



Business Intelligence Dashboard for Academic Program Management

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On the research side, I have been fortunate enough to secure a number of grants and have served on numerous international Ph.D. Thesis committees, been a member of the editorial boards for 7 international journals, and served as the Chair and Co-Chair for 12 international conferences. For recognition of my research activities, I have been invited to a number of international conferences as Invited Speaker, chaired panel discussions and numerous international conference sessions. I have served on more than 150 international conference program committees. Furthermore, I have published number of articles in peer-reviewed international journals and conferences. I am also an active member of ACM, ASEE, ASEE/PSW and CSAB.

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Abstract

In higher education institutions, people managing academic program may require data and an efficient analysis of the data in order to make well informed decisions regarding program offering, courses offerings, class staffing, etc.. Implementing a business intelligence data dashboard could improve efficiency in data retrieval and optimize data analysis for program management decision making. The purpose of this paper is to present the research, design, and implementation of a business intelligence data dashboard prototype to meet some of these requirements. The dashboard implementation utilized database structure, using ETL procedures, university data was organized and stored in a data mart using in Oracle and managed with SQL queries to retrieve data for the dashboard. The prototype data dashboard shows different types of graphs and tables, even though there were some moderate limitations on overall design due to data complexities. Specifically, the dashboard contains nine different tabs, that can be filtered on the Classes By Term, Section Details, Instructors By Program, and Instructor details by course, by adjusting date ranges or selecting by criteria allows for better views of the data in the dashboards. We enabled automatic data queries programmed for dashboard visualizations, while most data visualizations used were standard, such as line charts and bar graphs. Future work could focus on streamlining the data preparation and automating the dashboard visualizations for even better efficiency in academic program management.

Introduction

At National University (a private, non-profit, WASC-accredited university), courses are taught in an accelerated format compared to traditional universities. Instead of taking multiple courses per semester, students at National University complete their academic program by taking one course per month. The undergraduate and graduate classes are offered either on-site or on-line, and span five schools and one college: the schools of Engineering and Computing, Business and Management, Education, Health and Human Services, Professional Studies, and the College of Letters and Sciences.

With the large number of courses offered monthly, and over 100 academic programs, managing program scheduling is quite labor intensive. As in traditional universities, staff members work with department chairs to plan program and course offerings for students. A series of sequential course offerings is called a program string, and students who enroll in a string together form a cohort. Additionally at National University, faculty serve as program leads and are responsible for managing the scheduling, staffing, and assessment of the monthly courses in their academic program. Assisting and mentoring students in a cohort is also a responsibility of the program lead.

Program and course data is currently managed using the Student Orientation, Administration and Registration (SOAR) database. The program leads manually use SOAR-generated reports and pre-built queries for making program scheduling and

staffing decisions. These reports include year-over-year comparisons of student enrollment by school, and the percentage of active students in class by school and campus location. Built-in queries also return results on scheduled, staffed, and unstaffed classes by subject over a specified time period. However, the existing method for retrieving and analyzing this data is time consuming since each query must be run separately. Each time a query is executed, multiple search parameters such as date range, academic program, and/or class catalog number, must be specified. Once a query is run, the data is displayed as a spreadsheet. The spreadsheet format of the data does not allow for efficient analysis, as the query results can contain hundreds of rows and numerous columns of text and numbers. This data then needs to be manipulated manually by creating pivot tables or graphs to aggregate or visualize the results. The data can only be compared and analyzed after multiple queries have been run and manipulated manually.

It is important for program leads to be able to staff and schedule their program for future strings based on data driven decision making. A viable solution to improve these decisions is through the implementation and use of tools like an integrated data dashboard, which optimizes the process of retrieving and analyzing data. A data dashboard can then provide accurate and concise information using interactive graphs linked directly to data sources. With large amounts of data being generated within a university environment, it can become overwhelming for faculty or program leads or administrative directors to gather and use that data to extract information that would help to plan a scheduled offering of courses in their programs. The main concern that arises for some of these program leads deals with the inefficiency involving routine tasks for acquiring the required data. Acquiring data has to be planned, queried from a database, reviewed for inconsistencies, and thereafter can be ready for analysis. This process can become inefficient as more time is spent finding useful data than actually making a better decisions from the collected data.

Using state-of-the-art data warehousing tools and data visualization methods, a prototype business intelligence data dashboard was created. This required combining and restructuring separate existing data sources to meet academic program lead requirements for program management. The dashboard is an efficient tool for making program management decisions such as optimizing course staffing with the best instructors, monitoring class enrollment, and optimizing scheduling sequences. This paper will also cover a discussion on supporting tasks leading to dashboard creation, including project requirements gathering, data preparation, data modeling, database design, and dashboard implementation.

Research Background

This section provides the need for our research, a background in the uses and benefits of data dashboards in higher education, the importance of data visualization, and best practices in data dashboard implementation. A review of existing literature identifies a need for research in academic data dashboard development, specifically pertaining to day-to-day scheduling and staffing operations for program management activities. While

complex visualizations are great to use, many academic institutions still utilize line graphs, bar graphs, or pie charts to represent their data¹. Additionally, since dashboards have evolved to include interactivity among the graphs or charts of their data, users can identify new metrics not easily observed before.

It has become worthwhile in this information age to consider what data visualization really is and what it has meant for data analytics in general. Data visualization is therefore considered as simply a technique for describing data in a visual manner. When we think of data visualization, there can be many different ways to interpret and define it. One such review simplifies it as being a representation of data using visual applications rather than traditional spreadsheet reports². It is a discovery tool that makes it easier for users to quickly make informed decisions by depicting patterns, relationships, and other useful information not easily seen with a table of data³. The main reason for data visualization is to efficiently show key metrics from a given set of data tables. However, data visualizations must be easily accessible to users if it were to be shared. In addition, it must be easily maintainable and at the same time quick and easy to develop.

Several previous studies have focused on identifying metrics to evaluate different aspects of higher education performance as far back as the early 2000's.⁴ College sustainability measures, such as financial ratios, student retention rate, admissions to applications ratio, and tuition rates by year are metrics that could then be used for reporting to accreditation boards. Later on,⁵ identified the metrics related to student affairs: student housing, facility work orders, engagement, and retention. However, these studies focuses only on performance metric identification for higher education that cater to university officials other than program leads. Furthermore, a recent dissertation identified metrics pertaining to organizational change in higher education, but the dashboard metrics identified focused on program justification, such as student completion rates, and the effectiveness of faculty-lead workshops⁶. Although program completion rates by students are of great interest to program leads, our research will focus on developing a dashboard for daily program management in the areas of class enrollment counts and end of course evaluations.

Other studies and articles have looked at developing scorecards for higher education. Dashboards and scorecards are similar in the sense that both visualize data, but they serve different purposes. Scorecards are used to evaluate progress towards goals or benchmarks, allowing academic administrators to see what is happening in their organizations. However, dashboards visualize data on performance, allowing users to see why goals are or are not met⁷. These studies are also unrelated to academic program management, as they focus on creating awareness for the use of balanced scorecards in university settings⁸.

Application of Dashboards in Higher Education

As the amount of data generated by universities has grown, new solutions are needed to combine different data sources and efficiently analyze information for decision-making.

Many universities have realized the benefits of dashboard implementation, including increased efficiency of analyzing operational Key Performance Indicators (KPI), such as financial information and quality of staff service, which are more related to executive management than program performance. Over the past decade, dashboards have delivered a number of benefits to universities in the United States and beyond, including the ability to efficiently analyze key performance metrics and financial information. Dashboards are particularly useful because of their ability to summarize massive amounts of data visually.

In the early 2000's, Richland College implemented a spreadsheet style executive dashboard for assessing key performance metrics. Dashboard metrics, as shown in Table 1, included meeting community education needs, student success, employee success, implementation of technology for learning/operations, and improving the effectiveness of college functions⁹. As a very basic design, this dashboard scores five KPI's on a scale of 1 to 10, thus allowing college upper level management to quickly evaluate the university's performance by looking at the index score. The upper management can then drill down and see which KPI's were responsible for the change in monthly performance. Richland used these metrics until 2007, but the structure of their dashboard had evolved, adding visual cues in the form of traffic lights to allow for faster analysis¹⁰.

Table 1. Richland College Data Dashboard⁹

Strategic Priorities for Student Learning		
Key Performance Indices (Weighting Factors)	Monthly Score	Change from Previous Month
Richland College Monthly Key Performance Index Score	9.7	+0.6
Respond to Community Education Needs (20%)	9.9	
Enable Student Success for All Student Groups (35%)	9.9	
Enable Success for All Employee Groups (15%)	9.0	+0.4
Implement Purposeful and Economical Use of Technology to Enhance Learning and Operations (5%)	10.0	+0.3
Improve Effectiveness of College Functions (25%)	9.5	+1.6

In the year 2000, The University of California (UC) realized that it would need to make changes to its business architecture to accommodate its projected influx of future enrollments. Since the increased enrollments would require more funding for staff, buildings, technology and finances¹¹. In response to this need for change, UC rolled out a system wide financial dashboard in 2003 (shown in figure 1) to combine and share data from its separate campuses¹⁰. Apart from the UC financial dashboard, UCSD offers university managers separate dashboards that are linked to its university data warehouse. These dashboards focus on user self-service, thus allowing users to create their own reports. Users like customization options such as sorting data by category and time frame and appreciate that the dashboards are updated whenever a user logs in¹⁰. Another UC, The University of California, Irvine (UCI) required a self-service reporting solution to ease the strain that custom reports placed on its IT department¹².

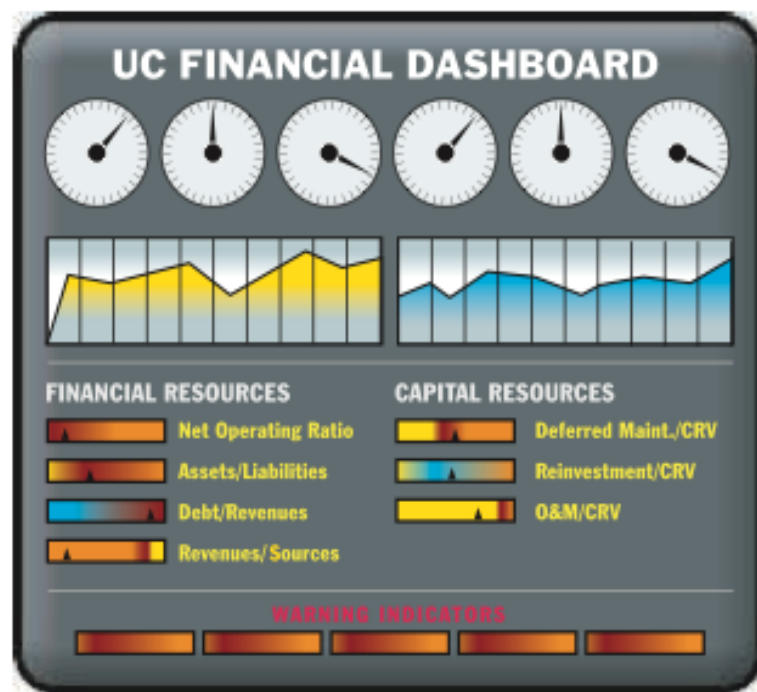


Figure 1. Example UC Financial Dashboard¹⁰

A broader approach to higher education dashboards comes from The Oklahoma State Regents for Higher Education, in an effort to graduate more students, make funding decisions based on data, and respond to government and public demands for reporting. The Oklahoma State Regents implemented a state-wide dashboard (shown in Figure 2) containing data from 25 public and private universities¹³. This dashboard offers filters, pie charts, and bar charts, shown as 1, 2 and 3 respectively. The filters add customizable options for users for viewing data of their choice. As a result of implementing this dashboard, The Oklahoma State Regents have been able to provide data to public on demand, make better funding decisions, and have improved their efficiency of operations¹³.

The University of Texas (UT) also consolidated its data reporting through dashboards. In an effort to analyze data against benchmarks and provide public access to data on its nine universities, the UT system partnered with statistics software vendor SAS to create a visual dashboard and analytics solution. Connected to UT's data warehouse, the productivity dashboard visualizes data on student enrollments, number of degrees awarded, student/faculty ratio, research expenditures, and cost of a 4 year degree. Figure 3 below shows one of the pages from UT's productivity dashboard. The new interactive dashboard benefits UT by offering on demand access to data, user self-service in the forms of filtering, for better decision making. The dashboard has been such a success that other departments such as risk management, university police, and compliance officers are asking for dashboard solutions to improve the efficiency of their operations as well¹⁸. The benefits of efficient dashboard reporting are not limited to colleges within the United States. Other countries are also realizing the benefits of efficient reporting. The University of Witwatersrand (UW) in Africa needed a method to communicate complex financial information from a number of sources to its executives thus dashboards were chosen as the solution. A survey of the executives using any form of dashboard for their operations found that more than 70 percent agreed dashboards had a positive impact on their decision making process, largely due to the efficient access of information¹⁴.



Figure 2. Oklahoma State Regents Dashboard¹⁵

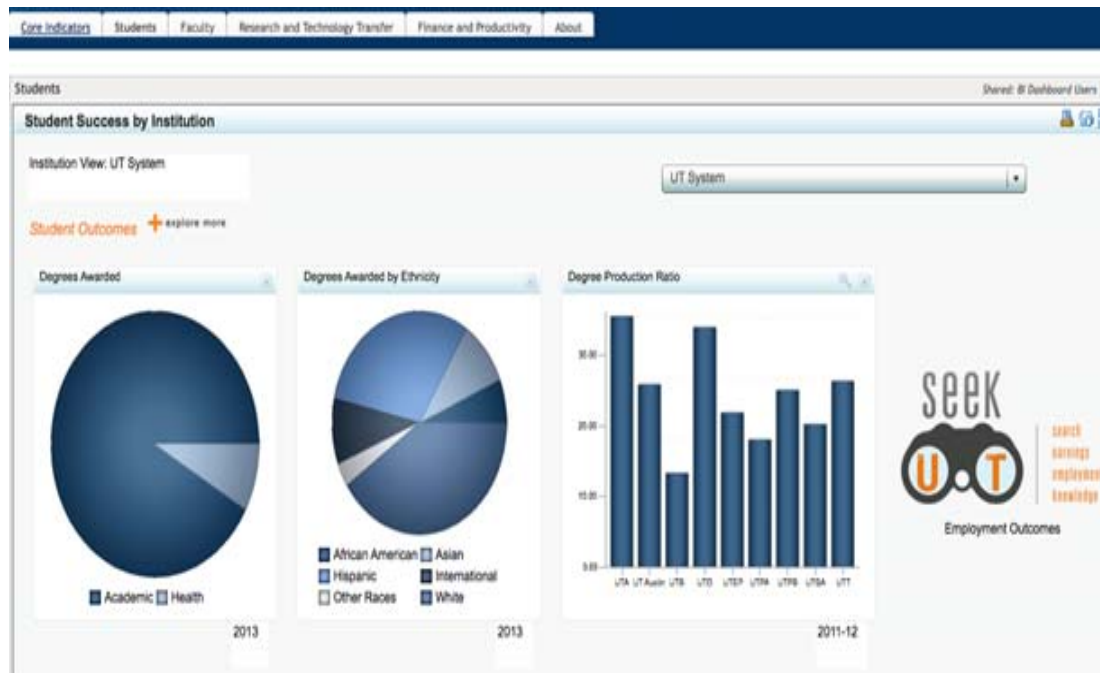


Figure 3. UT Productivity Dashboard¹⁶

Proper Dashboard Implementation Practices

Based on data visualization, and industry best practices in data dashboard implementation, successful dashboard design and implementation in higher education is attainable. In this section, the comparison of different software (database) options that are beneficial for creating and implementing a prototype data dashboard for program management is used to explain our data model and database coding. This section also explains our dashboard requirements, dataset, and methodology for constructing data model, and coding database schema. Finally we identify and clarify the reasons for using Tableau software as our dashboard design tool.

Like any other Business Intelligence (BI) project, requirements are gathered to determine and clarify the purpose and objectives of this project. In our case the purpose of the dashboard is to enable program leads to efficiently analyze program and course data for the purposes of making class schedule and staffing decisions based on class enrollment, and identify the best instructors to staff specific classes. Following are requirements that are gathered for this project.

Requirements of Different Data Dashboards

Program Strings. We have multiple starts a year for our programs, some programs starting 3 to 4 times per year, with each new start identified as a unique string. Therefore, we need line graph showing all courses scheduled by a particular string, where the courses appear as dots along the lines, color coding used to differentiate various strings.

In addition, options to filter all strings by date range, location and/or program were required. Basically, when the mouse cursor is placed over a class, a popup window should display the program name, month, class name, class location, instructor's name, and instructor's email address. Specifically, data dashboard for program strings should include the following items;

- A bar chart showing the average class size for the entire string in the program, where each bar is colored according to the string
- A table showing all unstaffed classes in a particular string
- A table of instructors who have previously taught the class should be shown, if these instructors are available to teach for the selected class and month, when an unstaffed class is selected from the dashboard
- A table of all classes with zero enrollment, with an additional option to filter the list by string identification

Classes by month (Term). Program leads need to make decisions each month regarding scheduling and staffing of courses. The data dashboard for monthly classes should include the following items and functionalities:

- A table of all classes offered in given month, with the course abbreviation and course number
- A line chart showing the average class size (enrollment) per month, where the months appear as dots along the line
 - When a user clicks on a class section from the class list, it shows the instructor name and instructor's email address
- A bar chart of the enrollment count by section, where the bars are colored by string number,
- A line graph showing the enrollment trends of a class over time
 - Options should be available to filter the data by date range and string number.
- A table of instructor information, including all of the class sections a particular instructor has taught and the status of the course evaluation (available or unavailable)
 - When the mouse cursor is placed over an instructor's name, a popup window shows their email address
- A bar chart of the average GPA for each class section, where the bar chart is colored by string number
- A bar chart of the average assessment of teaching for each class the instructor has taught, where the bar chart is colored by string number.
 - Options should be available to filter the results by the availability of course evaluations

After gathering and clarifying our requirements, the next step is to choose a dashboard creation software tool. Tableau is an industry leader in data visualization and dashboard software, ranking highly among its competitors in a variety of areas. A yearly study conducted by the Business Application Research Center (BARC), determined that

Tableau ranked best among its competitors in 19 of the 42 studied key performance indicators, including the following: dashboard vendor in business benefits, ad-hoc analysis vendor in business benefits, visual analysis and data discovery vendor in business benefits, visual analysis and data discovery vendor in goal achievement, and visual analysis and data discovery vendor in data volume¹⁷. Tableau has two types of User Interfaces (UI), one for creating worksheets, and a second for creating dashboards. Visualizations and tables are each created in separate worksheets and the worksheets are used to build the dashboards. Tableau’s worksheet UI contains seven object types as identified in Figure 4 below.

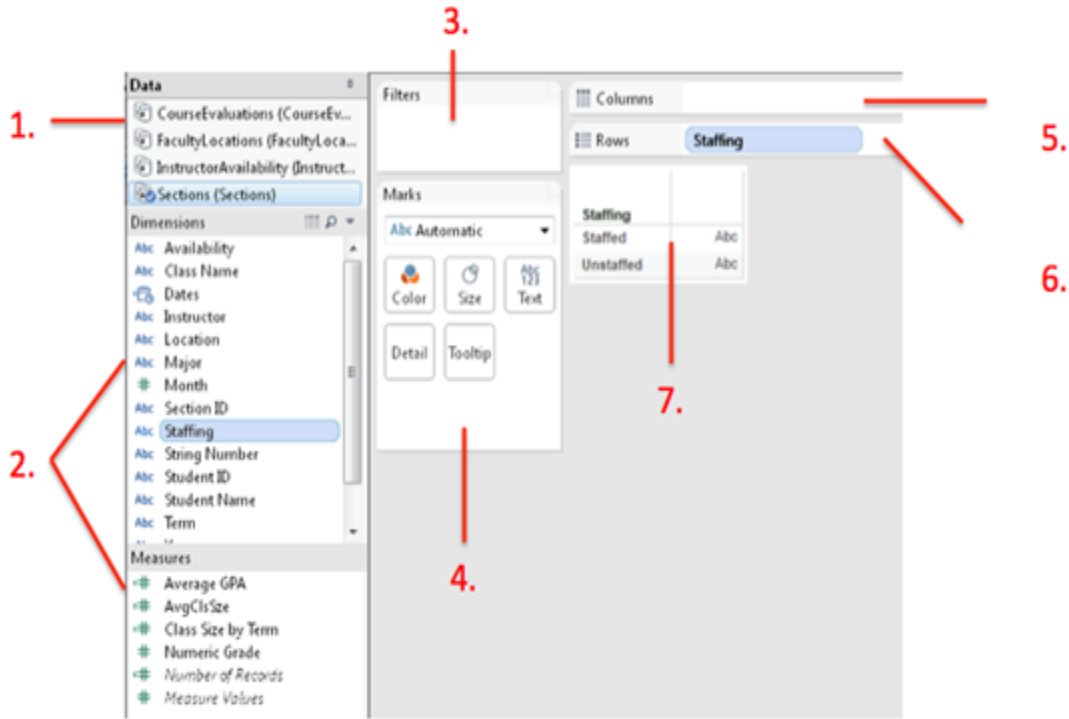


Figure 4. Seven Object Types in Tableau’s Worksheet UI

As shown in figure 4 above, the worksheet UI contains tables (1), attributes (2), filter controls (3), mark controls for color, size, text, detail, and tooltips (4), a columns shelf (5), a rows shelf (6), and the worksheet view (7). Attributes are added to the rows shelf, columns shelf, and mark controls to create visualizations and lists. When an attribute is added to any of these 3 shelves, it is known as a pill due to its narrow shape with rounded edges. The Staffing pill is seen in the rows shelf of item (6) from figure 4 above. Once a worksheet is created, it can be added to a dashboard using the dashboard UI.

Implementation

The purpose of this project, as described earlier, was to research, model, and implement a prototype business intelligence dashboard for program management at XXX University. Figure 5 shows a database schema (top) that was used to implement a database to organize essential data and link up to the completed data dashboard (bottom). By using

Extract, Transform and Load (ETL) procedures, university data was organized and stored in a data mart using Oracle software that was linked directly to Tableau for dashboard design. The creation of a data link between the database and the Tableau dashboard enabled automatic data queries to be programmed for dashboard visualizations. While most data visualizations used are standard, such as line charts and bar graphs, the design met the requirements for visual data analysis and users are able to navigate and manage specific data metrics by using their mouse cursor within each tab. By default, all data measures for required items are shown when the dashboard initially starts. Utilizing different filtered views by adjusting date ranges or selecting criteria allows a better view of the data in the dashboard. Other data visualizations are displayed as Pop-up tool tip windows when using the mouse cursor throughout certain parts of the graphs or charts.

Once the data schema has been implemented, it can be loaded into Oracle database. The data is in file formats of comma separated values (.csv) for each table that corresponds to database schema in Oracle. Tableau connects very easily to Oracle to link data together between both platforms. Tableau uses a connection bridge that has several built in drivers for a variety of different database solutions. Oracle Database 11g is among the simplest database management systems that Tableau can interact with by opening Tableau and clicking on the option “connect to data.” The results of our dashboard are organized into 9 tabs at the bottom of the dashboard window, each corresponding to a section of our sponsor’s requirements. As shown in figure 6 below, the first 5 dashboard label tabs are shown followed by the remaining 4 in figure 7. The resulting dashboard for the first item is shown in figure 8 below. The average enrollments by class, string, and month are shown on the top graph and the average class size by string is shown in the bottom bar chart. Filters on the right allow for adjusting date ranges, class location, and program types. Additional details for each visualization are described in the following figures. Figure 9 below displays the line graph and average class size dashboard that shows program strings from January 2010 to December 2016. The x-axis is labeled as “Month of Date” and the y-axis is labeled as “Avg. Enrollments”. Each colored string on the line graph represents a set of courses for a particular program. While the data strings on the graph are initially complex, visual improvements can be made by using the filters displayed on the right (1, 2, 3, 4). As shown in figure 9, the date range of the graph can be adjusted by utilizing the date range filter (1) in order to condense and display less strings at one time. Additionally, class strings can also be filtered depending on whether they are onsite or online utilizing the location filter tab (2) Furthermore, strings can be filtered by program (3) bachelor’s or master’s program in information systems. Lastly, strings can be identified by their associated color and ID as shown on the string ID tab (4).

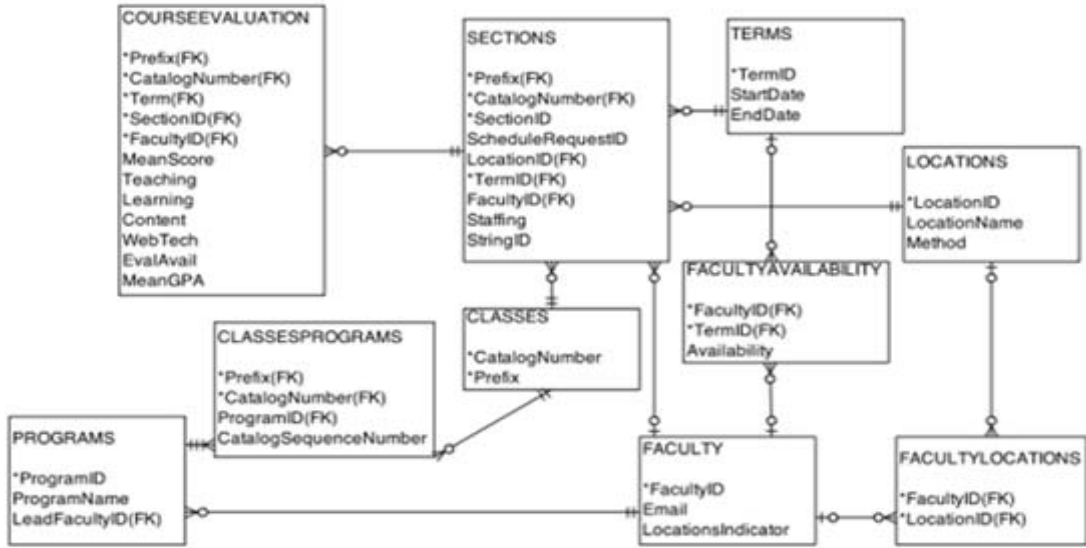


Figure 5. Data Model to Dashboard

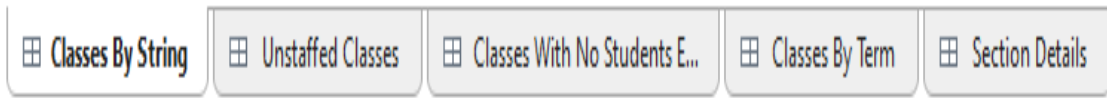


Figure 6. Dashboard Tabs 1-5



Figure 7. Dashboard Tabs 6-9

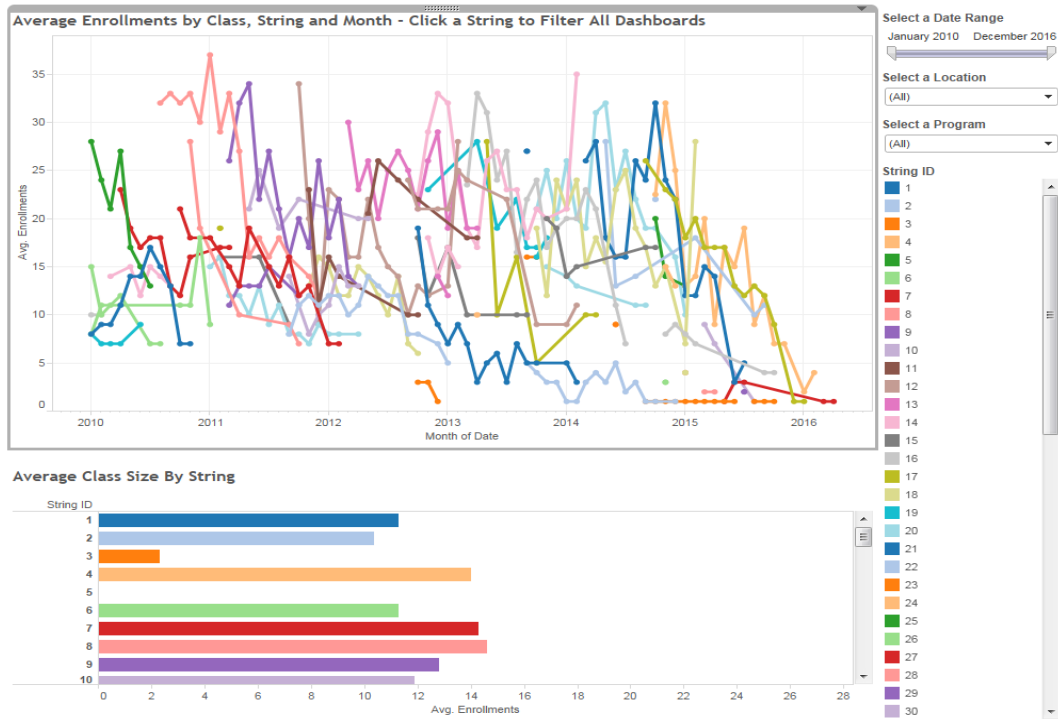


Figure 8. Classes by String Dashboard Result

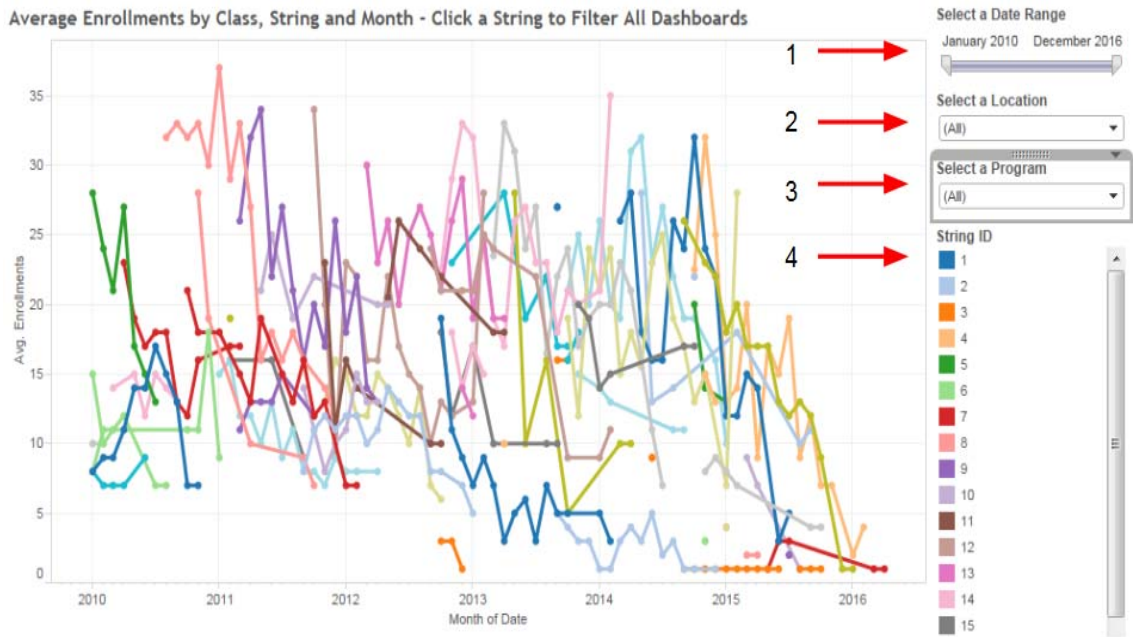


Figure 9. Classes by string Visualization

For example, a user is interested in analyzing strings between March 2011 and April 2014 for online classes in the master’s program of information systems. By adjusting each filter to suit requirements, the line graph transforms the visual as shown in figure 10. Once filtered, the resulting String ID’s: 30, 31, 35, 37, 39, & 40 are shown by their associated color and listed on the right side of the graph.

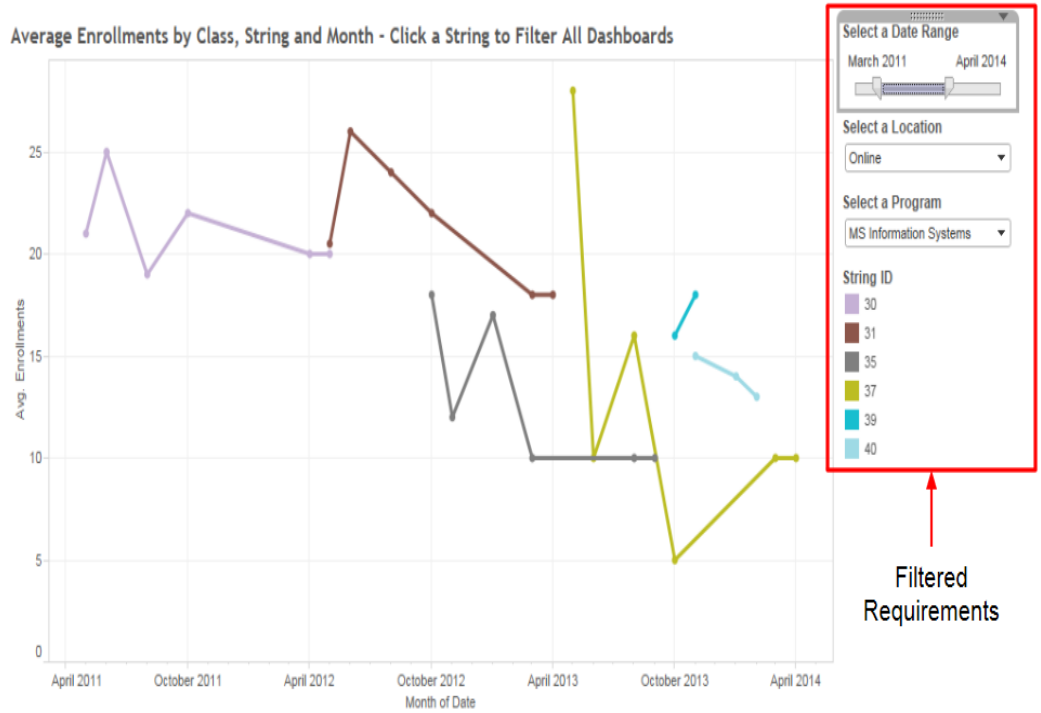


Figure 10. Filtered Classes by String Example

Continuing our example from figure 10 above and clicking on a specific string on the graph displays additional data metrics in a popup tooltip window. When a user clicks on one of the dots of a string representing a class, a tooltip window with program, term, class name, location, instructor, and email information is shown. As shown in figure 11 below, clicking on the class dot for March 2013 highlights string ID31 on the graph and a tooltip window is displayed.

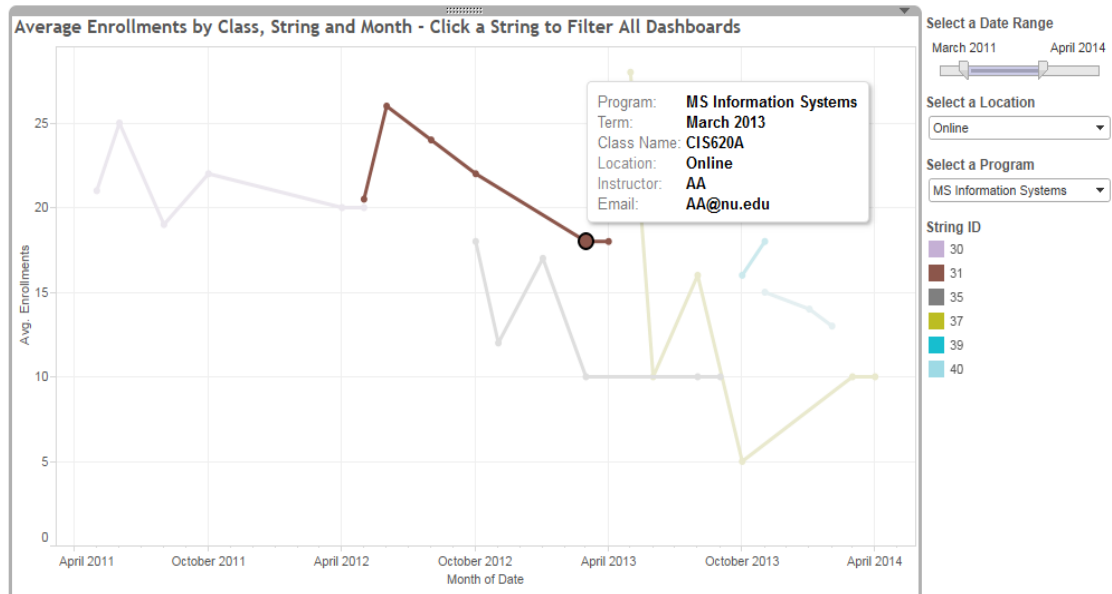


Figure 11. Class String Tooltip Example

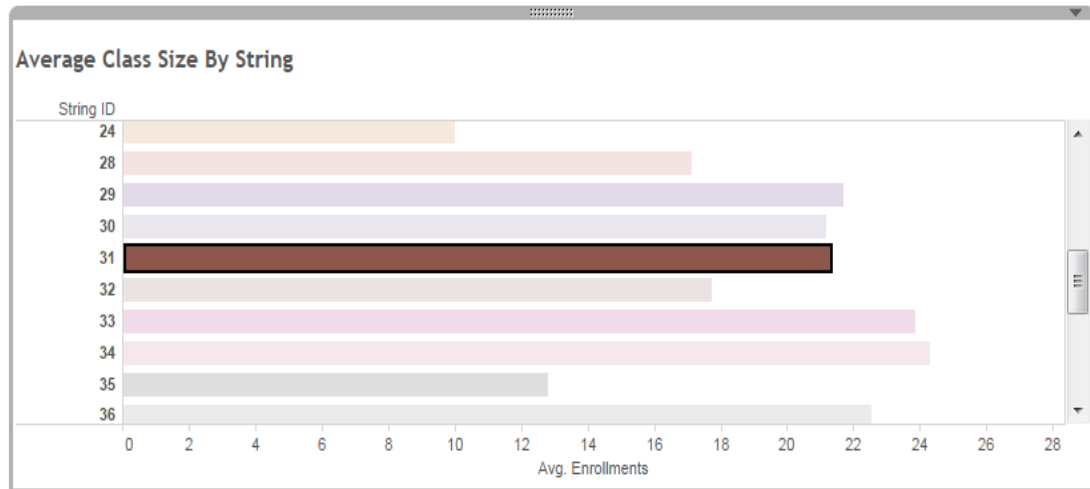


Figure 12. Average enrollment counts for a particular string

The tooltip window shows that the class selected is named CIS620A and was instructed by instructor ‘AA’ with email: AA@nu.edu. Furthermore, the tooltip window verifies that the program and term labels are accurate, for the filtered options used for this example. Additionally, approximate average enrollments for a particular string is visualized by a bar chart as shown in figure 12. The x-axis is labeled as “Avg. Enrollments” and the y-axis is labeled as “String ID”. As a requested requirement, this chart is used in order to make quick visual references to the approximate average enrollment count within the same dashboard.

Following with our example in this section, figure 12 above displays the bar chart with String ID31 highlighted, and shows that approximately 21 is the approximate average student enrollment for this string. However, if exact enrollment counts are essential then another dashboard item can address that requirement. The unstaffed classes table is created by adding the Term, Class Name, Section ID and Location pills to the rows shelf. The Instructors pill is added to the filter control to only show classes without an instructor. Then, the instructors by class and location table is created by adding the Instructor, Class Name, and Location pills to the rows shelf. The Instructor pill is also added to the filter control to remove instructors with null values from our instructors table. Next, we add the unstaffed classes and instructors by class and location worksheets to a new dashboard page. Then, two filter actions are enabled on the Unstaffed Classes dashboard. Both actions are set to filter the instructors by class and location table by clicking on a class in the unstaffed classes table. Class Name and Location are set as the filter attributes. The results for both tables are shown in Figure 13 below, with all unstaffed classes listed in the table to the left. When clicking on a specific blue box for a particular course, instructors who taught the class in the past are displayed to the right. For example, clicking on the blue box (1) for CIS330 provides the instructor names and their location who have taught this class in the past displayed by the table to the right (2). With this information, it enables possible options for staffing any one of these instructors for CIS330.

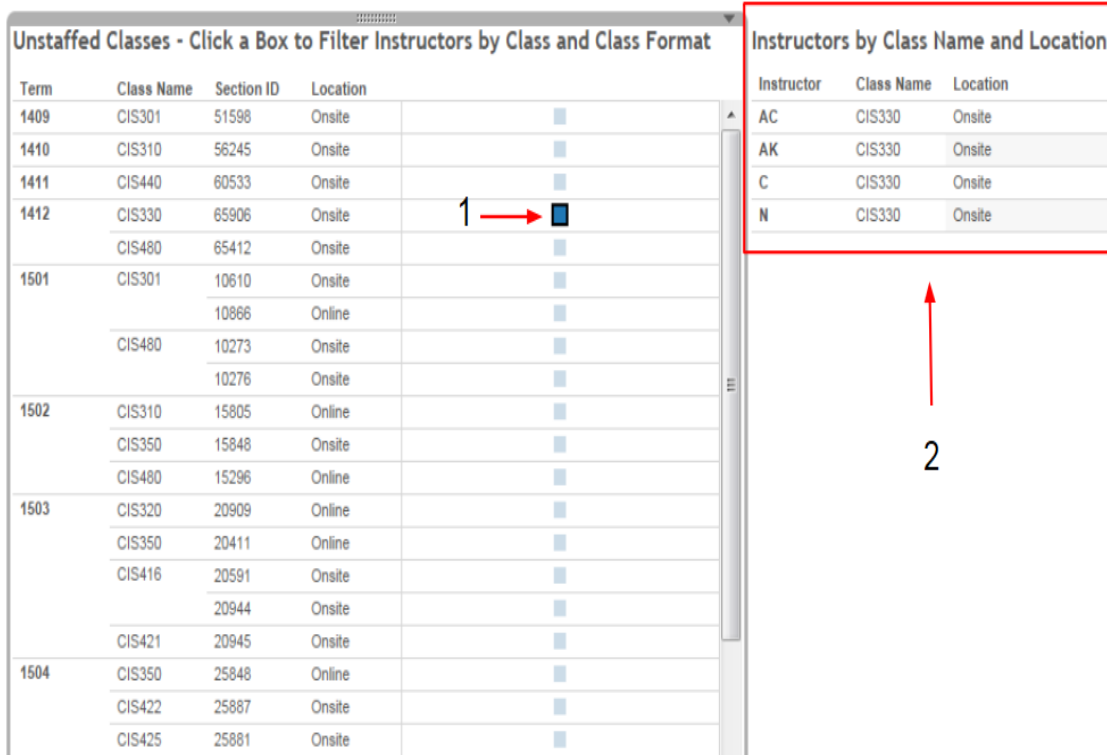


Figure 13. Unstaffed Classes

Limitations

Overall, the completed dashboard design incorporated data visualizations that addressed requirements for visual analysis. While requirements were satisfactorily met, moderate limitations did arise throughout the implementation process in our source data, dashboard software, and variety of data, which may affect the reasonable presentation of program metrics, technical capabilities of our dashboard, and complexity of visualizations.

Course datasets contain 491 unique courses; however, reliable course evaluation data is only available for 193 unique courses. The missing data restricts our calculations of mean evaluation scores and mean course GPA to classes with available course evaluation data, which may not reasonably represent the true mean evaluation scores for classes and instructors and the true mean GPA for courses and instructors' teaching assessments.

As with mean evaluation scores and mean course GPA, limitations also exist for course string ID's, which were manually entered in the dataset by following class sequences from the course catalog. Next, some course sections in the source datasets had attributes indicating that they were combined with other course sections. However, matching courses by term, course name, and instructor were not available for all combined course sections. All courses with the combined attribute were included in our prepared dataset as unique classes.

Finally, while the data we received allowed us to display information on many important metrics, such as course GPA, course evaluations, and instructor availability, there are

other metrics, such as retention and graduation rates, that program leads must analyze on a regular basis to manage their programs. Student retention and graduation data was not included in our dataset, so this information cannot be displayed in our dashboard.

Our dashboard combines data from course schedules and course evaluations, providing more information to faculty than any single query or report. However, our dashboard contains 7 years of course data for over 60 program strings, which adds complexity to our visualizations, as shown in figure 14. Figure 14 also shows the number of course strings and line colors make analysis of the unfiltered chart difficult, due to the large amount of information shown in a single graph. Additionally, our dashboard contains 9 different tabs, which can be filtered by using the available filter controls for a specific page or the drill down options on the Classes By Term, Section Details, Instructors By Program, and Instructor Detail By Program dashboards. While the filtering options allow for end user customization, they add complexity in understanding what information our filtered visualizations show.

Conclusion and Future Study

This project aimed to improve the efficiency of repetitive tasks and optimize the data analysis for program leads through data visualization. The necessary elements from separate queries are restructured and loaded into a new database schema to support the requirements of the data dashboard. Integrating the results of separate queries into a new database schema and providing a visual dashboard user interface improves the efficiency of data retrieval, analysis and decision making for program leads. Restructuring the data combines the different query results into a single location, eliminating the need to manually run separate queries. The dashboard view displays aggregated data visually, eliminating the need to manually create charts from queries. The dashboard also allows for dynamic filtering, which updates all relevant chart information with a simple mouse click, eliminating the need to rerun a query with new search parameters.

Our dashboard is created for one program lead and contains two programs, with undergraduate and graduate courses. However, National University has more than 100 programs. Future studies could involve building a single dashboard that supports multiple programs, where defined user permissions restrict dashboard views to only the data that applies to a specified user. Another potential area of future study is to publish a program lead dashboard to a server or SharePoint website, with the necessary security features to protect the data. Future studies could also apply automated ETL procedures between source data and the dashboard database, improving the efficiency of our manual data preparation methods. Furthermore, our study could be reproduced with a different dashboard tool that does not have Tableau's limitations. Finally, we examined only a sample of the metrics that program leads require to manage their programs. Future studies could research dashboards focusing on different metrics, such as student retention, graduation rates, and average time to graduation.

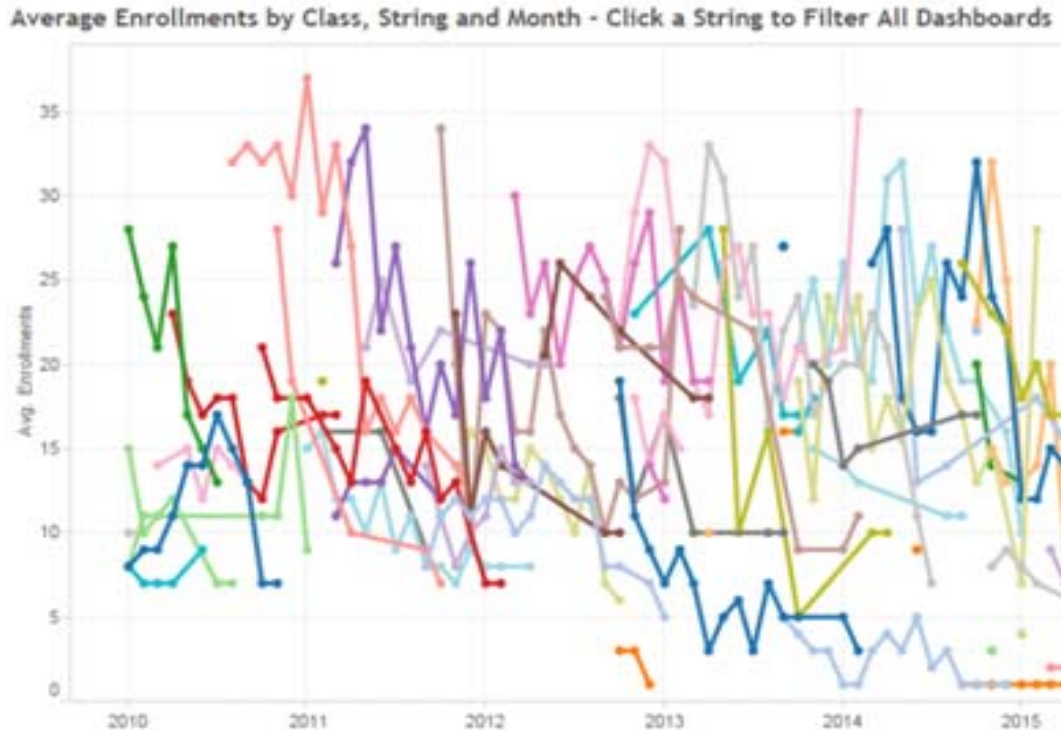


Figure 14. Visual Complexity of the Courses By String Dashboard

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