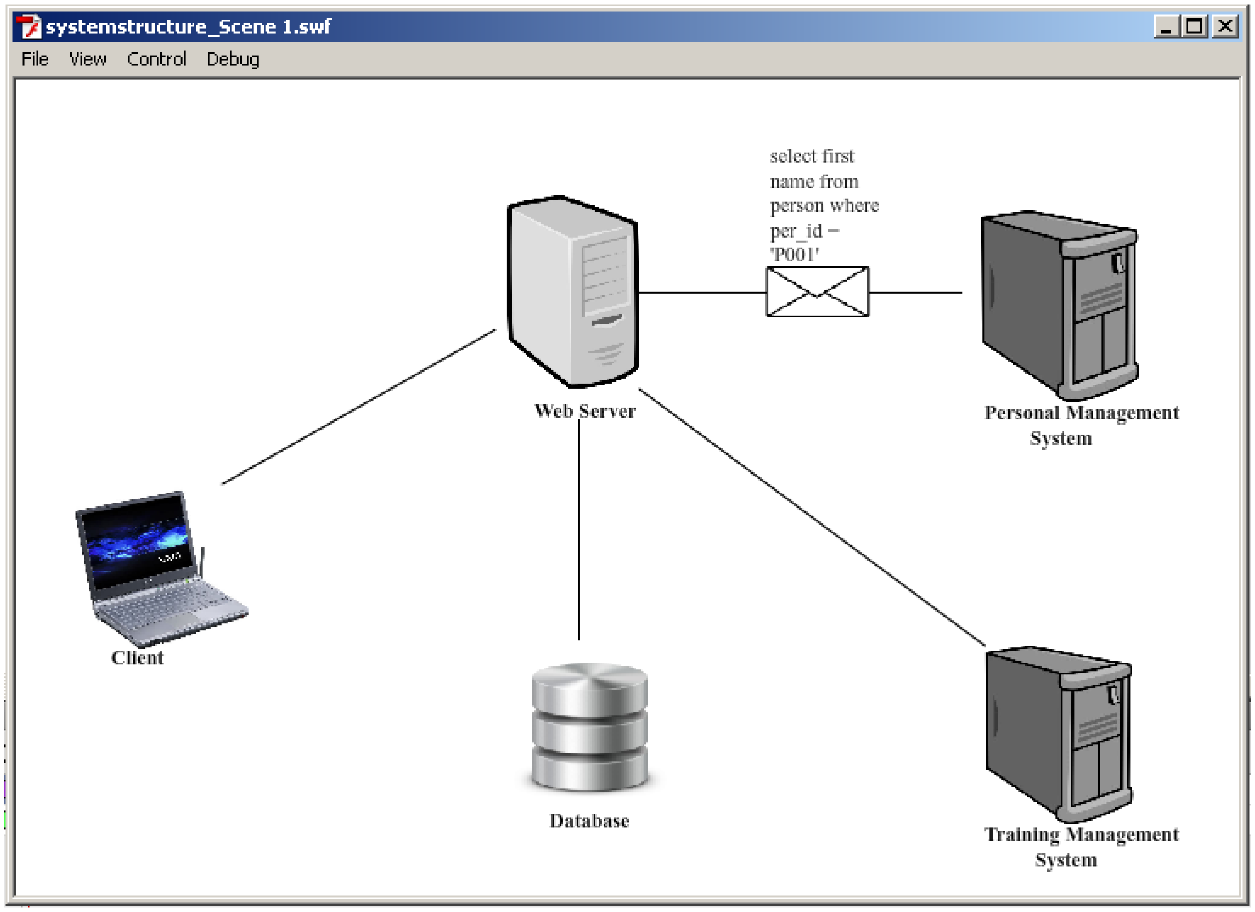
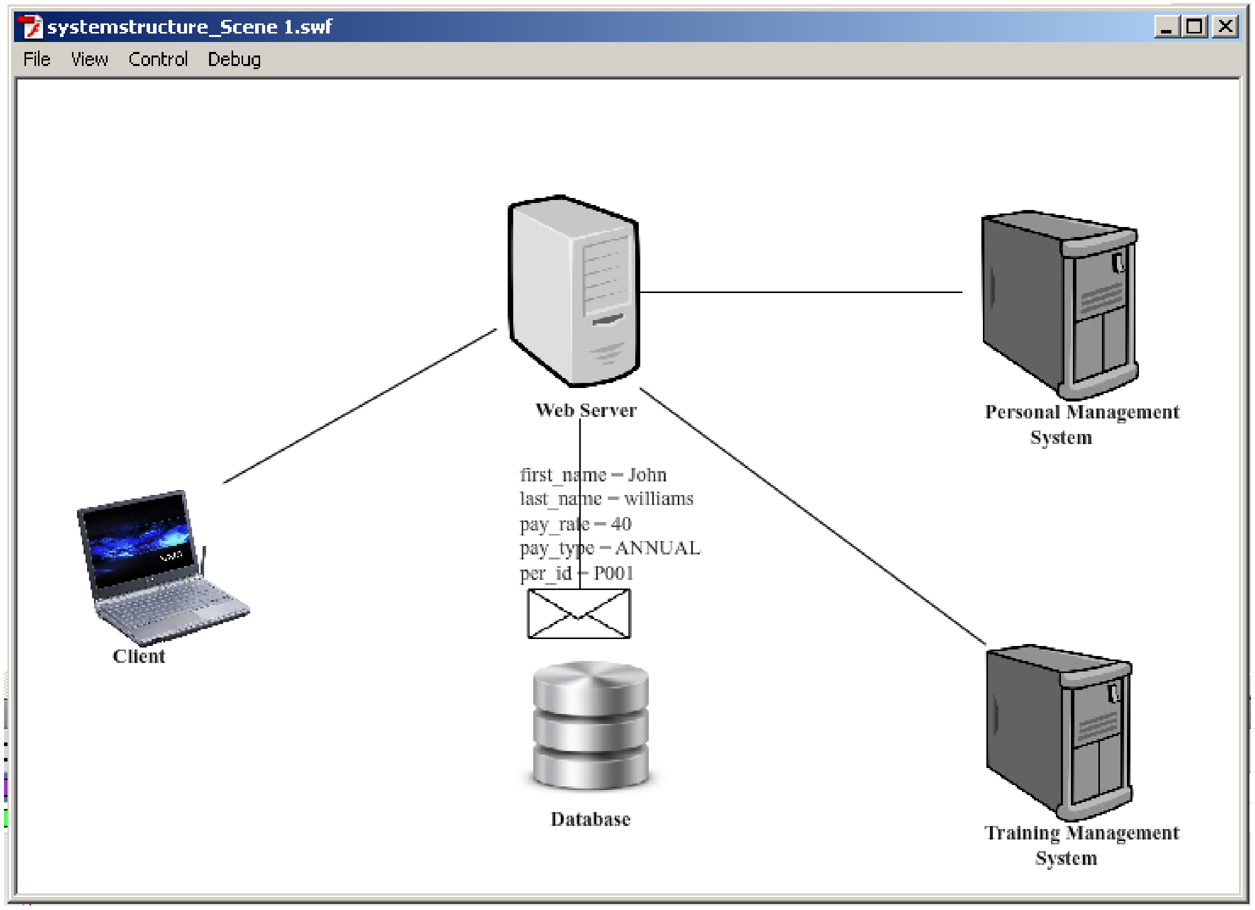

systemstructure_Scene 1.swf
File View Control Debug
select first name from person where per_id = 'P001'
Web Server
Personal Management System
Client
Database
Training Management System

Figure 6

The communication between these components is shown by a flying envelop carrying the messages between these components. The message which is carried by the envelope is dynamically generated, so any real time communications are reflected over the envelope. This feature makes it easy to track the query requests that are sent to the database and the results returned by the database to the client systems. In our project we have used a “flying envelope” to interpret the communication. This envelope carries messages which are dynamically updated.


systemstructure_Scene 1.swf
File View Control Debug
Web Server
Personal Management System
Client
Database
Training Management System

first_name – John
last_name – williams
pay_rate – 40
pay_type – ANNUAL
per_id – P001

Figure 7

The animation is achieved using the Action Script 3.0 scripting language provided by Adobe Flash Professional. Action Script 3.0 thoroughly follows the concepts of object oriented programming styles which makes it easier to code such kind of complex operations.

4. Implementation of Data Visualization

In the implementation of Data visualization, there are two critical operations:

a. To extract the meta data required from the SQL query

b. To extract the key values needed to be highlighted

The meta data of an SQL query is used to display the column names of the table and highlight the result of the query in the dynamic visual tool. To extract this meta data we have created a “QueryParser” class which takes the SQL query as a parameter and extract’s the required meta data. This query parser is designed to parse four important SQL statements, namely the SELECT, INSERT, UPDATE and DELETE statements.

4.1 Implementation of Visualization of Data Manipulation in Database

INSERT, UPDATE and DELETE are the three data manipulation operations that our tool visualizes. A precondition for doing visualization is to collect the proper set of information for each statement from the database. In section 4.1.1 through 4.1.3, we have described this information collection process for the three statements. In section 4.1.4 we have described the actual visualization.

4.1.1 Insert

We have used simple string manipulation functions such as substring and indexOf to extract the table names and the values in the INSERT statement. These values serve as key values for our visual tool. The following shows the implementation,

```
    //code to extract thee table name from the INSERT statement
1.  if( query.indexOf(" ", query.indexOf("INTO") + 5) < query.indexOf("(",
    query.indexOf("INTO") + 5) ) {
2.          tablename = query.substring(query.indexOf("INTO") + 5, query.indexOf(" ",
    query.indexOf("INTO") + 5));
3.  } else {
4.          tablename = query.substring(query.indexOf("INTO") + 5, query.indexOf("(",
    query.indexOf("INTO") + 5));
5.  }

    //create a new query which is later used to display the data present in the table
6.  modquery = "SELECT * FROM {tablename} ";

    //code to extract the values that are being inserted into the table, these values //serve //as the
    key values which are later highlighted in the visual tool
7.  var temp:String = query.substring(query.indexOf("VALUES"));
8.  temp = temp.substring( temp.indexOf("(") + 1, temp.indexOf(")") );
9.  var tmparry:String [] = temp.split(",");
10. var tempkeyvalues = KeyValues{};
11. for(i in tmparry) {
12.         insert i into tempkeyvalues.keyvalue;
13.         tempkeyvalues.trimLastValue();
    }

    //store the newly extracted key values in a global variable which is later accessed //to
    highlight the critical data
14. insert tempkeyvalues into keyvalues;
```

Figure 8

The code in Figure 8 extracts the table name and the key values from the query. The key values are stored in a global “keyvalues” variable which is later used to highlight the newly inserted row. The following steps describe more about the code in Figure 8,

Step 1: The code from line 1-5 extracts the table name from the INSERT statement

Step 2: In line 6, we create a new query which is used to display the data present in the table

Step 3: The code from 7-10 will extract the values of newly inserted row, which are used as key values during the visualization of INSERT statement.

Step 4: The code from 11-13 will format the key values and store them in a temporary array, which is later stored in a global variable in line number 14.

4.1.2 Update

The interpretation of the UPDATE statement was relatively simple compared to the INSERT statement. After extracting the table name from the SQL query using simple string manipulation functions, we need to search and extract the WHERE clause in the update statement. This WHERE clause plays the crucial role in extracting the key values that are needed to be highlighted. Using this WHERE clause we create a new SELECT statement that is applied on the table. The result that we obtain after applying this new query on the table is the key values that are necessary for our visual tool. This result is stored in our global "keyvalues" variable which is later accessed to highlight the newly updated row(s).

The following code shows the implementation of the above,

```
    //code to extract the table name from the UPDATE statement
1.  tablename = query.substring(query.indexOf("UPDATE") + 7, query.indexOf(" ",
    query.indexOf("UPDATE") + 7));

    //create a new query which is later used to display the data present in the //table
2.  modquery = "SELECT * FROM {tablename} ";

    //we need to extract the WHERE clause used by the UPDATE statement which is later //used to
    retrieve the key values from the database
3.  if(query.indexOf("WHERE") != -1){
```

(figure continued)

```
    // create a new query using the WHERE clause
4.          newquery = "SELECT * FROM {tablename}
           {query.substring(query.indexOf("WHERE"))}";
5.  } else {
6.          newquery = "SELECT * FROM {tablename}";
    }


    //use the newly created query to extract the key values from the database
7.  var rs=da.processDBQuery(newquery);
8.  var rsmd = rs.getMetaData();
9.  while(rs.next()) {
10.        var tempkeyvalues = KeyValues{};
11.        for(i in [1..rsmd.getColumnCount()]) {
12.                var val = rs.getString(i);
13.                if(val == null)
            val = "null";
14.         insert val into tempkeyvalues.keyvalue;
            }

    //store the newly extracted key values in a global variable which is later accessed to //highlight the
    critical data
15. insert tempkeyvalues into keyvalues;
    }
```

Figure 9

In Figure 9, the method of extracting the table name from the query is similar to that of INSERT statement. The process of extracting the key values is different, the following steps give an explanation.

Step 1: The UPDATE statement only updates the values which satisfy the criteria specified in the WHERE clause, so to obtain the key values in this case we extract the WHERE clause from the UPDATE statement from line 3-6

Step 2: Using the WHERE clause extracted in previous step we create a new SELECT statement in line 4/6 which is used to extract key values from the database in line 7-14

Step 3: Finally, after storing the key values in a global variable in line 15, we can now use these key value to perform visualization

4.1.3 Delete

The interpretation of DELETE statement is similar to that of the implementation of UPDATE statement. The only major difference is that the key values in this case are extracted from a backup table keeps a backup of the table on which the DELETE statement was applied.

The following code shows the implementation of DELETE statement,

```
    //code to extract the table name from the DELETE statement
1.  tablename = query.substring(query.indexOf("DELETE") + 7, query.indexOf(" ",
    query.indexOf("DELETE") + 7));

    //delete rows are backed up a backup table, therefore we use the //backup //table //rather than
    the original table
2.  tablename = "{tablename}BACKUP001";


    //create a new query which is later used to display the data present in the table
3.  modquery = "SELECT * FROM {tablename} ";

    //we need to extract the WHERE clause used by the UPDATE statement which is //later
    //used to retrieve the key values from the database
4.  if(query.indexOf("WHERE") != -1){

    // create a new query using the WHERE clause
5.  newquery = "SELECT * FROM {tablename}
    {query.substring(query.indexOf("WHERE"))}";
6.  } else {
7.          newquery = "SELECT * FROM {tablename}";
    }
```

(figure continued)

```
var rs=da.processDBQuery(newquery);
var rsmd = rs.getMetaData();
while(rs.next()) {
        var tempkeyvalues = KeyValues{};
        for(i in [1..rsmd.getColumnCount()]) {
                var val = rs.getString(i);
                if(val == null)
                      val = "null";
        insert val into tempkeyvalues.keyvalue;
}

//store the newly extracted key values in a global variable which is later accessed to //highlight the
critical data
insert tempkeyvalues into keyvalues;
}
```

Figure 10

In Figure 10, the method of information collection for the DELETE statement is identical to that of UPDATE statement. The difference is that we make use a backup table instead of the target table in order to extract the key values from the target table. The backup table is the table which contains all the values that were deleted from the target table.

4.1.4 JavaFX Code For Visualization

After obtaining the required data for visualization of data manipulation operations by following any of the previous methods, we perform visualization by highlighting the crucial data from the rest of the rows present in the table. This crucial data will help the students in making critical decisions and brainstorming their understanding of database during the learning cases. The Figure 11 shows the implementation of visualization,

```
// this function compares the values of every row with the key values that were extracted earlier

public class DataCell extends HeaderCell {
        public var notifyData = bind data on replace {
            if(index.size() == 0) {
                //search all the keyvalues for a matching data
                for(tempkv in QueryParser.keyvalues) {
                    //if found then set match = true and load the current row into the key and set index = 1
                    if(tempkv.keyvalue[0] == notifyData){
                        keysize = tempkv.keyvalue.size();
                        insert tempkv into key;
                        insert 1 into index;
                    }
            } else {
                //if key[index] == notifyData then set match = true and index++
                var i:Integer = 0;
                for(tempkv in key) {
                    if(tempkv.keyvalue[index[i]] == notifyData){
                        index[i]++;
                    }
                    i++;
                }
            }
        }

//after searching a row to see if it contains any crucial data that need to be highlighted we call the
//following function to reset variables before searching the next row

public function resetGlobalVariables() {
        delete index;
       delete key;
       keysize = -1
}

//this function is crucial in taking the decision to highlight a row in the presented table

public function colorRow():Boolean {
        for(tempindex in index){
//check if all the values in this row have matched with the key values
            if(keysize == tempindex) {
                resetGlobalVariables();
                return true;
            }
        }
        resetGlobalVariables();
        return false;
}
```

Figure 11

In Figure 11, the logic is simple,

Step 1: The code section 2-19 will search every row of the table and tries to compare these values with the key values.

Step 2: After comparing all the values of a row in the previous step, the code section from 25-34 checks if all the values in this row have matched

Step 3: If all the values match in the previous step then it returns "true" when the function is called. Then we can externally set the color of the row with a simple boolean value.

Step 4: The code section from 20-24 resets the temporary variables which were used to validate a row with key values. These variables can now be used to validate the next row.

4.2 Implementation of Visualization of Data Retrieved from Database

To identify the data that have been retrieved from the database among the rest of the table, we highlight each of the rows that satisfy the selection criteria.

Implementation of visualization of data retrieved from database is the complicated and important part of the "QueryParser" class. Parsing SELECT statements is not as simple as parsing the data manipulation statements. The string manipulation functions available in JavaFX are not sufficient to parse SELECT statements. To be able to parse SELECT statements we make use of the tools available in the database. The EXPLAIN PLAN[1] utility in the Oracle database is used to structurally break down any SELECT statement. We use this information to obtain the required meta data from the SELECT statement. The sequence of SQL statements shown in Figure 12 breaks down any complex SELECT statement and extract the meta data, from which, we can retrieve the table name, selected column names, and the key values.

[1] http://download.oracle.com/docs/cd/B10500_01/server.920/a96533/ex_plan.htm

```
1.  DELETE query_parser

2.  EXPLAIN PLAN into query_parser for
    SELECT person.first_name, person.last_name
    FROM  person, job
    WHERE person.job_code = job.job_code
    ORDER BY first_name

3.  SELECT projection, object_alias
    FROM query_parser
    WHERE object_alias!='null' AND projection!='null'
    ORDER BY object_instance
```

Figure 12

The code in Figure 13 shows the implementation of the above,

```
//create new query which is used to retrieve the data present in the table
newquery = "SELECT * {query.substring(query.indexOf("FROM"))}";

//create a modified query to retrieve the key values from the table
modquery = "SELECT * {orgquery.substring(query.indexOf("FROM"))}";

//code to preserver the WHERE, GROUP, ORDER BY clauses in the modified query
if(query.indexOf("WHERE")!=-1){
        if((query.indexOf("GROUP")==-1 and query.indexOf("ORDER")!=-1) or
         (query.indexOf("ORDER")!=-1 and ( query.indexOf("ORDER") <
         query.indexOf("GROUP") ) )){
                modquery = "{modquery.substring(0, query.indexOf("WHERE") - (query.length() -
modquery.length()))} {modquery.substring(query.indexOf("ORDER") –
(query.length() - modquery.length()))}";
 }

else if((query.indexOf("ORDER")==-1 and query.indexOf("GROUP")!=-1) or
query.indexOf("GROUP")!=-1 and ( query.indexOf("ORDER") >
query.indexOf("GROUP") )){
        modquery = "{modquery.substring(0, query.indexOf("WHERE"))}
{modquery.substring(query.indexOf("GROUP"))}";
} else {
         modquery = "{modquery.substring(0,
        (modquery.toUpperCase()).indexOf("WHERE"))}";
```

(figure continued)

```
   }
}

//retrieve the key values from the database using the modified query
var rs=da.processDBQuery(newquery);
var rsmd = rs.getMetaData();
while(rs.next()) {
     var tempkeyvalues = KeyValues{};
     for(i in [1..rsmd.getColumnCount()]) {
            insert rs.getString(i) into tempkeyvalues.keyvalue;
  }

//store the key values in a global variable which is accessed later to highlight the critical //data
insert tempkeyvalues into keyvalues;

}

//use the EXPLAIN PLAN database tool to structurally break down the query and retrieve //all the
columns names of the table
da.processDBQuery("delete query_parser");
da.processDBQuery("explain plan into query_parser for {modquery}");
rs=da.processDBQuery("select projection from query_parser where operation='TABLE ACCESS'
order by object_instance");
while(rs.next()) {
      var temp = rs.getString(1);
      var pattern = Pattern.compile("\"");
      var matcher = pattern.matcher(temp);
      if(matcher.find())  {
              temp = matcher.replaceAll("");
       }

//code to format the retrieved columns names
     pattern = Pattern.compile("\\s*" );
     matcher = pattern.matcher(temp);
     if(matcher.find())  {
          temp = matcher.replaceAll("");
     }
      pattern = Pattern.compile("\\]," );
     var tempcolnames = pattern.split(temp);
     for(colname in tempcolnames){
           pattern = Pattern.compile("\\[.*" );
           matcher = pattern.matcher(colname);
           if(matcher.find())  {
                 insert matcher.replaceAll("") into colnames;
           }
      }
}

//again use the EXPLAIN PLAN database tool to structurally break down the original query and
```

(figure continued)

```
//retrieve the key column names that were requested by the original query
da.processDBQuery("delete query_parser");
da.processDBQuery("explain plan into query_parser for {orgquery}");
rs=da.processDBQuery("select projection, object_alias from query_parser where

object_alias!='null' AND projection!='null' order by object_instance");
while(rs.next()) {

//properly format the retrieved key column names
    var temp = rs.getString(1);
    var tablename = rs.getString(2);
    tablename = tablename.substring(0, tablename.indexOf("@")) ;
    var pattern = Pattern.compile("\"");
    var matcher = pattern.matcher(temp);
    if(matcher.find())  {
          temp = matcher.replaceAll("");
     }
     pattern = Pattern.compile("\\s*" );
     matcher = pattern.matcher(temp);
      if(matcher.find())  {
           temp = matcher.replaceAll("");
       }
        pattern = Pattern.compile("\\]," );
        var tempcolnames = pattern.split(temp);
        for(colname in tempcolnames) {
              pattern = Pattern.compile("\\[.*" );
             matcher = pattern.matcher(colname);
             if(matcher.find())  {
                   temp = matcher.replaceAll("");
                   pattern = Pattern.compile("\\." );
                   matcher = pattern.matcher(temp);
                        if(matcher.find()!=true){
                              insert "{tablename}.{temp}" into keycolnames;
                              }  else {

//store these key column names in a global variable which is later accessed to highlight the //critical
data
                              insert temp into keycolnames;
                                  }
                          }
             }
}
```

Figure 13

The Figure 13 shows the raw JavaFX code used to parse the SELECT statement; the following steps give a more detailed explanation of the logic executed by the code:

Step 1: the code section from 3-12 will create a new query which we use to retrieve key values from database. Besides, the WHERE clause, the ORDER BY, GROUP clause can also be applied on SELECT statement. This code will preserve all these clauses in order to extract the key values.

Step 2: the code section from 13-19 will use the query created in Step 1 to retrieve the key values and store the values in a global variable in line 20.

Step 3: Along with the key values, we also need the column names that are associated with each table in original query. To find the column names, the code section from 22-24 will extract the column names of all the tables that were referred in the original query using the EXPLAIN PLAN tool. These column names are properly formatted and stored in a global variable from line 25-43.

Step 4: We also need the key column names that were requested in the original query in order to highlight the specific data that was requested by the query. To find the key column names, the code section from 44-46 is executed. These column names are properly formatted and stored in a global from line 47-77.

By following the above four steps we have collected the required meta data to visually represent the SELECT statement. The JavaFX code for actual visualization is similar to that in section 4.1.4.

4.3 Implementation of Visualization of Communication Messages

The communication messages in this project are visualized in Adobe's FLASH environment. The static diagram which represents the structural design of this project is purely implemented in FLASH, but the communication messages which are carried by the flying envelop between any two applications is mixed with both static and dynamic content. The motion between the applications is defined using the motion tweening feature available in FLASH.

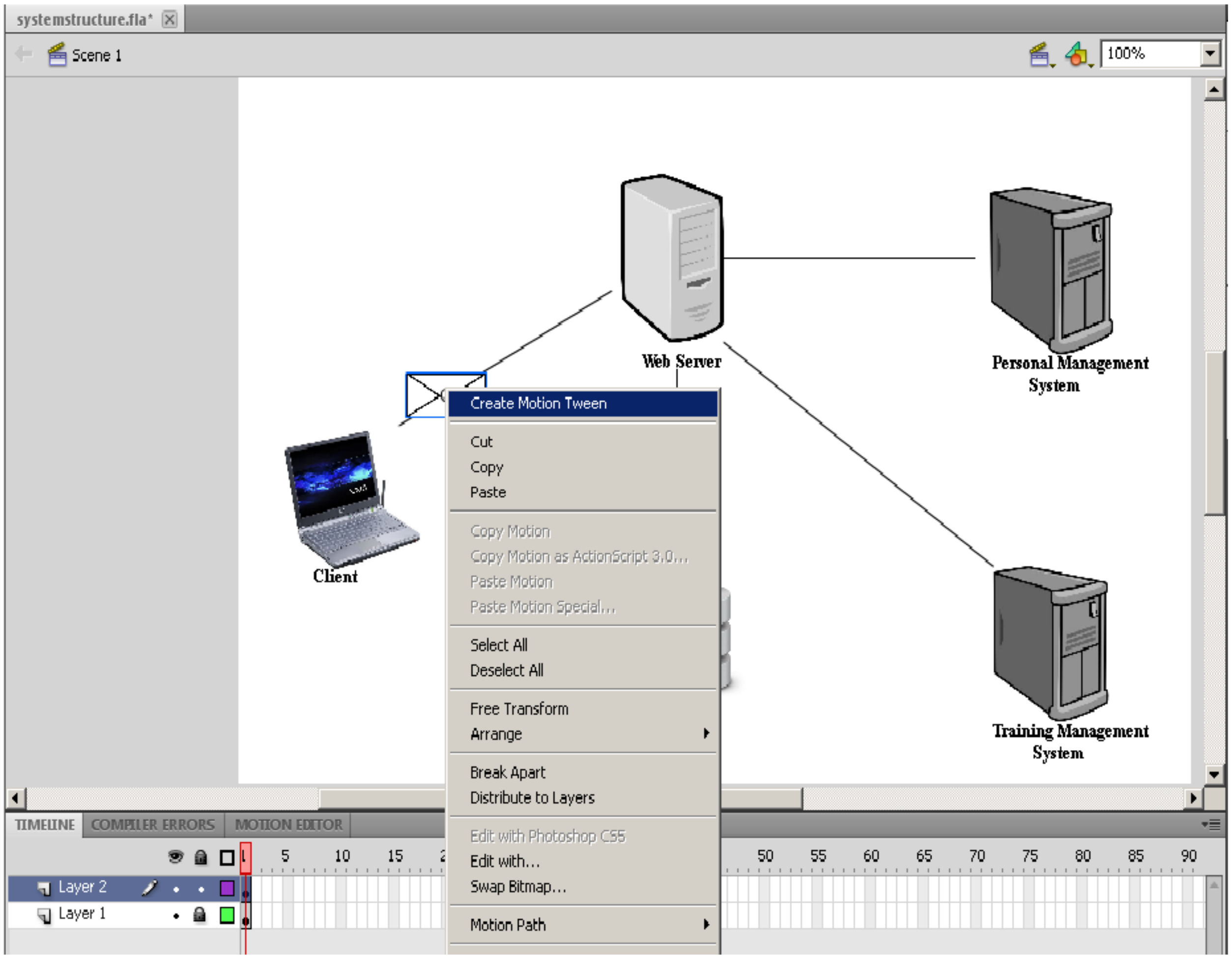


Figure 14

In order to make this static content carry a dynamic message we need to access this motion tween at the code level. So we convert this motion into the Action Script 3.0 code.

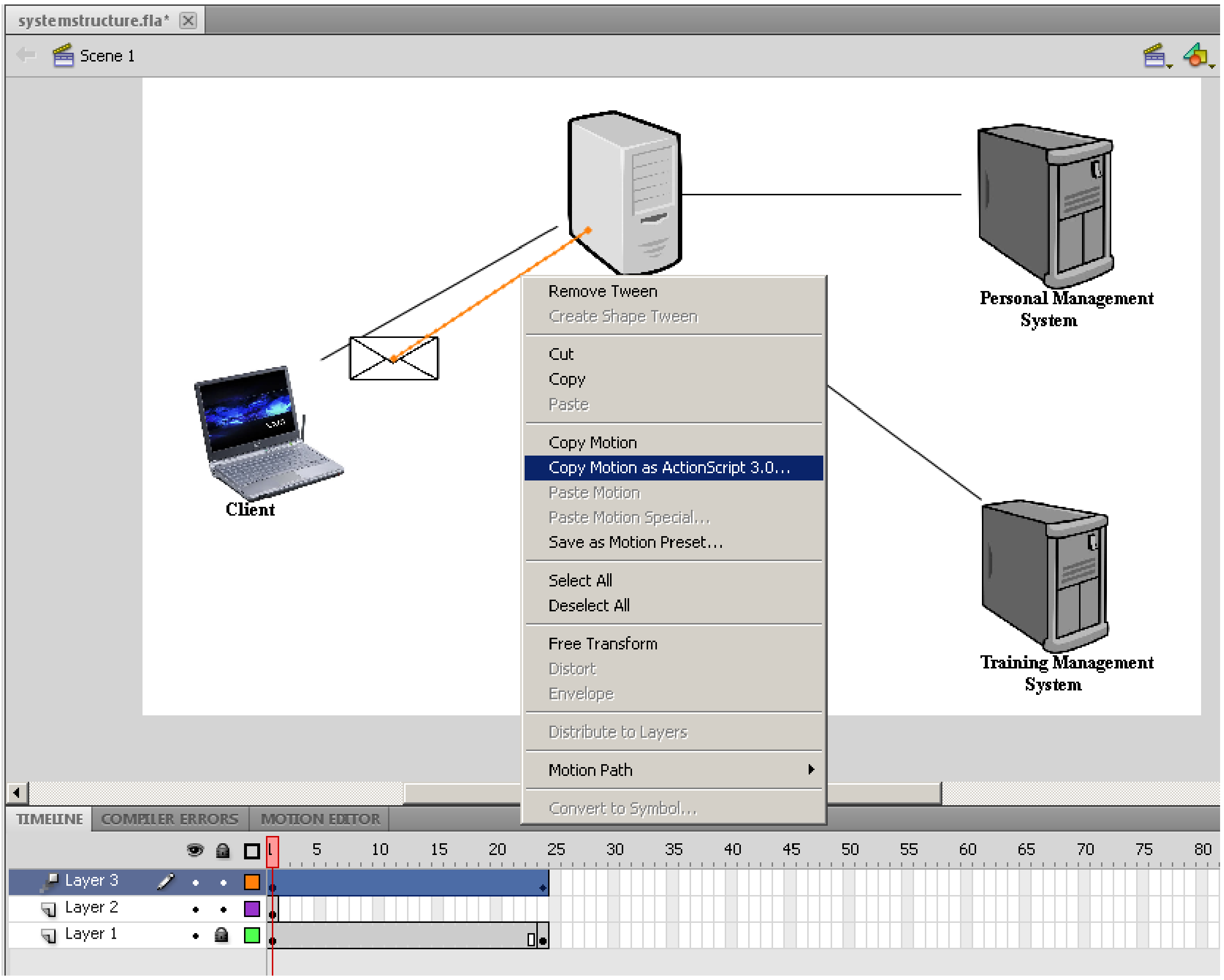


Figure 15

After obtaining the code to perform motion, we can make use of the code to move any object on the same path. We have taken the advantage of this feature and apply this technique on textual objects to make them move along with the flying envelop. Figure 15 illustration an example of such implementation.

```
1.  var __motion_envelop_3:MotionBase;
2.  if(__motion_envelop_3 == null) {
3.  __motion_envelop_3 = new Motion();
4.  __motion_envelop_3.duration = 90;

    // Call overrideTargetTransform to prevent the scale, skew,
    // or rotation values from being made relative to the target
    // object's original transform.
    // __motion_envelop_3.overrideTargetTransform();

    // The following calls to addPropertyArray assign data values
    // for each tweened property. There is one value in the Array
    // for every frame in the tween, or fewer if the last value
    // remains the same for the rest of the frames.
5.  __motion_envelop_3.addPropertyArray("x",
    [0,2.53933,5.07865,7.61798,10.1573,12.6966,15.236,17.7753,20.3146,22.8539,25.3933,27.9
    326,30.4719,33.0112,35.5506,38.0899,40.6292,43.1685,45.7079,48.2472,50.7865,53.3258,5
    5.8652,58.4045,60.9438,63.4831,66.0225,68.5618,71.1011,73.6404,76.1798,78.7191,81.258
    4,83.7978,86.3371,88.8764,91.4157,93.9551,96.4944,99.0337,101.573,104.112,106.652,109
    .191,111.73,114.27,116.809,119.348,121.888,124.427,126.966,129.506,132.045,134.584,13
    7.124,139.663,142.202,144.742,147.281,149.82,152.36,154.899,157.438,159.978,162.517,1
    65.056,167.596,170.135,172.674,175.213,177.753,180.292,182.831,185.371,187.91,190.449
    ,192.989,195.528,198.067,200.607,203.146,205.685,208.225,210.764,213.303,215.843,218.
    382,220.921,223.461,226]);
6.  __motion_envelop_3.addPropertyArray("y", [0,-4.89831,-9.79663,-14.6949,-19.5933,-
    24.4916,-29.3899,-34.2882,-39.1865,-44.0848,-48.9831,-53.8815,-58.7798,-63.6781,-
    68.5764,-73.4747,-78.373,-83.2713,-88.1697,-93.068,-97.9663,-102.865,-107.763,-112.661,-
    117.56,-122.458,-127.356,-132.254,-137.153,-142.051,-146.949,-151.848,-156.746,-
    161.644,-166.543,-171.441,-176.339,-181.238,-186.136,-191.034,-195.933,-200.831,-
    205.729,-210.628,-215.526,-220.424,-225.322,-230.221,-235.119,-240.017,-244.916,-
    249.814,-254.712,-259.611,-264.509,-269.407,-274.306,-279.204,-284.102,-289.001,-
    293.899,-298.797,-303.696,-308.594,-313.492,-318.39,-323.289,-328.187,-333.085,-
    337.984,-342.882,-347.78,-352.679,-357.577,-362.475,-367.374,-372.272,-377.17,-382.069,-
    386.967,-391.865,-396.763,-401.662,-406.56,-411.458,-416.357,-421.255,-426.153,-
    431.052,-435.95]);
7.  __motion_envelop_3.addPropertyArray("scaleX", [0.225891]);
8.  __motion_envelop_3.addPropertyArray("scaleY", [0.145889]);
9.  __motion_envelop_3.addPropertyArray("skewX", [0]);
10. __motion_envelop_3.addPropertyArray("skewY", [0]);
11. __motion_envelop_3.addPropertyArray("rotationConcat", [0]);
```

(figure continued)

```
12. __motion_envelop_3.addPropertyArray("blendMode", ["normal"]);
13. __motion_envelop_3.addPropertyArray("cacheAsBitmap", [false]);

    // Create an AnimatorFactory instance, which will manage
    // targets for its corresponding Motion.
14.   var __animFactory_envelop_3:AnimatorFactory = new
      AnimatorFactory(__motion_envelop_3);
15.    __animFactory_envelop_3.transformationPoint = new Point(0.545742, 0.597940);

    // Call the addTarget function on the AnimatorFactory
    // instance to target a DisplayObject with this Motion.
    // The second parameter is the number of times the animation
    // will play - thae default value of 0 means it will loop.
16.   __animFactory_envelop_3.addTarget(envelop1, 0);
17.   __animFactory_envelop_3.addTarget(text1, 0);
 18.  envelop1.alpha = 0.5;
 19. text1.alpha = Flash2GlobalVariables.alphavalue;
20. }
```

Figure 16

The function **__animFactory_envelop_3.addTarget();** is called at line 17 to add motion of textual objects. At this point, we can add any object to follow the same animation path. These textual messages are dynamically loaded during runtime which shows the communication messages between working software systems. This process is repeated for all the messages that need to be passed between any two entities.

5. Applying Data Visualization in Database Studies

We need a working software system to demonstrate the VDL model in real time. For this purpose we have chosen a personnel and training management system,

5.1 Description of the Database Application System

The Personnel Training System is a Web based system which maintains all the details regarding the employee's skills, certificates, projects, and companies and properly shows the required skills for an employee to be placed in a project. This Web based system is backed up by a database to store the details regarding the employee's & companies which gives us the opportunity to turn this system into an efficient learning system.

A personnel training system collects the working skills of employee's and finds the missing skills in each employee to provide them with proper training. Once the employee has all the skills required according to industry standards the employee is placed in an appropriate company. We have simplified this system. The following diagram provides an overview of the Web based system,

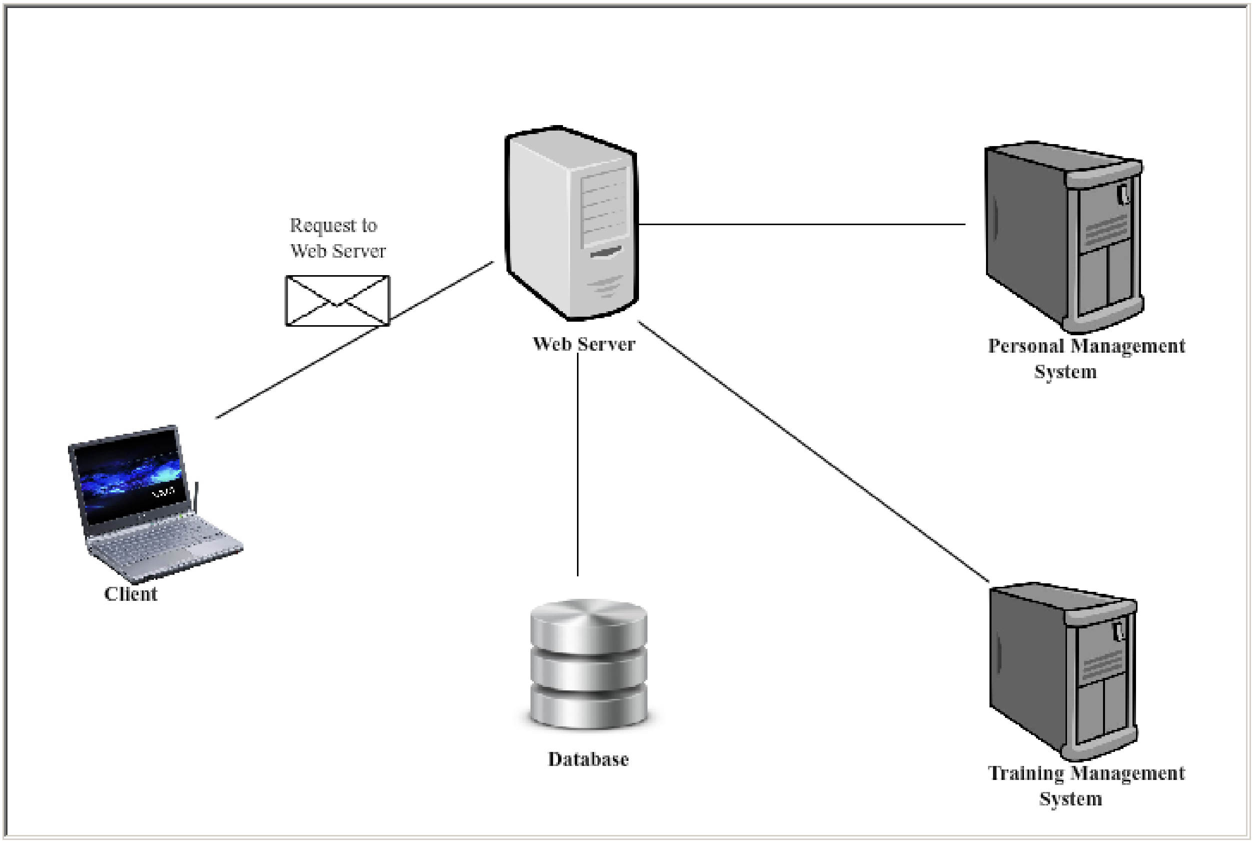


Figure 17

The considered database serves two subsystems namely the personnel system and the training system.

The personnel system manages information of persons and organizations that hold jobs of positions. Some jobs are associated with projects. The training system provides two types of learning opportunities, academic courses and job related training. The mission of the training system is to fill up any knowledge/skill gap between the personnel's possession and the requirements of the jobs.

A person may work on one or more jobs. A job is described as a position that requires various knowledge/skills. Some positions require one or more certificates. Some jobs require special skills in addition to the skills required by its corresponding position. Typically, there are multiple jobs of the same position.

The training system manages information of workers' education, skills and training, and to help find workers suitable for a job. Generally, academic courses help students learn knowledge; training courses help trainees gain skills.

5.1.1 Developing The Underlying System

The underlying system is a three tier architecture with the following components,

a) JSP pages serve as the front end

b) Java Beans as the middle end and

c) Oracle server as the back end.

The front end JSP pages play a simple role of collecting the required information and send it to the Java Bean classes in the middle end. These java classes serve as the core of this system. These classes communicate with front end and the back end applications to run the system, so we have carefully developed three categories of these bean classes.

a) PersonCatalog

The PersonCatalog retrieves and processes all the information regarding the employees ranging from personal information to current working status of employees

b) JobCatalog

The JobCatalog processes the information regarding the available jobs, required knowledge skills, and missing knowledge skills.

c) Company

The Company bean accesses the company profiles, the number of employees working in company and the salary for each of the company employees.

The backend Database plays a key role of storing the information processed by the bean classes in the middle tier. The following ER-diagram provides basic outline about the database architecture.

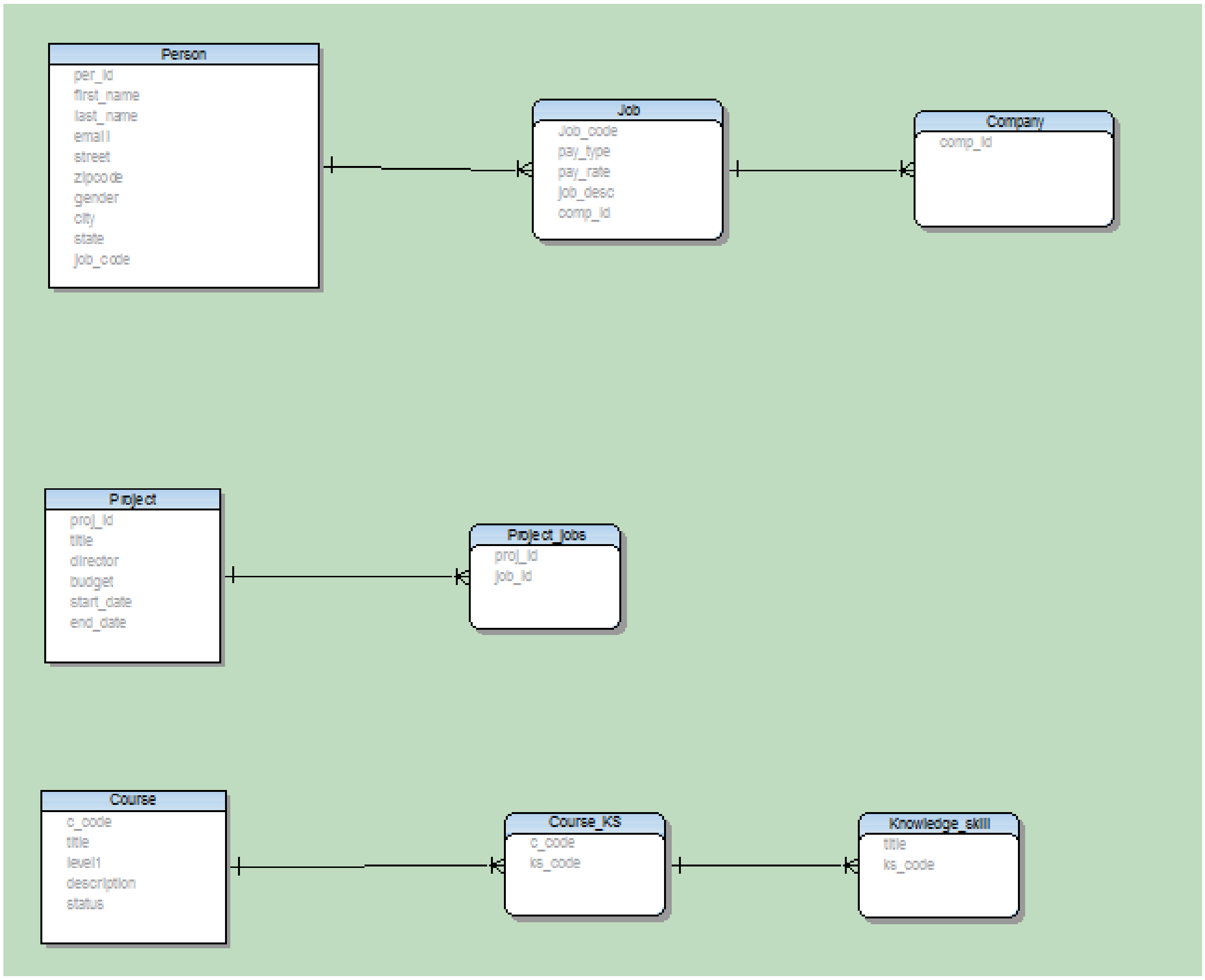


Figure 18

5.2 Turning the Production System to a VDL System

In order to use the aforementioned database application as a VDL system, many features have been added to turn it into a learning system. The two major changes are the bugs implanted in the queries, and a visual tool that shows the operations performed on a database.

We have systematically implanted bugs in the functioning system in order to make the students identify the bug and get a better understanding of the working software systems.

The goal of this learning system is to make students understand the query operations performed on database, so we have implanted the bugs in SQL queries. The visual tool is the tool which interprets the query operations. This tool used by the students to examine the query operation performed on the database. We have developed learning cases to systematically implant bugs.

5.2.1 Learning Case

Learning Case #1: List a company's workers by names.

In the first learning case, the Web application sends a request to the database to list all the employees working in a company.

The query to retrieve the workers names by company is,

```
SELECT person.first_name, person.last_name
FROM person, job
WHERE person.job_code=job.job_code AND job.comp_id='"+comp_name+"'
ORDER BY first_name
```

To convert this case into a learning case we have implanted a bug by removing the WHERE clause from the original query,

```
SELECT person.first_name,person.last_name
FROM person, job
ORDER by first_name
```

Since the WHERE clause is omitted, the modified query's result will display employee names from all the companies.

Objective: To learn about the importance of conditions in the WHERE clause.

Procedure:

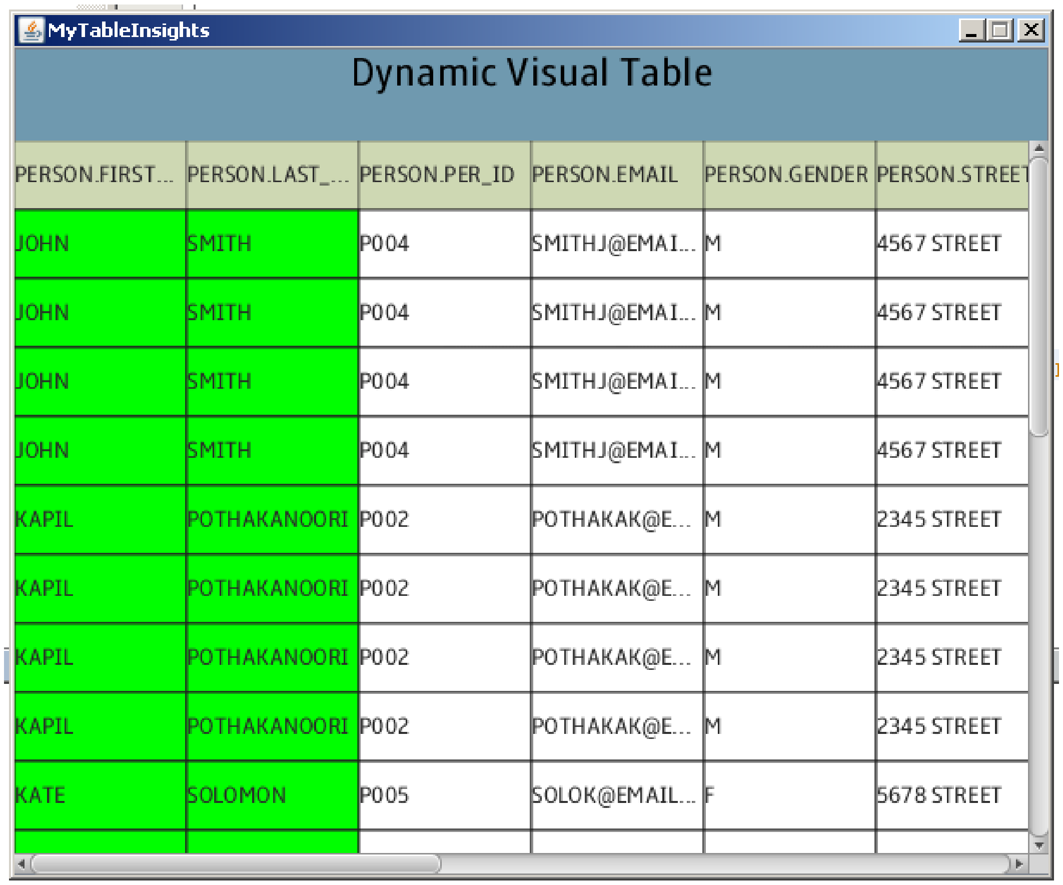
The student selects the company id for which he/she wishes to list the names of employees and hit the submit button.

Results:

The result from the database contains the following values,

FIRST_NAME	**LAST_NAME**
JOHN	SMITH
JOHN	SMITH
JOHN	SMITH
JOHN	SMITH
KAPIL	POTHAKANOORI
KAPIL	POTHAKANOORI
KAPIL	POTHAKANOORI
KAPIL	POTHAKANOORI
KATE	SOLOMON
KATE	SOLOMON
KATE	SOLOMON
KATE	SOLOMON
PETER	SOLOMON
PETER	SOLOMON
PETER	SOLOMON
PETER	SOLOMON
SIRISHA	TANKASHALA
SIRISHA	TANKASHALA
SIRISHA	TANKASHALA
SIRISHA	TANKASHALA

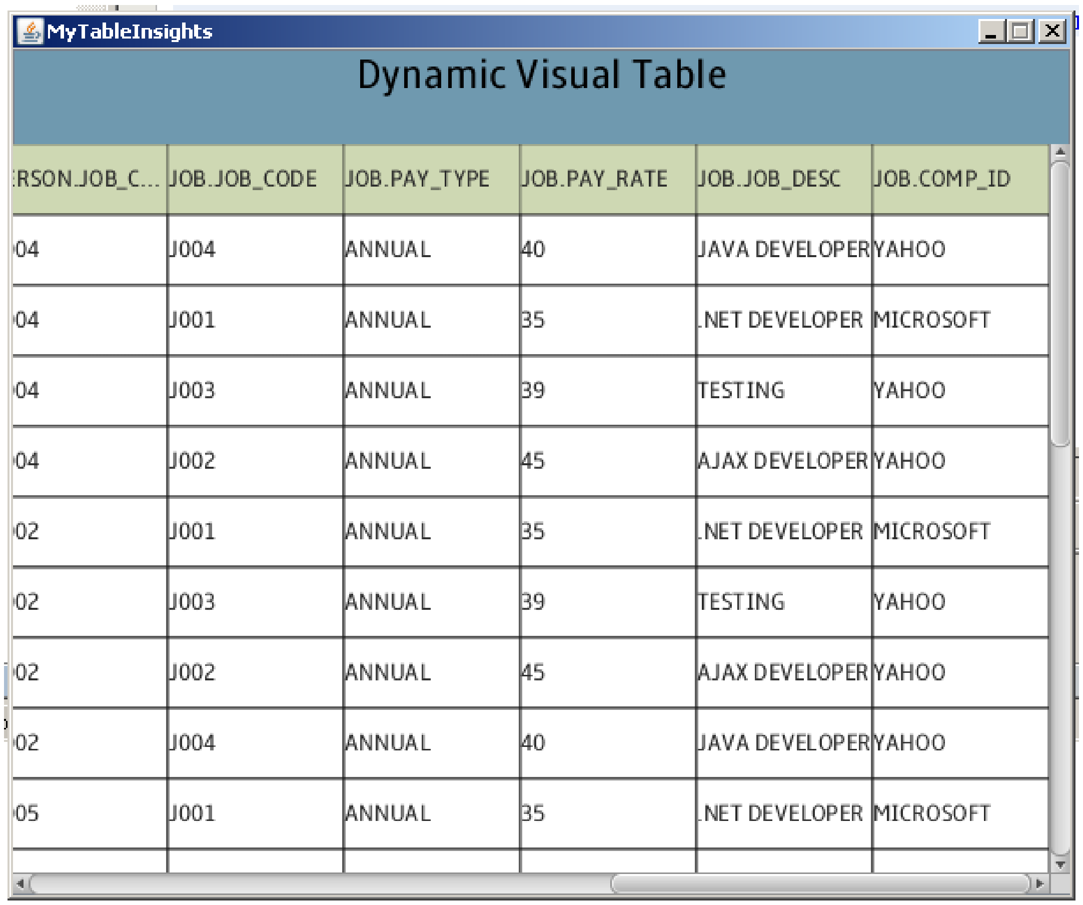
By observing the above values, students can understand that a bug is implanted in the query. To identify the bug, students can examine the dynamic visual tool which provides with detailed information about the table and the results selected from the table


MyTableInsights

Dynamic Visual Table

PERSON.FIRST...	PERSON.LAST_...	PERSON.PER_ID	PERSON.EMAIL	PERSON.GENDER	PERSON.STREET
JOHN	SMITH	P004	SMITHJ@EMAI...	M	4567 STREET
JOHN	SMITH	P004	SMITHJ@EMAI...	M	4567 STREET
JOHN	SMITH	P004	SMITHJ@EMAI...	M	4567 STREET
JOHN	SMITH	P004	SMITHJ@EMAI...	M	4567 STREET
KAPIL	POTHAKANOORI	P002	POTHAKAK@E...	M	2345 STREET
KAPIL	POTHAKANOORI	P002	POTHAKAK@E...	M	2345 STREET
KAPIL	POTHAKANOORI	P002	POTHAKAK@E...	M	2345 STREET
KAPIL	POTHAKANOORI	P002	POTHAKAK@E...	M	2345 STREET
KATE	SOLOMON	P005	SOLOK@EMAIL...	F	5678 STREET

Figure 19

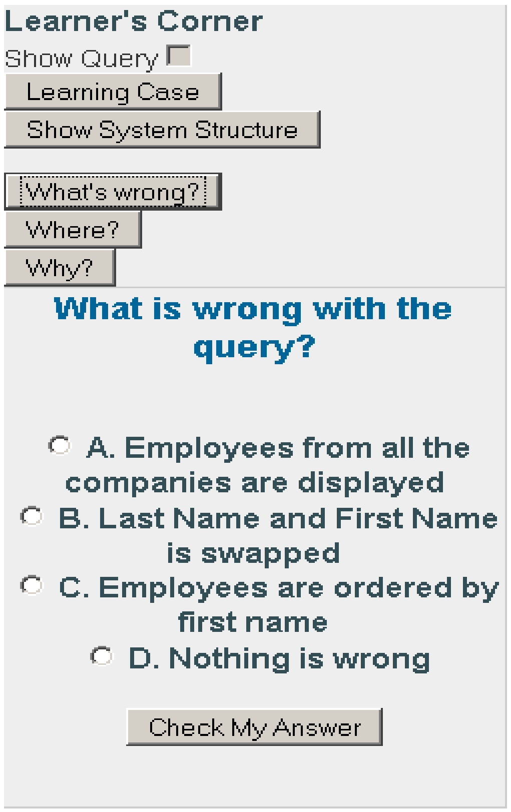


:RSON.JOB_C...	JOB.JOB_CODE	JOB.PAY_TYPE	JOB.PAY_RATE	JOB.JOB_DESC	JOB.COMP_ID
·04	J004	ANNUAL	40	JAVA DEVELOPER	YAHOO
·04	J001	ANNUAL	35	.NET DEVELOPER	MICROSOFT
·04	J003	ANNUAL	39	TESTING	YAHOO
·04	J002	ANNUAL	45	AJAX DEVELOPER	YAHOO
·02	J001	ANNUAL	35	.NET DEVELOPER	MICROSOFT
·02	J003	ANNUAL	39	TESTING	YAHOO
·02	J002	ANNUAL	45	AJAX DEVELOPER	YAHOO
·02	J004	ANNUAL	40	JAVA DEVELOPER	YAHOO
·05	J001	ANNUAL	35	.NET DEVELOPER	MICROSOFT

Figure 20

By examining the extended query results displayed by the visual tool, student can understand that employee names from all the companies are displayed instead of the specified company.

Now the "what's wrong?" option in the learner's corner can be utilized to check the answer. After selecting the option "Employees from all the companies are displayed" we will advance to the next learning case.


Learner's Corner

Show Query ☐

Learning Case

Show System Structure

What's wrong?

Where?

Why?

What is wrong with the query?

○ A. Employees from all the companies are displayed

○ B. Last Name and First Name is swapped

○ C. Employees are ordered by first name

○ D. Nothing is wrong

Check My Answer

Figure 21

Learning Case #2: List a company's staff in the descending order of their salary.

In the second learning case, the Web application sends a request to the database to list all the employees working in a company in descending order of their par rate.

The following query is used by the underlying system to list the employee names,

```
SELECT person.first_name, person.last_name
FROM person, job
WHERE person.job_code = job.job_code AND job.comp_id='"+comp_name+"'
ORDER BY pay_rate DESC
```

But to transform this case into a learning case, the "DESC" parameter on the ORDER BY clause, which sorts all the resulting tuples in descending order of the pay rate, was purposefully omitted so that the employees are listed in default ascending order.

```
SELECT person.first_name, person.last_name
FROM person, job
WHERE person.job_code=job.job_code AND job.comp_id='"+comp_name+"'
ORDER BY pay_rate
```

Objective: To show that the default sorting may not meet the requirement of an application

Procedure:

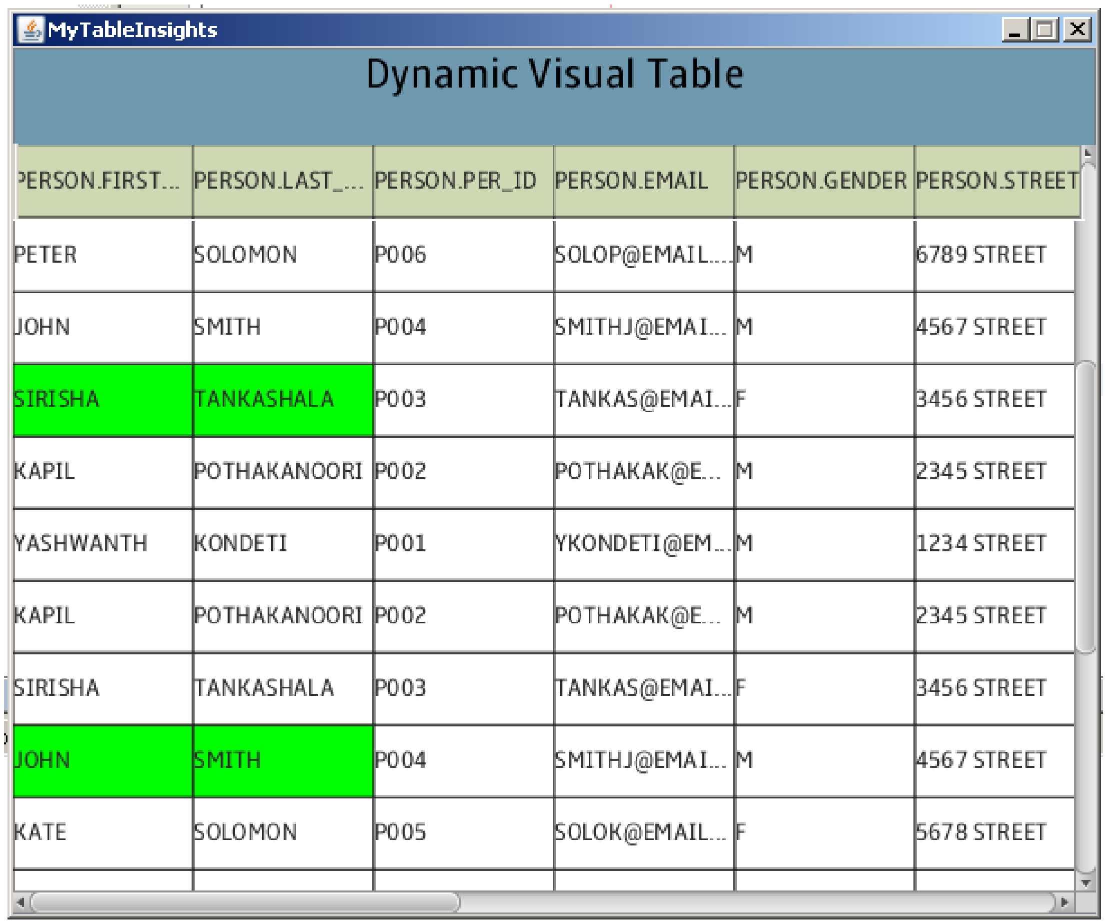
The student select's the appropriate company id from the given list of companies and hit the submit button

Results:

The results displayed after executing the incorrect query is,

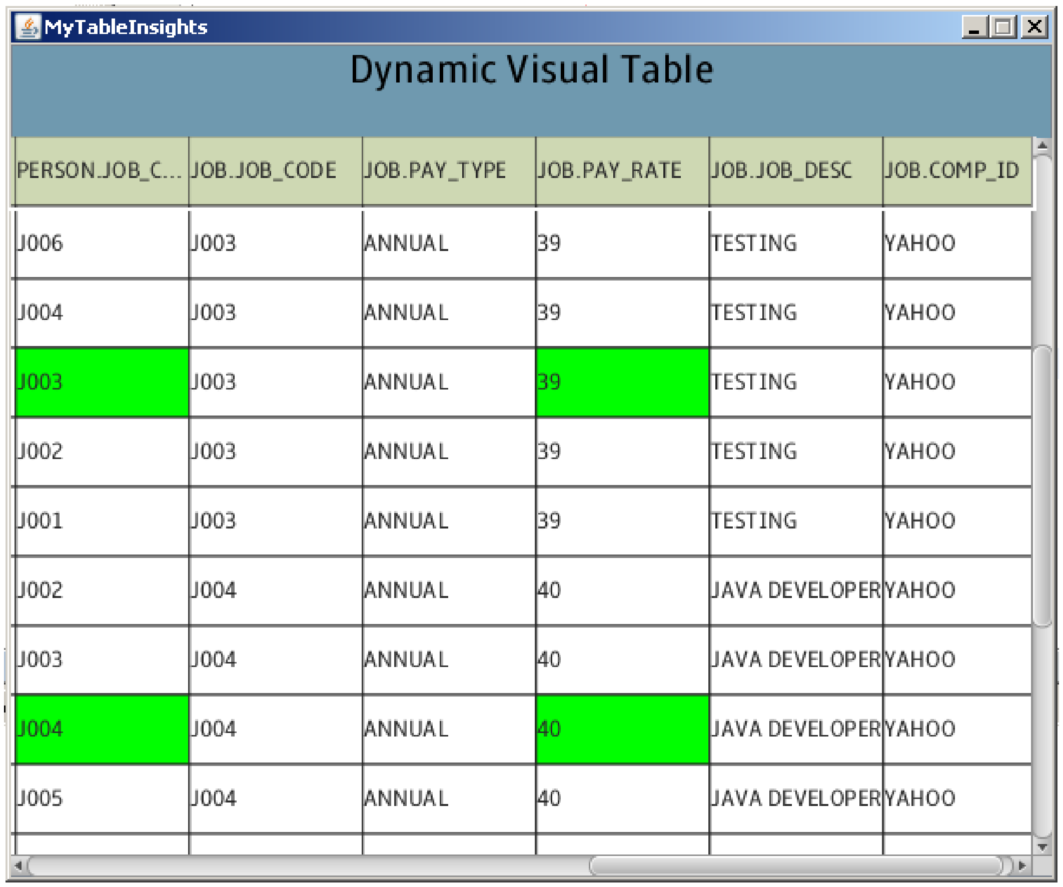
FIRST_NAME	**LAST_NAME**
SIRISHA	TANKASHALA
JOHN	SMITH
KAPIL	POTHAKANOORI

When the student examines the dynamic visual tool, the student can easily spot that the employee names are displayed in ascending order instead of the requested descending order.



PERSON.FIRST...	PERSON.LAST_...	PERSON.PER_ID	PERSON.EMAIL	PERSON.GENDER	PERSON.STREET
PETER	SOLOMON	P006	SOLOP@EMAIL...	M	6789 STREET
JOHN	SMITH	P004	SMITHJ@EMAI...	M	4567 STREET
SIRISHA	TANKASHALA	P003	TANKAS@EMAI...	F	3456 STREET
KAPIL	POTHAKANOORI	P002	POTHAKAK@E...	M	2345 STREET
YASHWANTH	KONDETI	P001	YKONDETI@EM...	M	1234 STREET
KAPIL	POTHAKANOORI	P002	POTHAKAK@E...	M	2345 STREET
SIRISHA	TANKASHALA	P003	TANKAS@EMAI...	F	3456 STREET
JOHN	SMITH	P004	SMITHJ@EMAI...	M	4567 STREET
KATE	SOLOMON	P005	SOLOK@EMAIL...	F	5678 STREET

Figure 22



Dynamic Visual Table

PERSON.JOB_C...	JOB.JOB_CODE	JOB.PAY_TYPE	JOB.PAY_RATE	JOB.JOB_DESC	JOB.COMP_ID
J006	J003	ANNUAL	39	TESTING	YAHOO
J004	J003	ANNUAL	39	TESTING	YAHOO
J003	J003	ANNUAL	39	TESTING	YAHOO
J002	J003	ANNUAL	39	TESTING	YAHOO
J001	J003	ANNUAL	39	TESTING	YAHOO
J002	J004	ANNUAL	40	JAVA DEVELOPER	YAHOO
J003	J004	ANNUAL	40	JAVA DEVELOPER	YAHOO
J004	J004	ANNUAL	40	JAVA DEVELOPER	YAHOO
J005	J004	ANNUAL	40	JAVA DEVELOPER	YAHOO

Figure 23

The "what's wrong?" option in the learner's corner can be utilized to check the answer. After selecting the option "Ascending order of employees is displayed" we will advance to the next learning case.

Learning Case #3: List all the workers who are working for a specific project.

In the third test case, the Web application sends a request to the database to list all the employees working in a specific project.

The following query is used by the underlying system

```
SELECT first_name, last_name
FROM project, person, project_jobs
WHERE project.proj_id = 'proj_id' AND person.job_code = project_jobs.job_id AND
project.proj_id = project_jobs.proj_id
```

But to convert this case into a learning case, the person id and gender of the each of the employees is displayed instead of the first and last names of the employees working in the project

```
SELECT per_id, gender
FROM project, person, project_jobs
WHERE project.proj_id = 'proj_id' AND person.job_code = project_jobs.job_id AND
project.proj_id = project_jobs.proj_id
```

Objective: To find the missing column in the result

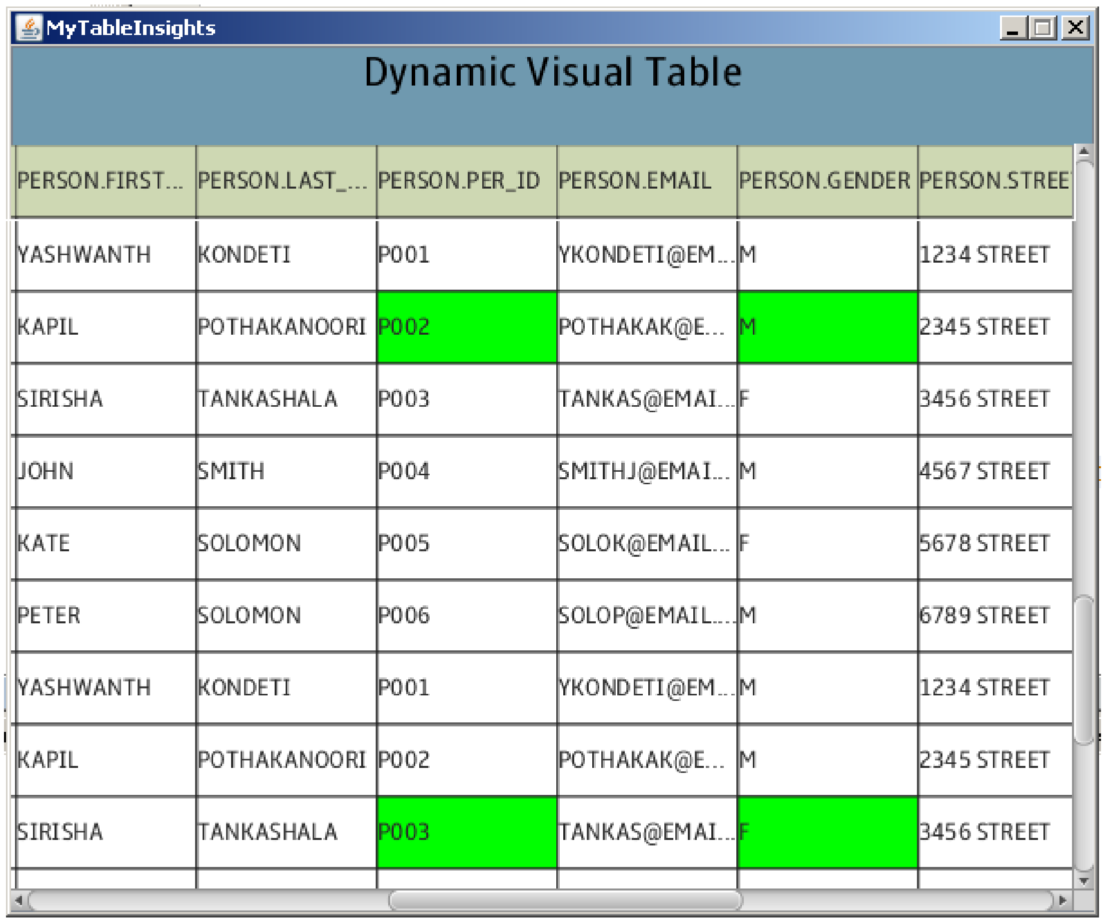
Procedure:

Select the appropriate project id from the given list of projects and hit the submit button

Results:

FIRST_NAME	**LAST_NAME**
P002	M
P003	F
P004	M

With the obtained result student clearly understands that the query was executed incorrectly. To get a better grasp of the query execution, the student examines the visual tool.



Dynamic Visual Table

PERSON.FIRST...	PERSON.LAST_...	PERSON.PER_ID	PERSON.EMAIL	PERSON.GENDER	PERSON.STREE
YASHWANTH	KONDETI	P001	YKONDETI@EM...	M	1234 STREET
KAPIL	POTHAKANOORI	P002	POTHAKAK@E...	M	2345 STREET
SIRISHA	TANKASHALA	P003	TANKAS@EMAI...	F	3456 STREET
JOHN	SMITH	P004	SMITHJ@EMAI...	M	4567 STREET
KATE	SOLOMON	P005	SOLOK@EMAIL...	F	5678 STREET
PETER	SOLOMON	P006	SOLOP@EMAIL....	M	6789 STREET
YASHWANTH	KONDETI	P001	YKONDETI@EM...	M	1234 STREET
KAPIL	POTHAKANOORI	P002	POTHAKAK@E...	M	2345 STREET
SIRISHA	TANKASHALA	P003	TANKAS@EMAI...	F	3456 STREET

Figure 24

By looking at the visual interpretation, students can easily identify that instead of showing the employee names working in the projects, the person id and gender is being displayed. The "what's wrong?" option in the learner's corner can be utilized to check the answer. After selecting the option "person id and gender of employees is displayed" we will advance to the next learning case.

Learning Case #4: List a person's active certificates.

In the fourth test case, the Web application sends a request to the database to list the person's active certificates.

The original query used is,

```
SELECT title
FROM certificate, person_certificate
WHERE per_id = 'person_id' AND person_certificate.cert_code = certificate.cert_code AND
certificate.expiry_date > current_timestamp
```

In this case the condition in the WHERE clause which compares the dates is omitted, so both active and inactive certificates are displayed

```
SELECT title
FROM certificate, person_certificate
WHERE per_id = 'person_id' AND person_certificate.cert_code = certificate.cert_code
```

Objective: To show that the date field plays a crucial role in systems

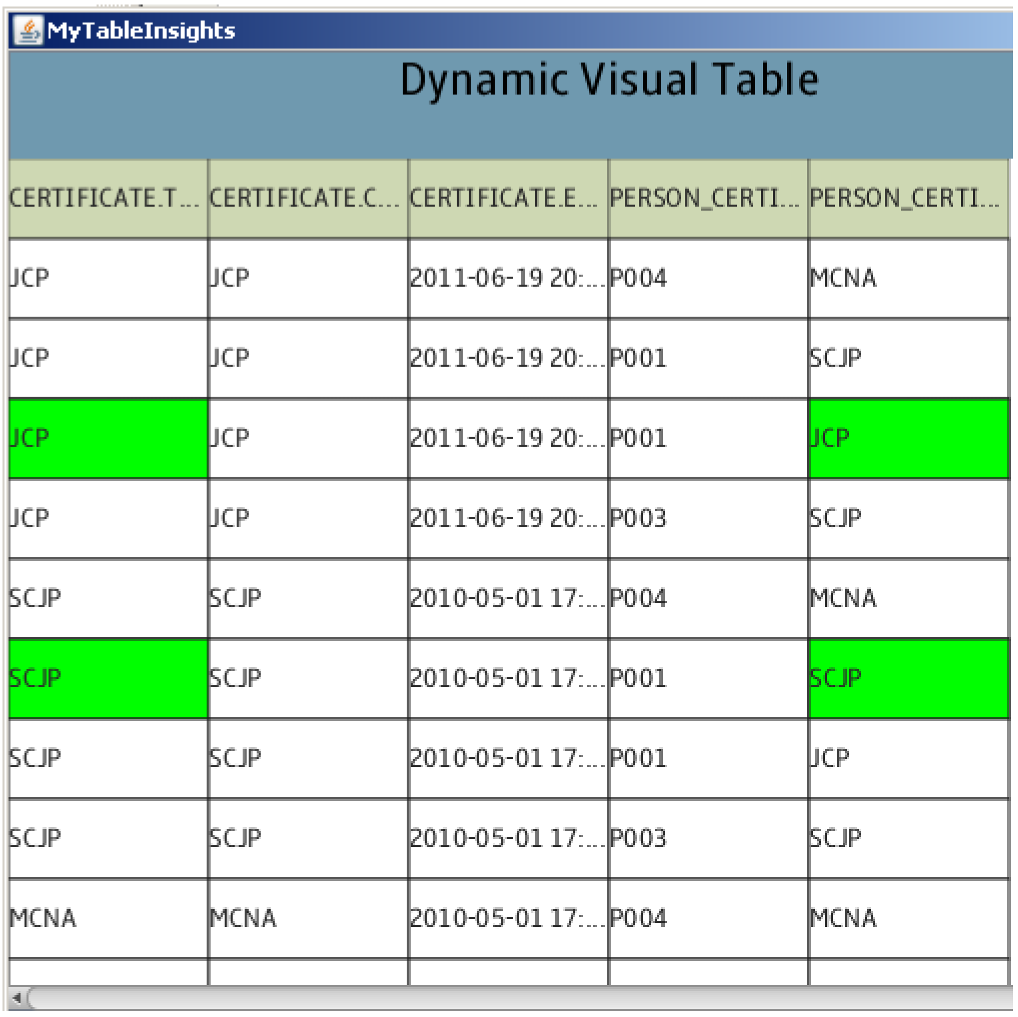
Procedure:

Select the appropriate person id from the given list of person's and hit the submit button

Results:

TITLE
SCJP
JCP

After reviewing the above results and the following visual tool the student can grasp that both active and inactive certificates are displayed.



MyTableInsights

Dynamic Visual Table

CERTIFICATE.T...	CERTIFICATE.C...	CERTIFICATE.E...	PERSON_CERTI...	PERSON_CERTI...
JCP	JCP	2011-06-19 20:...	P004	MCNA
JCP	JCP	2011-06-19 20:...	P001	SCJP
JCP	JCP	2011-06-19 20:...	P001	JCP
JCP	JCP	2011-06-19 20:...	P003	SCJP
SCJP	SCJP	2010-05-01 17:...	P004	MCNA
SCJP	SCJP	2010-05-01 17:...	P001	SCJP
SCJP	SCJP	2010-05-01 17:...	P001	JCP
SCJP	SCJP	2010-05-01 17:...	P003	SCJP
MCNA	MCNA	2010-05-01 17:...	P004	MCNA

Figure 25

The “what’s wrong?” option in the learner’s corner can be utilized to check the answer. After selecting the option “Both the active and inactive certificates are displayed” we will advance to the next learning case.

Learning Case #5: List the required knowledge/skills of a position in a readable format.

In the fifth test case, the Web application sends a request to the database to list the required knowledge/skills of a position in a readable format.

In this case we have not implanted any bug in the SQL query.

```
SELECT ks.title
FROM position p, position_skills ps, knowledge_skill ks
WHERE ks.ks_code = ps.ks_code AND ps.pos_code = p.pos_code AND p.pos_code =
'position_id'
```

Objective: To demonstrate the working of a system without any bugs

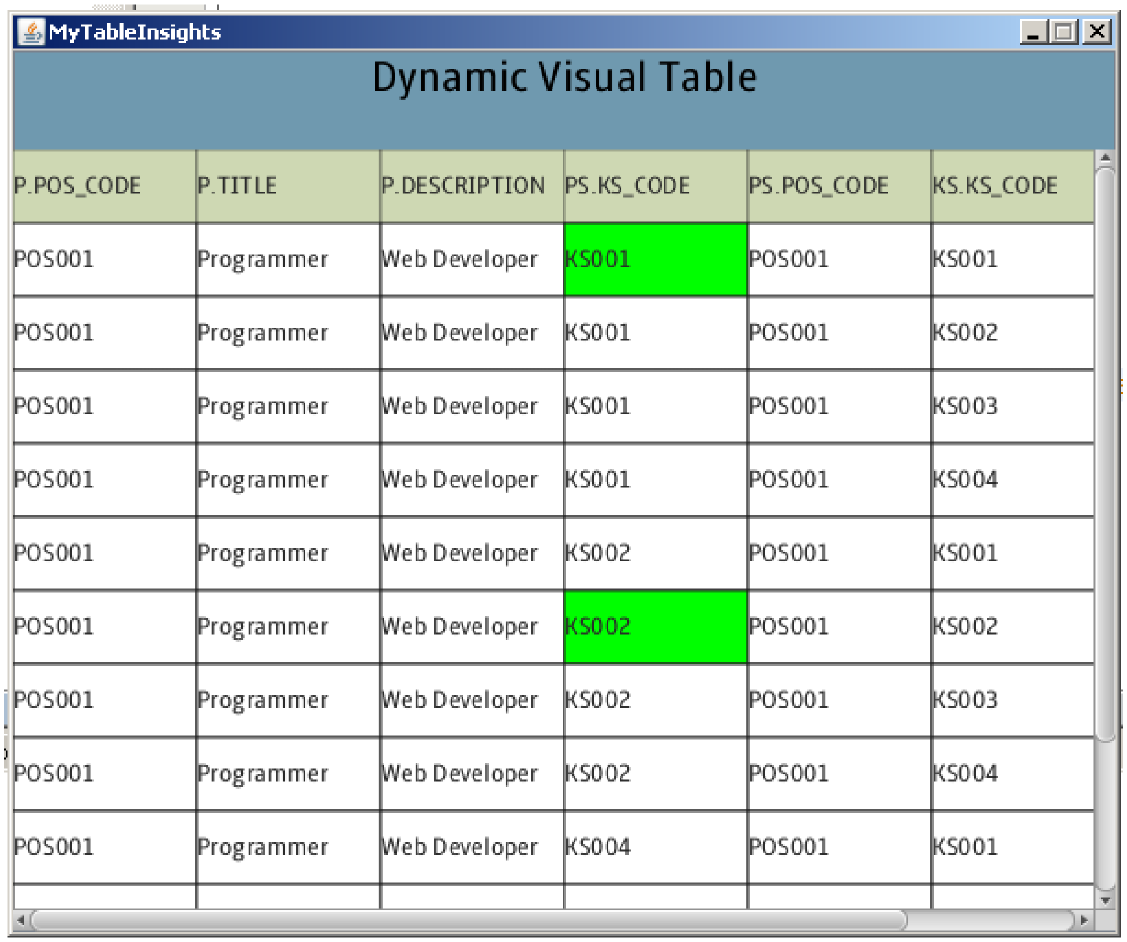
Procedure:

Select the appropriate position id from the given list of positions and hit the submit button

Results:

TITLE
KnowledgeSkill001
KnowledgeSkill002
KnowledgeSkill004

Now, if the student examines the above result and the following visual tool, he/she can infer that the query has displayed the correct results from the table.



MyTableInsights

Dynamic Visual Table

P.POS_CODE	P.TITLE	P.DESCRIPTION	PS.KS_CODE	PS.POS_CODE	KS.KS_CODE
POS001	Programmer	Web Developer	KS001	POS001	KS001
POS001	Programmer	Web Developer	KS001	POS001	KS002
POS001	Programmer	Web Developer	KS001	POS001	KS003
POS001	Programmer	Web Developer	KS001	POS001	KS004
POS001	Programmer	Web Developer	KS002	POS001	KS001
POS001	Programmer	Web Developer	KS002	POS001	KS002
POS001	Programmer	Web Developer	KS002	POS001	KS003
POS001	Programmer	Web Developer	KS002	POS001	KS004
POS001	Programmer	Web Developer	KS004	POS001	KS001

Figure 26

The “what’s wrong?” option in the learner’s corner can be utilized to check the answer. After selecting the option “Nothing is wrong” we will advance to the next learning case.

Learning Case #6: Insert a new person with all the required details into the database.

In the sixth test case, the Web application sends a request to the database to insert data about a person into person table.

The original query is,

INSERT INTO person (FIRST_NAME, LAST_NAME, PER_ID, EMAIL, GENDER, STREET, CITY, STATE, JOB_CODE)

```
VALUES ('TOM', 'WILLIAMS', 'P000', 'WILLIAMST@EMAIL.COM', 'M', '3456 STREET ',
'NEW ORLEANS', 'LA', 'J000');
```

The first and last names of the person are swapped with each other to convert this case into a learning case,

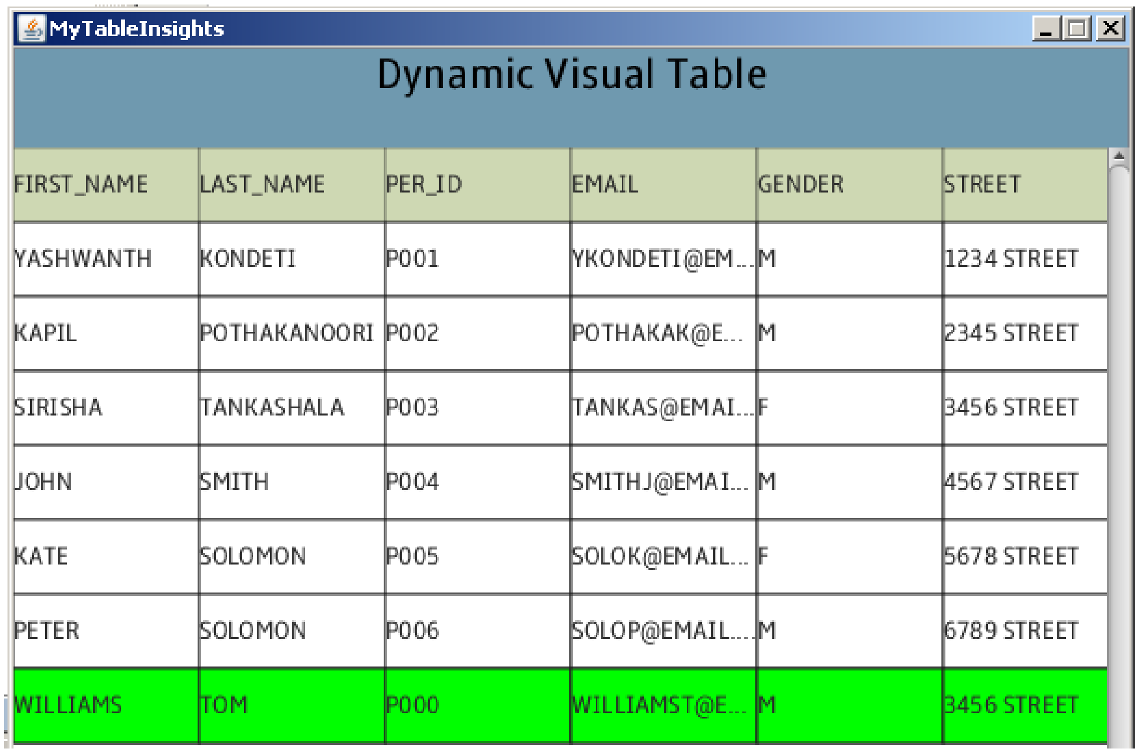
```
INSERT INTO person (FIRST_NAME, LAST_NAME, PER_ID, EMAIL, GENDER, STREET,
CITY, STATE, JOB_CODE)
VALUES ('WILLIAMS', 'TOM', 'P000', 'WILLIAMST@EMAIL.COM', 'M', '3456 STREET ',
'NEW ORLEANS', 'LA', 'J000');
```

Objective: To learn about the INSERT statement

Procedure:

Enter the person details in the form and click on the submit button

After getting a success notification from the database the student can review the table by looking at the visual tool,



Dynamic Visual Table

FIRST_NAME	LAST_NAME	PER_ID	EMAIL	GENDER	STREET
YASHWANTH	KONDETI	P001	YKONDETI@EM...	M	1234 STREET
KAPIL	POTHAKANOORI	P002	POTHAKAK@E...	M	2345 STREET
SIRISHA	TANKASHALA	P003	TANKAS@EMAI...	F	3456 STREET
JOHN	SMITH	P004	SMITHJ@EMAI...	M	4567 STREET
KATE	SOLOMON	P005	SOLOK@EMAIL...	F	5678 STREET
PETER	SOLOMON	P006	SOLOP@EMAIL....	M	6789 STREET
WILLIAMS	TOM	P000	WILLIAMST@E...	M	3456 STREET

Figure 27

In the visual tool the student can inferred that the first and last names are swapped.

The "what's wrong?" option in the learner's corner can be utilized to check the answer. After selecting the option "first and last name are swapped in database" we will advance to the next learning case.

Learning Case #7: Update a previously inserted record in the database.

In the seventh learning case, the Web application sends a request to the database to update data about a person in the person table. The where clause is omitted because of which all the persons job_code is updated with new job_code

```
//original query
UPDATE job
SET job_desc = 'DEVELOPER'
WHERE job_code = 'J001'
```

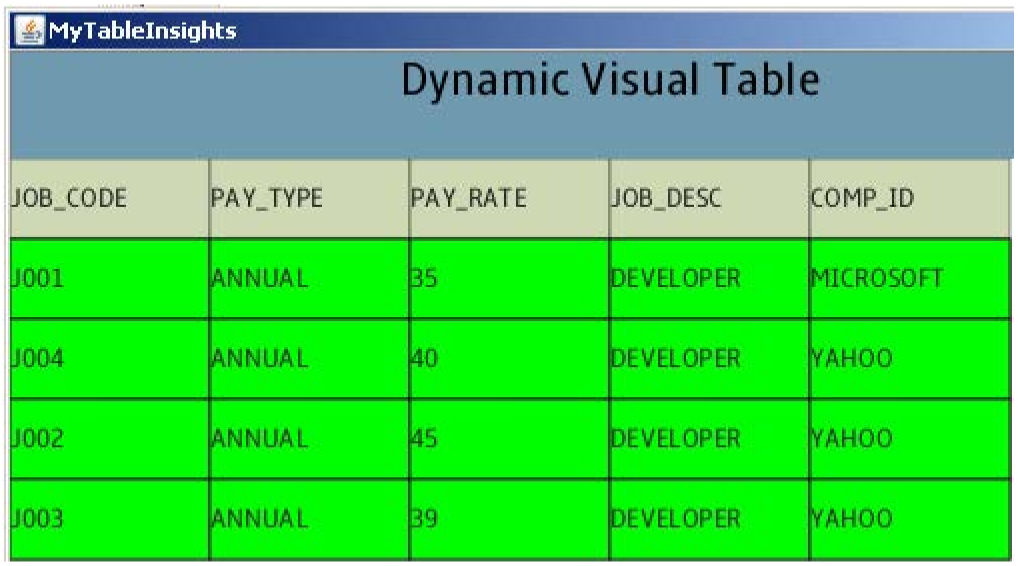
```
//modified query
UPDATE job
SET job_desc='DEVELOPER'
```

Objective: To emphasize the critical role of the WHERE clause in UPDATE statement by illustrating a disastrous result of a mistake.

Procedure:

Student selects the desired row whose job description has to be updated

After receiving a success notification from database, the visual tool shows the table with all the changes that have been made.



JOB_CODE	PAY_TYPE	PAY_RATE	JOB_DESC	COMP_ID
J001	ANNUAL	35	DEVELOPER	MICROSOFT
J004	ANNUAL	40	DEVELOPER	YAHOO
J002	ANNUAL	45	DEVELOPER	YAHOO
J003	ANNUAL	39	DEVELOPER	YAHOO

Figure 28

From the visual tool the student can understand that all the rows are updated instead of the requested row.

The “what’s wrong?” option in the learner’s corner can be utilized to check the answer. After selecting the option “All records are updated instead of one record” we will advance to the next learning case.

Learning Case #8: Delete expired certificates from the certificates table.

In the eight and the last test case, the Web application sends a request to the database to delete expired certificates from certificate table.

The where clause is again omitted because of which all the rows are deleted from the table.

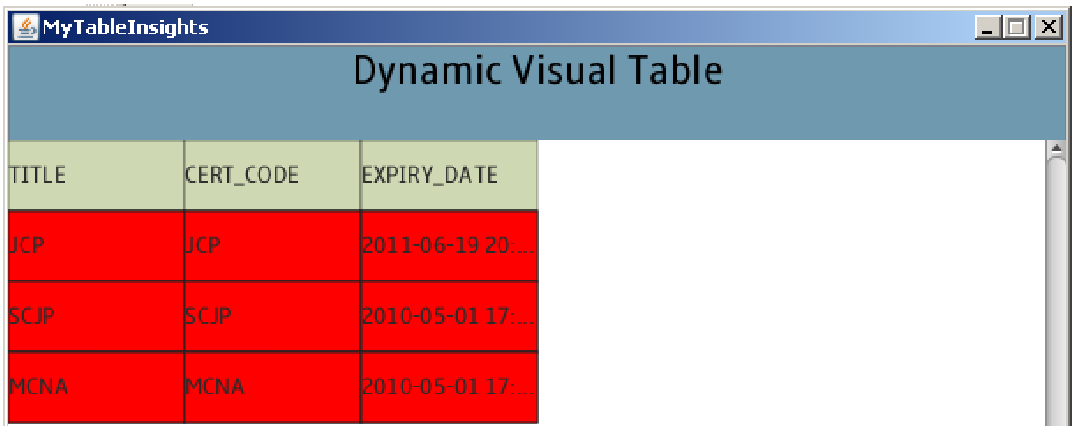
```
//original query
DELETE certificate
WHERE expiry_date < current_timestamp


//modified query
DELETE certificate
```

Objective: To emphasize the critical role of WHERE clause in DELETE statement

Procedure:

Enter the expiry date to compare with the records in the table

After getting the success notification from the database, the visual tool highlights the disaster that has been caused on the table.



MyTableInsights

Dynamic Visual Table

TITLE	CERT_CODE	EXPIRY_DATE
JCP	JCP	2011-06-19 20:...
SCJP	SCJP	2010-05-01 17:...
MCNA	MCNA	2010-05-01 17:...

Figure 29

The “what’s wrong?” option in the learner’s corner can be utilized to check the answer. After selecting the option “All records are deleted instead of expired record” we will advance to the next learning case.

6. Discussion & Conclusion

The aim of Verification Driven learning model is to help the students understand the key elements of database systems more thoroughly and intriguingly. To achieve this goal a rigorous research work is still needed. In order to validate our tool, we have to develop more learning cases and apply the learning cases in classrooms. The modulized components for visualization developed in this project should be able to help further development of learning techniques.

References

[1] K. Sung, “Computer Games and Tranditional CS Courses”, CACM, 52(12), 74-78, Dec. 2009

[2] Shengru Tu, Sehun Oh, Rushikesh Kale, Aditya Kellem, Shireesha Tankashala, “Developing Verification-Driven Learning Cases”, in the proceedings of the 5th Annual Conference on Innovation and Technology in Computer Science Education, Ankara, Turkey, June 26-30, 2010.

Vita

Aditya Reddy Kallem was born in Hyderabad, India. He earned his Bachelor’s Degree in Computer Science as major at Osmania University, India from 2004 to 2008. He was enrolled in the graduate program in Computer Science Department at the University of New Orleans in August 2008.