

Teaching and Assessing Database Concepts using GIS

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ABSTRACT

In this paper, a process for trialling and assessing GIS (Graphical Information Systems) principles in a database development course for level six students currently undertaking an information and communications technology (ICT) degree is described. This paper builds on previous research and provides a description of how GIS shape data was incorporated in the form of practical lessons into the database development curriculum in order to integrate with relational database objects; Views, Stored Procedures and Triggers. A description and the results of a formal assessment is presented and compared against the previous year. Student feedback on the GIS spatial data database assignment is also presented and discussed. The study found that the incorporation of GIS shape data into the curriculum to be educationally viable, and also suggests a resulting increased interest level from students.

Keywords: GIS, database education, course design

1. INTRODUCTION

A Geographical Information Systems (GIS) is aptly described by Zink (2000) as a computer system designed to input, store, process, study, manage, and display geographical data. Advances in computer technology have led to the inclusion of GIS in many desktop and mobile devices and the uses of this technology continue to grow. Raper and Green (1992) identified that the rapid advancement in the use of GIS has led to a shortage of skills and that there is large potential in the use of GIS within an educational context.

Many GIS systems rely on the use of the Structured Query Language (SQL) for the manipulation of both normal relational data and also spatial data. The teaching of SQL fundamentals typically includes; creating, reading, updating, and deleting (CRUD), as well as performing join, group by, and aggregation operations on data. This is well covered by the literature (Caldeira 2008), (Kearns et al. 1996), (Raadt et al. 2006).

Burt (2011) theorised that spatial database software could be used for teaching the Structured Query Language (SQL). Burt reasoned that queries that included spatial data could be displayed visually, and consequently, would provide instant feedback to students in a form they would be likely able to comprehend. Importantly, he argued that no additional software would need to be written.

The Universal College of Learning's (UCOL) BICT (Bachelor of Information and Communications Technology) teaching team has been interested in providing students with the opportunity to utilise GIS concepts and learn skills necessary for working with spatial data at the database level. Initially, informal GIS lessons were introduced to the D211 Database Development course in 2012 which provided students with the knowledge to perform select queries with spatial data in order to produce maps of countries. Due to initial feedback being positive with regards to the GIS content, Dargie and Steele (2013) decided to expand the GIS content to include its use within database Views, Stored Procedures and Triggers. Lesson plans were created to do this and trialled with students in 2014, the development, and

results of this trial forms the focus of this study.

The authors of this paper were interested to learn if Burt's theories could be utilised by including GIS concepts into an existing course, and whether this could be done without affecting the SQL learning outcomes. It was hoped that this addition would make the course more interesting, as well as giving students an insight into the use of GIS within a database management system (DBMS), and in doing so, lead some students to study GIS further and overcome the identified GIS skills shortage.

2. BACKGROUND

As mentioned, in 2012 practical lessons for the D211 Database Development course were updated to incorporate the previous studies done by Burt (2011) who had suggested the incorporation of spatial database software into existing SQL curriculums. This was done in order to test the hypothesis that the instant visual feedback provided by the GIS spatial data would be easily understandable by students and would consequently be advantageous to student learning. Although the GIS concepts were introduced, the lessons were never assessed as they were only included to observe the reaction students had to writing SQL queries and seeing the results returned in the form of maps. Nevertheless, initial feedback from the students was positive and accordingly, it was decided to keep the newly introduced content and also extend it by incorporating the GIS component into the Stored Procedures and Trigger aspects of the database development course.

This resulted in Dargie and Steele (2013) developing lesson plans which incorporated a GIS component into database Views, Triggers and Stored Procedures. In order to supplement student understanding of GIS and spatial data in database concepts, the lessons also included a brief history of GIS as well as some other key concepts.

In 2014, the additional lesson plans were introduced into the paper and trialled with the current cohort of students. A summative assessment involving the GIS concepts was given to the students. Accordingly, this paper builds on the work started by Burt (2011), Dargie and Steele (2013) and presents the results of the enhanced trial of GIS concepts within the database development course.

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3. METHOD

3.1 Lesson and Assessment Development

Spatial data had already been incorporated into the database development course from the previous year and had focused around the Data Definition Language (DDL) and Data Manipulation Language (DML) aspects of SQL. This included the addition of the GEOGRAPHY spatial data type as a field in a table called countries. This field stored the shape of each country in the form of a polygon. The table also contained the population, area in square miles, capital city, and foreign key values that linked the country table to the currencies, and regions tables.

As was the case from the previous year, students were given instructions on how to create the countries table and relate it to the other tables using the Transact Structured Query Language (TSQL).

Data was provided to the students for the countries table in the form of TSQL pre-written insert statements. This data was provided because the spatial values were in a binary hexadecimal format which made it too difficult and too time consuming to enter in by hand. Students did however have to create insert statements to populate the other tables. Students then conducted common DDL operations such as adding, dropping and renaming columns as well as column CHECK constraints to restrict data values allowable.

The DML exercises consisted of SQL queries which gradually introduced the WHERE, GROUP BY, HAVING and ORDER BY clauses. Where possible the GEOGRAPHY field was included to produce a visual map of the result (see Figure 1).

Exercise 3

Display a map showing the regions that have the 'Rand' for its currency. (INNER JOIN)

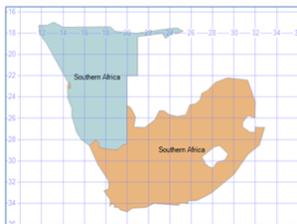


Figure 1: Sample DML exercise with expected result

Following this, the new material created in 2013 was introduced into the paper for a number of practical lessons to extend the GIS concepts.

The order in which the new material was added was important as it built on knowledge gained from previous practical lessons. For example, the concept of database Views followed on from the lessons that involved select queries. Database Stored Procedures followed Views as these could be incorporated within a Stored Procedure. Finally, database Triggers were introduced because they could act on the previous Views and Stored Procedures that had been created.

In order to provide effective pedagogical practice, the instructor provided a concise introduction to the GIS components that were involved in that part of the exercise to supplement the written content. Where possible, a visual output in the form of the expected result was provided for each exercise (see Figure 1).

On completion of the practical lessons, a practical assignment was given to the students to assess their comprehension of SQL and the associated GIS components.

Students were expected to develop a number of Stored Procedures to create tables, insert spatial data, and display shapes from that spatial data within MS SQL Server. The Views were created and then used within some Stored Procedures to retrieve and display the shapes. Triggers were required to prevent the dropping of the View and Stored Procedure objects that were created. Logging of any attempt to drop a View or Stored Procedure was also required. This was to be written into the Trigger.

As part of the assignment, students needed to obtain the spatial data from Google Maps. This data was in the form of coordinates and needed to be converted from the Keyhole Markup (KML) format, into the Well Known Text (WKT) format (see Figure 2), this was done in order to allow storage of the data within MS SQL Server (the database tool being used for the assignment).

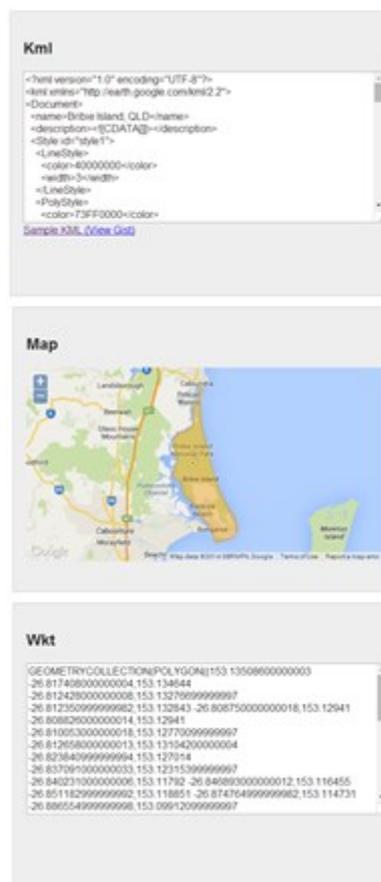


Figure 2: Conversion tool to produce WKT format

Three types of shapes were required to be stored and manipulated. These included POINT, LINESTRING and POLYGON data. From these shapes the student was required to write SQL code that used a number of spatial data type methods to display the LINESTRING lengths in meters, the area of the POLYGON in meters squared or display only those POINT's that fall within a certain buffer zone of a central POINT.

Central to the assessment was the requirement for each student to obtain the coordinate data that focused on their own residential address, the nearest school to that address and two roads that form the route to the school from their house. This was done in order to get the student to produce outputs that were unique to them. Students were expected to demonstrate their assessment to the lecturer by executing the Stored Procedures, show the logging of an attempted dropping of a

database View and correctly answer questions related to the assignment.

3.2 Student Feedback

Upon completion of the GIS assignment students were also invited to complete an anonymous assignment feedback survey that was designed to measure various aspects of the assignment. The survey sought to determine student perspectives of the difficulty of the assessment, whether the inclusion of spatial data into the assessment made it more interesting as opposed to using just standard data types, and finally, the areas of spatial data/geographical information systems they might be interested in if they decided to study the subject further. The survey included both quantitative Likert scale questions as well as open ended short answer questions. The results of the survey are presented and discussed in the following section.

4. RESULTS AND DISCUSSION

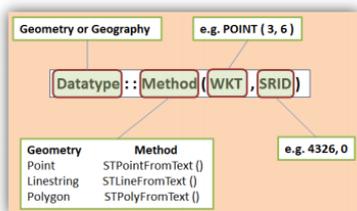
In this section the results relating to the additional lessons plans created in 2013 and trialled in 2014 are discussed. This is followed by a discussion focused on the 2014 GIS assessment given to students (subsequent to the completion of the practical lessons). Finally results of the feedback survey given to students upon completion of the D211 Database Development course are presented and discussed.

4.1 2014 Trial

In 2014 a series of practical instructions were provided to students with the spatial data necessary to produce visual results in the form of shapes. The lesson plans included a combination of step-by-step instructions and exercises which built on from the lessons trialled in 2013. The 2013 lessons provided the foundation for storing GIS spatial data and displaying that data in the form of visual maps of countries and regions using TSQL.

The additional 2014 practical instructions required students to import raw GIS coordinate data and create spatial shape objects from them (see Figure 3). The objects created were of the GEOMETRY or GEOGRAPY data type. The shapes imported were in the form of a POINT, POLYGON or LINESTRING. Ideas to form practical lessons were adapted from Lean (2008) and Fox (2013).

The syntax for creating a geometry or geography object using WKT in MS SQL Server is as follows:



So an example of creating a POINT in MS SQL Server would be:

```
GEOMETRY::STPointFromText('POINT (3 4)', 0);
```

Figure 3: The method to convert WKT coordinates to a geometry spatial object

Step-by-step instructions were given to demonstrate the use of applying SQL Server spatial methods on a shape. These included but were not limited to the use of STBuffering to increase the diameter of a POINT or STDistance to determine the distance between two sets of POINT coordinates.

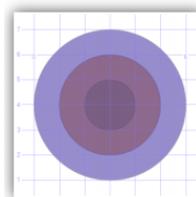
Within each set of practical instructions, students were required to solve a number of problems. Figure 4 shows an example of two problems where students are asked to

reproduce the shapes shown, using knowledge gained from the lesson (see Figure 5).

Steps
<p>1 Below the previous code, enter the following to create two polygons:</p> <pre>DECLARE @single_point GEOMETRY; DECLARE @single_polygon GEOMETRY; SET @single_point = GEOMETRY::STPointFromText('POINT (3 4)', 0); SET @single_polygon = GEOMETRY::STPolyFromText('POLYGON ((20 10, 30 0, 40 10, 30 20, 20 10))', 0); SELECT @single_point.STBuffer(2) UNION ALL SELECT @single_polygon</pre>
<p>2 Highlight the code shown above and execute it.</p>

Figure 4: Instructions to create and display two spatial shapes using the UNION ALL operator

1. Create the following shapes using the `GEOMETRY::STPointFromText()` method and `STBuffer` method:



2. Create the following shapes using the `GEOMETRY::STPolyFromText()` method and the `UNION ALL` operator:

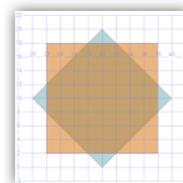


Figure 5: Sample exercises given to students

The knowledge that students gained from the creation and manipulation of GIS spatial data could then be used in combination with database Views, Stored Procedures and Triggers which are important components in order for students to develop a fuller understanding of relational database development. The next three sections discuss how GIS spatial data was used within the three relational database components.

4.1.1 Views

A View can be defined as “any *SELECT* query that has been given a name and saved in the database” (Jewett, 2006). Practice lessons for Views involved teaching the basic syntax and principles used to construct and execute them using TSQL. These increased in difficulty to include but not limited to, the extraction of spatial data and the use of spatial methods to work out distances between points and square areas of polygons.

4.1.2 Stored Procedures

Practice lessons for Stored Procedures involved teaching the basic syntax and principles used to construct and execute them using TSQL. A stored procedure is a set of SQL statements which get compiled into a standalone object which can then be executed when needed (Microsoft, 2014a). The

first Stored Procedures created in the lessons were simple, and displayed messages to the screen. Eventually they involved the use of spatial data. An example for inserting spatial data into a database table using a Stored Procedure is shown in Figure 6.

```
CREATE PROCEDURE udsp_insert_point ( @coordinates VARCHAR (MAX), @label )
AS
DECLARE @point GEOMETRY
SET @point = GEOMETRY::STPointFromText ( @coordinates, 0 )

INSERT geometry_points_tbl VALUES ( @point, @label )
```

Figure 6: Inserting spatial data using a stored procedure

4.1.3 Triggers

Microsoft (2014b) describes database triggers as “a special kind of stored procedure that automatically executes when an event occurs in the database server”. The practical instructions for Triggers focused on the logging of event data relating to the attempted dropping of database Tables and Views. The only relationship that involved GIS spatial data and Triggers was that the GIS component resided inside the Tables and Views. The event data that was stored into a table when an attempt was made to drop a Table or View included the current user, object name, attempt type and date/time.

4.2 2014 Assessment

Subsequent to the GIS lessons, the authors were interested to see if the students could take their database and GIS knowledge and apply it in a practical assignment. On completion of the practical exercises, a practical assignment was given that related uniquely to individual students residential addresses. This was to be completed within a three week period. The question contents of the assignment were in line with the BICT SQL curriculum and focused on assessing the student’s ability to implement quality processes in a Database Management System (DBMS). As Views, Stored Procedures and Triggers are all useful components for incorporating quality processes into a DBMS, the authors believed there would be a number of benefits of including the GIS spatial component, such as:

- A more enjoyable experience for the students, as they would now need to explore and obtain GIS coordinate data unique to their own living environment (see Figure 7). In previous assessments, students were given more traditional data in the form of customers, orders and products.
- The additional knowledge gained from acquiring their own GIS data, importing it into a SQL Server DBMS and applying spatial functions to that data to solve realistic problems associated with that data.
- As the student works through the assignment it was hoped that they would be able to recognise additional scenarios that the knowledge gained could be applied to real world scenarios. An example of this was the requirement to research into and find realistic uses of the spatial STIntersects () function.
- The inclusion of the GIS spatial component would not be difficult as the Views and Stored Procedures in particular are able to support its inclusion without affecting the data stored.
- As the data collected is unique to each student, the likelihood of copying someone else’s work is reduced.

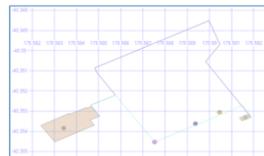
As in previous years for this assessment, students were required to present and discuss their code solutions in class with the lecturer. Students were graded on the successful execution of each question and how well they were able to answer questions surrounding their solutions.

You will require:

- At least five POINTS (i.e. your house, the nearest school to your house, and three or more road intersections on a route from your house to the school).



- Create a view called “VW_ALL_SHAPES” which displays all the shapes from all three tables. See example below. (3 marks)



- Using the linestring values stored in the *geometry_linestrings* table, create a stored procedure called “UDSP_SHORTEST_ROUTE IN METERS” that displays the shortest linestring length in metres. Hint – you will need the ToString () method. See example below. (5 marks)



- Create a database trigger called “TRG_PREVENT_VIEW_DROP” that will prevent the dropping of any view and display the following message: (3 marks)



Figure 7: Sample assignment questions

The same type of assessment in was given to students in previous years, as they contained questions regarding database Views, Stored Procedures and Triggers. Students were required to construct and execute SQL statements within these objects. The data provided for these assessments was provided by the lecturer and consisted of more traditional content such as customer, order and products.

Grading of these assessments was problematic since the data was the same for every student and it was often difficult to determine if the work produced was in fact their own. Grading consisted of sitting with each student and getting them to demonstrate their answers by executing each Stored Procedure, and View, and examining the logging of data which would have been caused by the Trigger. Students were expected to discuss aspects of the code to determine whether they understood it. This could be as simple as why a particular data type was selected for a Stored Procedure parameter or more complex such as what is the data type that holds the Event_Data() information when a database event is triggered (the Event_Data() function holds information including the name of the object that triggered the event or the system user who triggered it).

By requiring the students to obtain spatial data that was unique to their own residential address, as well as two or more roads that connected that address to the nearest school, the authors hoped it would lessen the likelihood that students would copy each other’s work.

Lecturer observations concluded that students were engaging in a positive manner, and were observed to be exploring ways in which to obtain their own spatial data. Verbal feedback from students during the assignment was mostly positive. This was encouraging as students who commented, found it good mix in regards to both interest and difficulty. This is also further confirmed by the survey results presented later in this section.

The authors anticipated that the 2014 assignment would be more difficult than in previous years because of the GIS spatial data inclusion. It required students to obtain data unique to them. It was also felt that some of the questions

might be harder to solve because there is less information on spatial data and MS SQL Server available. As an example, a question regarding a database View might have required students to understand the principles of table JOINS and aggregation to solve it. In this instance there is a lot more information available to them. This information is not as easy to obtain when the need to convert the GEOMETRY data type to GEOMETRY in order to obtain the length of LINESTRING's in meters.

The same approach to marking the assignment was done as in previous years. Because some of the assignment was unique to the student and the inclusion of spatial data was new, the authors were prepared for lower grades overall once the marking was completed. However, the final grades for the class were on par with previous years which indicated that the addition of GIS into the assessment was providing at least an equivalent learning and assessment for the students.

4.3 Student Feedback

The assignment feedback survey was completed by 17 students and provided some encouraging feedback with relation to the inclusion of GIS components into the curriculum and assessment.

The first question asked “on a scale of 1-10, how difficult did you find the assignment? (1 = very easy, 10 = very hard)”. The results for this question are given in Figure 8. The majority of respondents found the assignment relatively difficult, with the mean result being 7.36.

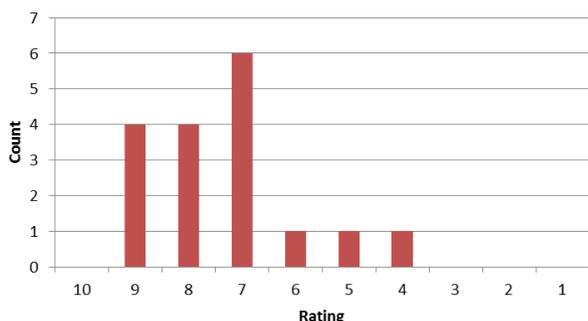


Figure 8: Assignment Difficult Rating

To accompany the scale difficulty question, students were also asked why they gave their difficulty ratings. Responses from two students who rated the assignment a seven were:

It took some time for me to figure out how to do the code to get some of the functionality happening. I really like how there are some easier, some harder, and some really challenging questions in the assignment. It gives a good spread and an opportunity for good students to challenge themselves while still allowing people to pass.

Was fun and challenging requiring self-learning to complete the task.

These responses indicate that the assessment was difficult, however in a positive challenging way.

The next set of questions examined student interest, the scale question asked “On a scale of 1-10, how interesting did you find the assignment (1 = very boring, 10 = very interesting)”. The results are given in Figure 9. Again, the majority of the class found the assignment interesting and the mean result was for interest was 7.

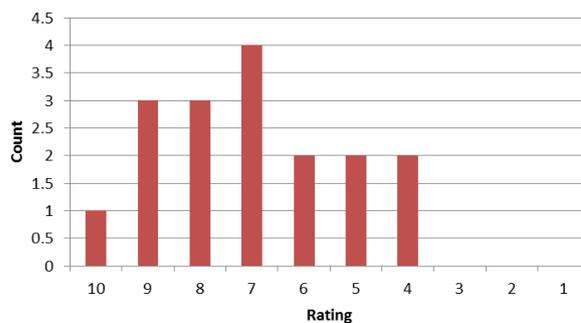


Figure 9: Assignment Interest Rating

The associated short answer question again asked why students had given the preceding ratings. Some of the responses included:

I haven't done much coding this year and I enjoyed the opportunity. Spatial data is something a bit different and I'm interested in maps, charts, navigation and geography anyway. I think working out how to make the challenging procedures work was the most interesting bit.

Even though it was a very tough assignment, I felt that it was still very interesting. It was fun to play around with the street maps and generate coordinates, then manipulate these in SQL.

Playing with shapes is much more fun than playing with dummy data

The responses tend to suggest that student interest levels were increased due to the use of spatial data in the assignment with the majority of respondents citing the mapping, shape, and geographic aspects as positives.

The next question corresponded to the previous in terms of interest, but instead asked “On a scale of 1-10, if the assignment did not involve the use of spatial data, how interesting did you think it would have been? (1 = very boring, 10 = very interesting)”. Interestingly, the responses were much lower with the class average being 4.88 (see Figure 10). Again when the results presented in Figure 9 and Figure 10 are compared a noticeable difference can be seen.

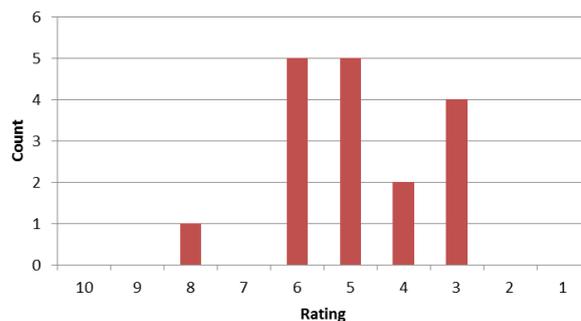


Figure 10: Non-spatial Interest Rating

Another corresponding question asked “If the assignment did not involve the use of spatial data, and instead only used standard data types (for example: dates, times, names, currency, etc.) would you have found it as interesting?” In response to this question four out of the 17 answered yes, while the remaining 13 answered no. Again, this supports the suggestion that the incorporation of GIS spatial data into the assessment helped increase student interest levels.

5. CONCLUSION

This paper set out to trial the increased use of GIS spatial data for the teaching and assessment of SQL within a level six database development course. The paper has presented an

overview of how practical lessons were developed and provided to students, as well as a summary of an associated summative assessment focused of the GIS and spatial data skills that were covered (this included the advanced use of spatial data in relation to Stored Procedures, Views, and Triggers). The lessons and assessment were successfully trialled with students and assessment results were found to be comparable with previous years. Furthermore, student feedback was also collected in relation to the GIS components of the course and was found to be supportive of the GIS inclusion. In particular, feedback tended to suggest an increase in student interesting levels due to the GIS components.

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