Geographic Distribution of STEM Degree Return on Investment

CAPSTONE PROJECT

MGIS Program

The Pennsylvania State University

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Abstract

Over the last decade, U.S. educators and politicians have focused on addressing the workforce deficit in the areas of science, technology, engineering, and math (STEM). However, some recent studies indicate the STEM labor crisis may be overstated. Certain fields and geographies actually show a surplus of STEM workers, promised jobs are in some cases not available, and return on investment (ROI) is often prohibitively long. The findings of these studies are typically presented in tabular and chart form and are categorized by major grouping (e.g., engineering, physical sciences, etc.). My project attempts to inform the STEM debate by providing a web application to explore the geographic distribution of employment opportunities and salary ROI for a wide array of STEM majors. Data from the Bureau of Labor Statistics and the National Center for Education Statistics were compiled to calculate the approximate number of years it will take to earn back the total tuition cost. This paper describes the data and technologies used to build the application and demonstrate how potential users (e.g., college-bound students and policy makers) can use the interactive maps and charts to better inform their decision-making.

Keywords: STEM, Geography Education, web application, jobs, ROI

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1. Project Background and Objectives

1.1. Project Background

On February 2, 2006, President George W. Bush announced the American Competitiveness Initiative (ACI) (Bush, 2006). In response to the growing global economy and labor market demands, the ACI introduced new standards for evaluating science, technology, engineering, and math (STEM) education programs. Building on these efforts, President Barack Obama secured $1 billion in private investment for STEM education (Handlesman, 2016). Clearly there is bi-partisan government support for increasing the number of qualified STEM teachers and college graduates. According to the Bureau of Labor Statistics (BLS), the United States will create an estimated 9 million new STEM-related occupations between 2012 and 2022 (Vilorio, 2014). These new jobs are a critical component of the new knowledge-based economy, yet the average US K-12 student lags behind other countries on standardized science and math tests (Roberts, 2017).

However, despite over a decade of governmental studies on STEM, there are a number of researchers that believe the predicted STEM labor crisis is overinflated, the promised jobs are simply not available, or that the cost of tuition does not justify the early-career return on investment (ROI). STEM covers a wide array of occupations and while some fields experience a deficit of qualified workers (e.g. nuclear and electrical engineering), other fields such as biology have a surplus.

According to Harvard Law School Senior Research Associate Michael Teitelbaum, the United States has experienced five STEM-related cycles since the 1940s. These cycles follow a similar pattern: a clarion call for STEM workers is sounded, more students are educated in these fields, a surplus of graduates flood the market, and interest in STEM fields wain. This is a serious consideration for the nearly 70% of college students who graduate with student loan debt (Hershbein, et al., 2014).

1.2. Project Objective

To help students determine the potential financial costs and benefits of majoring in a STEM field, the available data needs to be presented in succinct format. More than general nationwide STEM job predictions, students need the ability to analyze STEM salaries, employment outlook, and job market saturation for each major by geography. Previous studies have compiled related information by state including tuition costs, starting salaries for popular STEM majors, as well as calculated ROI for a general college degree program. These studies aggregate the costs and benefits of STEM majors at the state or individual university level but do not analyze the ROI for each STEM major. Less popular majors such as Geographic Information Systems (GIS) are often overlooked in STEM research. And although college graduates majoring in STEM fields tend to earn higher salaries, salaries within the same field vary greatly by geography (NACE, 2016).

This project builds on the existing body of knowledge on this topic by developing an interactive web application (app) that combines tuition rates, job opportunities, and graduation rates to calculate a simplified ROI for every undergraduate STEM major by state. The purpose of this exploratory tool is to help high school and college students find answers to three main questions:

- Do the early career earnings for a given major justify the tuition at a specific university?
- What is the return on investment in a given major by state?
- Is there a surplus or deficit of graduates for a given major around the country?

By providing answers to these questions in a single resource, students will be able to assess their ability to pay back student loans and the likelihood of finding a job in their major based on geography.

1.3. Project Approach

The following sections include a literature review of previous works, description of the data sources and methodology used, web application interface, technological approach, user testing results, and areas for future research.

2. Literature Review and Previous Work in Analyzing STEM Job Market Trends

2.1. Summary Review of Previous Academic Publications

The value of a college degree in a STEM field is well-documented (NACE, 2016). What is less understood is the geographic distribution of finding a job in a STEM major, earning potential, and the time required to earn back tuition costs. This section reviews some of the recent studies and web applications related to job market trends for college STEM majors.

In 2015, Georgetown University published a report on the *Economic Value of College Majors*. The report analyzed the 2013 entry-level and mid-career earnings for seven categories on a nation-wide scale. College majors were aggregated into STEM, business, teaching and service, health, humanities, career-focused, and social sciences. The report revealed several key findings:

- Not all Bachelor's degrees are created equal. STEM and Health majors earned more than Humanities majors. This earning gap grows over the span of a career.
- STEM and Business majors are among the highest-paying majors.
- Nearly all of the highest-paying majors are in engineering.

The report's major contribution is the comprehensive calculation of expected earnings for each college major. It, however, stops short of breaking down these earnings by geography (Canevale, 2015).

A slightly older Georgetown University report (Carnevale, 2011) found that while STEM majors have a bright financial future, there is a workforce shortage. "High and rising wage premiums are being paid to STEM workers in spite of the increasing global supply. This suggests that the demand for these workers is not being met…the demand for workers in STEM occupations is increasing at every education level."

Robert Charette of the The Institute of Electrical and Electronics Engineers (IEEE) however has a different view on the looming STEM worker shortage – it is a myth. In his 2013 article, he states the following:

- New college graduates through late career STEM workers are struggling to find employment due to layoffs at large tech companies.
- The Georgetown study (Carnevale, 2011), projected a steady STEM job increase from 2010-2018. It did not take into consideration the Great Recession and therefore over inflates the STEM workforce shortfall.

Although the IEEE's view represents the minority of the literature reviewed on this subject, these considerations are important to college students choosing where to attend college. The economic repercussions of the Great Recession were not equally dispersed geographically and job opportunities vary greatly by state.

2.2. Summary Review of Related Web Applications

The ability to quickly pay back student loans may be an enticing reason for students to major in STEM according to *US News* (Broman, 2012). The chart in Figure 1 is a web app from The Hamilton Report that enables users to compare earning potential across various education levels and STEM degree options (Hershbein et al., 2014). Although comparing lifetime career earnings by major may encourage some students to continue their education beyond high school and major in a STEM field, it does not take regional salary differences into consideration.

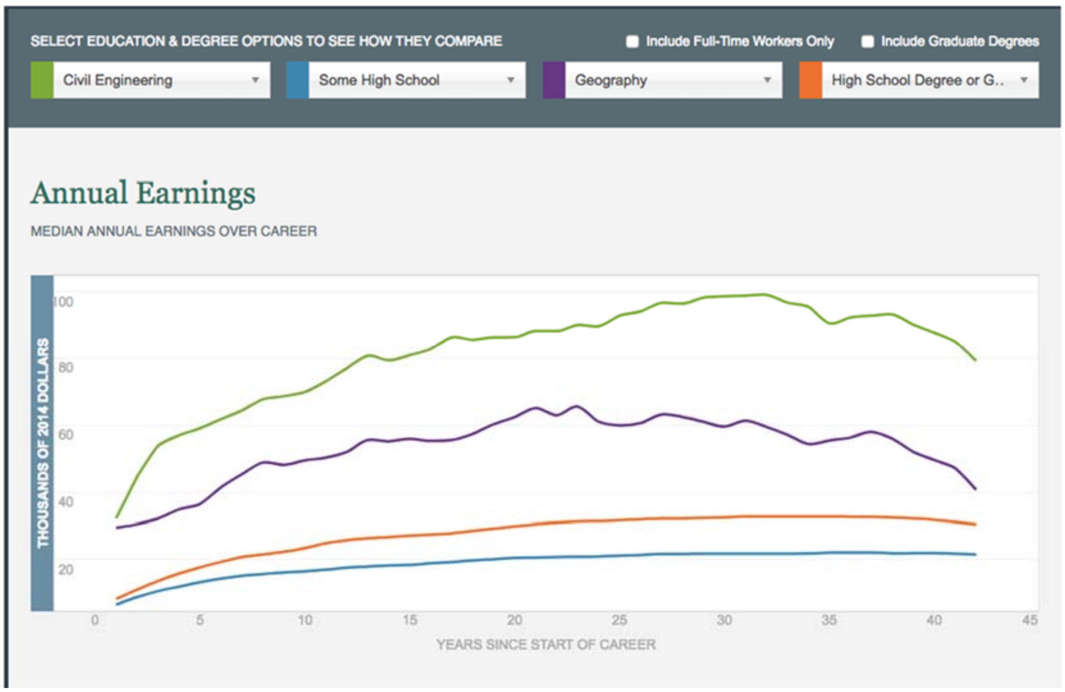


Figure 1. Interactive chart from The Hamilton Report shows an example of the disparity between a STEM degree, a non-STEM degree, some high-school education, and a high-school degree.

Compensation analyst company, Payscale, developed an interactive web app that combines many of the features discussed earlier (Figure 2). The Mapping College ROI app (2014), produced a choropleth map visualization that calculates the percentage of STEM graduates and the 20-year ROI for selected colleges by state. While this web application does provide the cost of tuition and calculates the ROI by college on a statewide basis, it does not include employment forecasts or salary ranges by STEM major. However, the basic functionality of this web application served as inspiration for this project's web application.

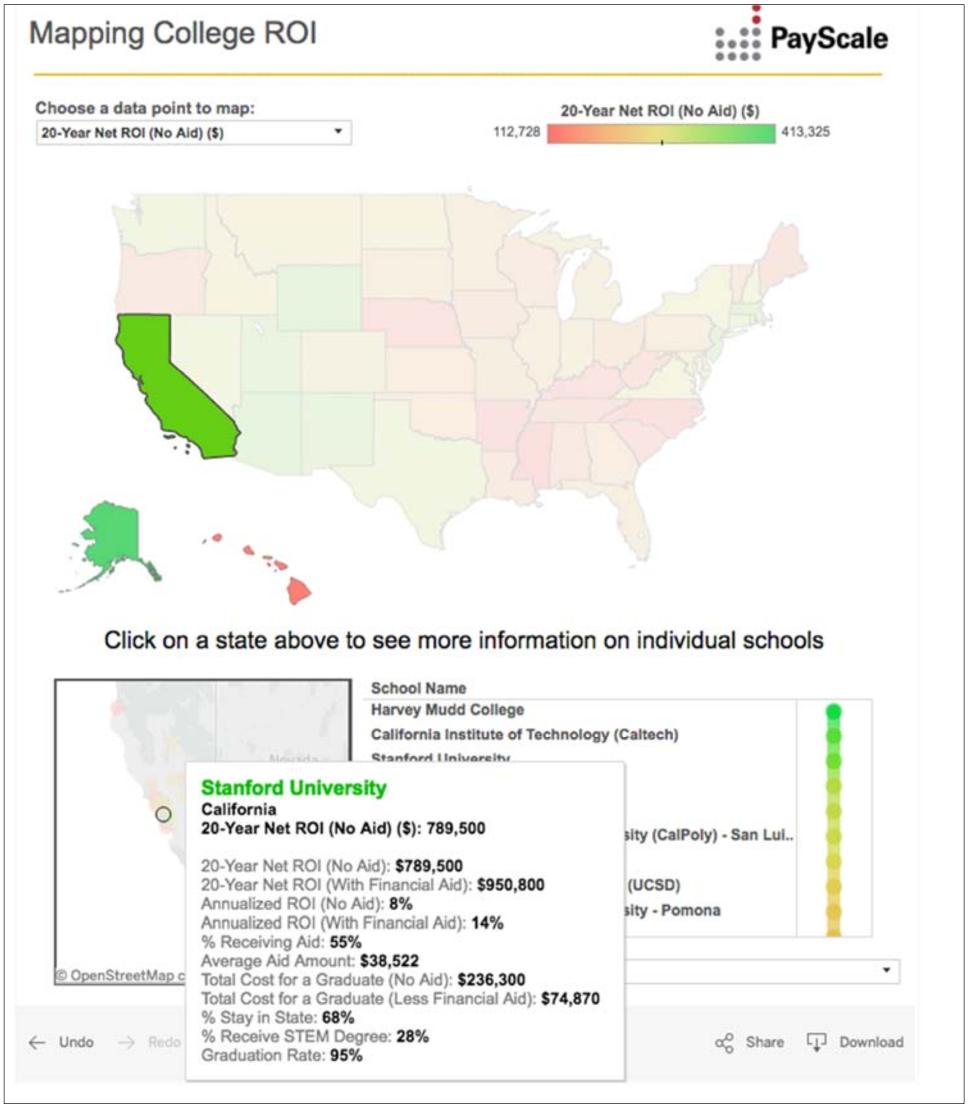


Figure 2. Web application developed by Payscale, which displays the financial return on investment for selected colleges in each state.

Similarly, *The Economist* developed a chart illustrating which degrees give the best financial returns (2015). Using data from PayScale and the National Center for Education Statistics, the scatter plot compares the 20-year average annual return on degree with the university admission rate for American universities in 2012-2013. Data from 452 universities were grouped into types of degrees (Figure 3) and separated into five categories. As anticipated, engineering and computer science majors realized a 12% return over a 20-year timeframe. Economic and non-STEM business also averaged nearly 9% return. Arts and humanities majors saw mixed returns. This analysis suggests that students in STEM experience a better financial ROI than non-STEM majors regardless of a university's selective admission rate. It is possible that less prestigious universities (e.g., state schools) may help students meet their long-term financial goals just as well as more prestigious university (e.g., private schools). However, the impact of available jobs by geography remains an important element of this analysis.

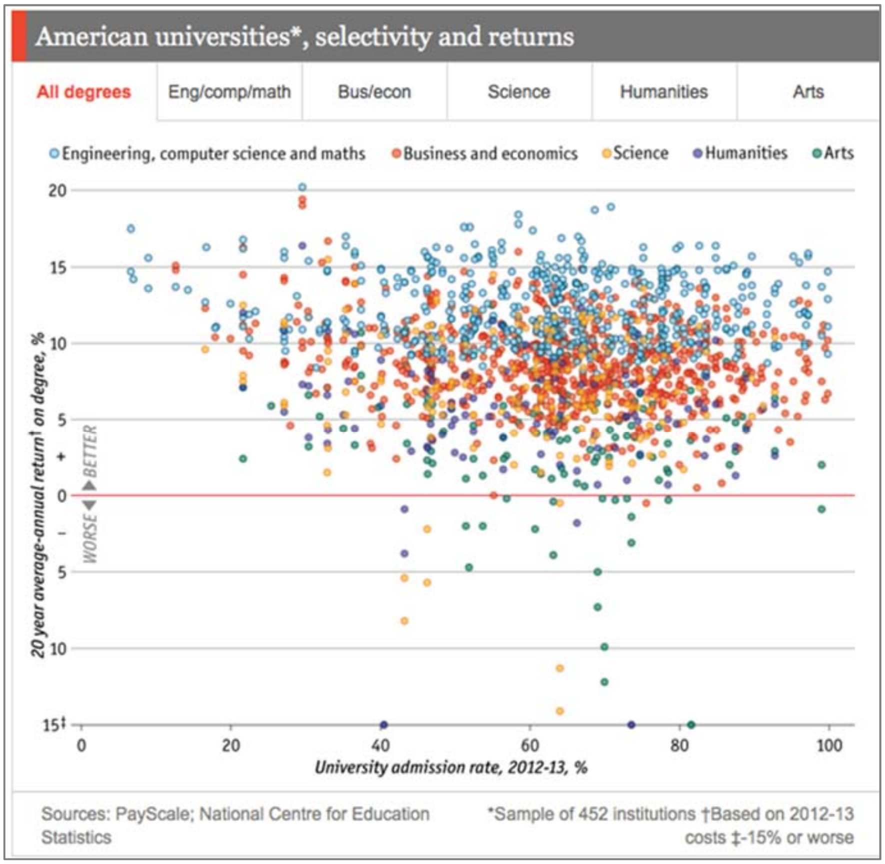


Figure 3. Web application developed by The Economist compares university admission rates with the 20-year average annual ROI by college degree.

Senior researcher Jonathan Rothwell at the Brookings Institute believes a 4-year degree is not always required to enter the STEM workforce. By expanding the definition of STEM to include “nontraditional blue-collar” STEM occupations (e.g. construction trade worker), he found that “Baton Rouge, LA, Birmingham, AL, and Wichita, KS, have among the largest share of STEM jobs in fields that do not require four-year college degrees (Rothwell, 2013)”. Figure 4 shows a screen capture of Rothwell’s interactive map illustrating the percentage of STEM workers in various metropolitan areas using this expanded definition of STEM. A sample of STEM jobs for the Baton Rouge area is shown in Figure 5.

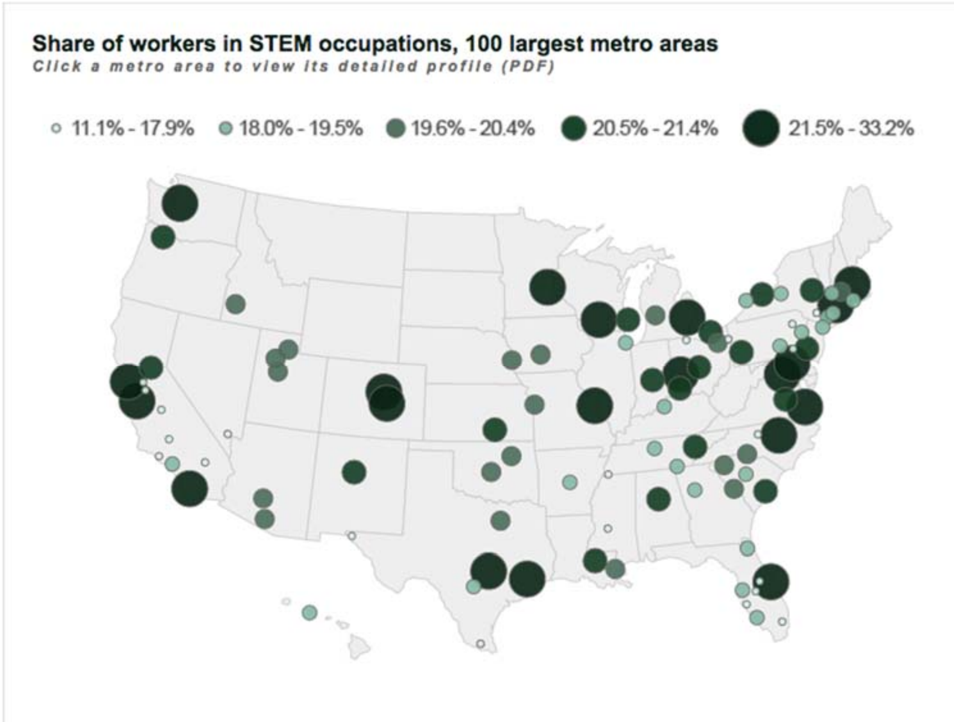


Figure 4. Interactive map showing the percentage of STEM workers in metropolitan areas. The Brookings report expands the definition of STEM to include non-traditional blue-collar jobs.

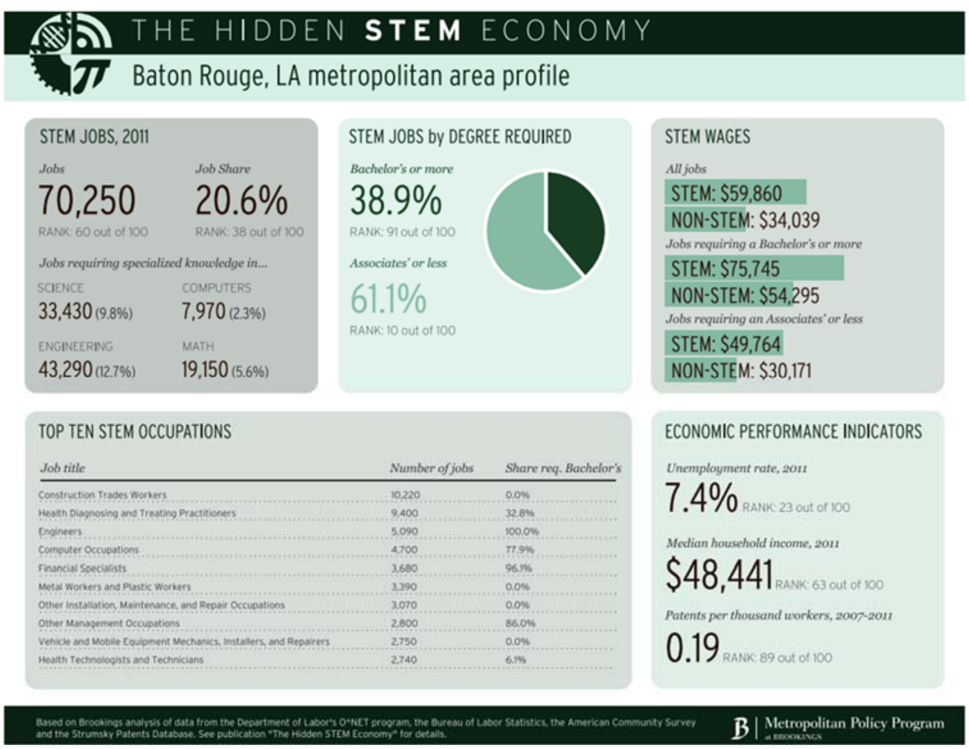


Figure 5. Profile of STEM occupations in Baton Rouge, LA based on the Brookings report expanded definition of STEM.

Although the redefinition of STEM occupations is outside the scope of this project, it is important to note that students without a strong educational background in math and science still have the opportunity to enter a lower-level STEM or STEM-adjacent field (Hedgecock, 2016).

Employment trends and projected salaries are tracked by the BLS. As part of its published findings, the BLS created a series of web maps showing the results of the May 2016 Occupational Employment Statistics program (OES). The OES measures current employment and wage rates down to the state and metropolitan statistical area (MSA) levels. Figure 6 shows an example of the number of persons currently employed as cartographers and photogrammetrists. A detailed map at the MSA level is shown in Figure 7 (BLS, 2016b).

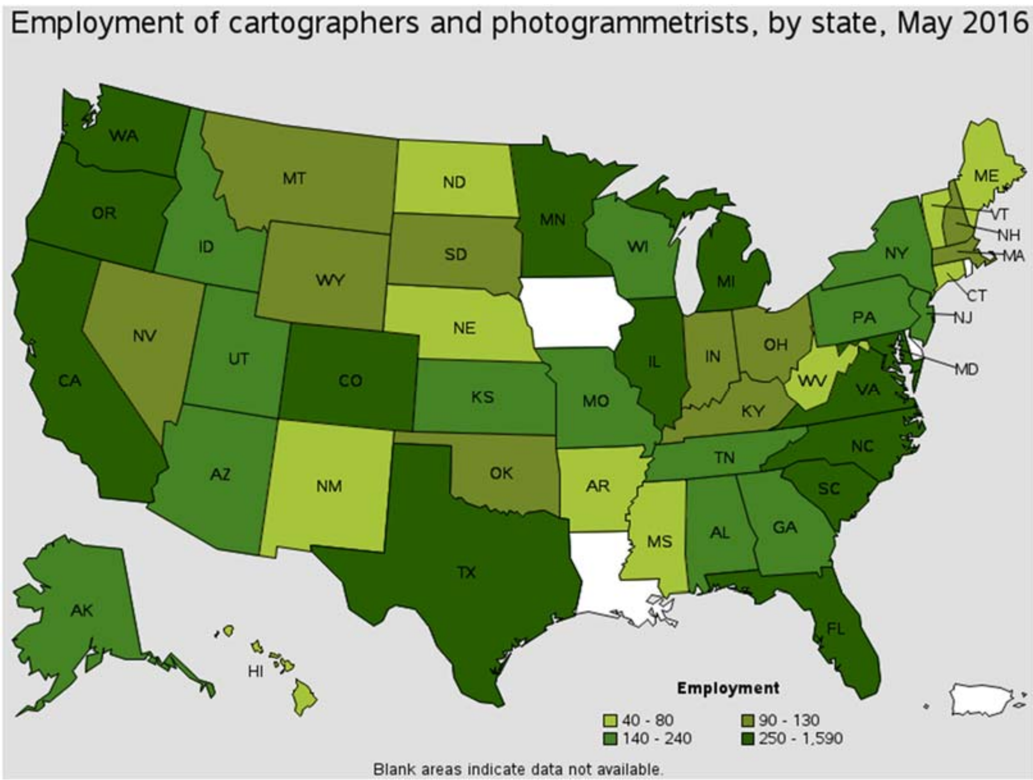


Figure 6. Number of employed cartographers and photogrammetrists by state based on the Bureau of Labor Statistics Occupational Employment Statistics survey (May 2016). https://www.bls.gov/oes/current/map_changer.htm

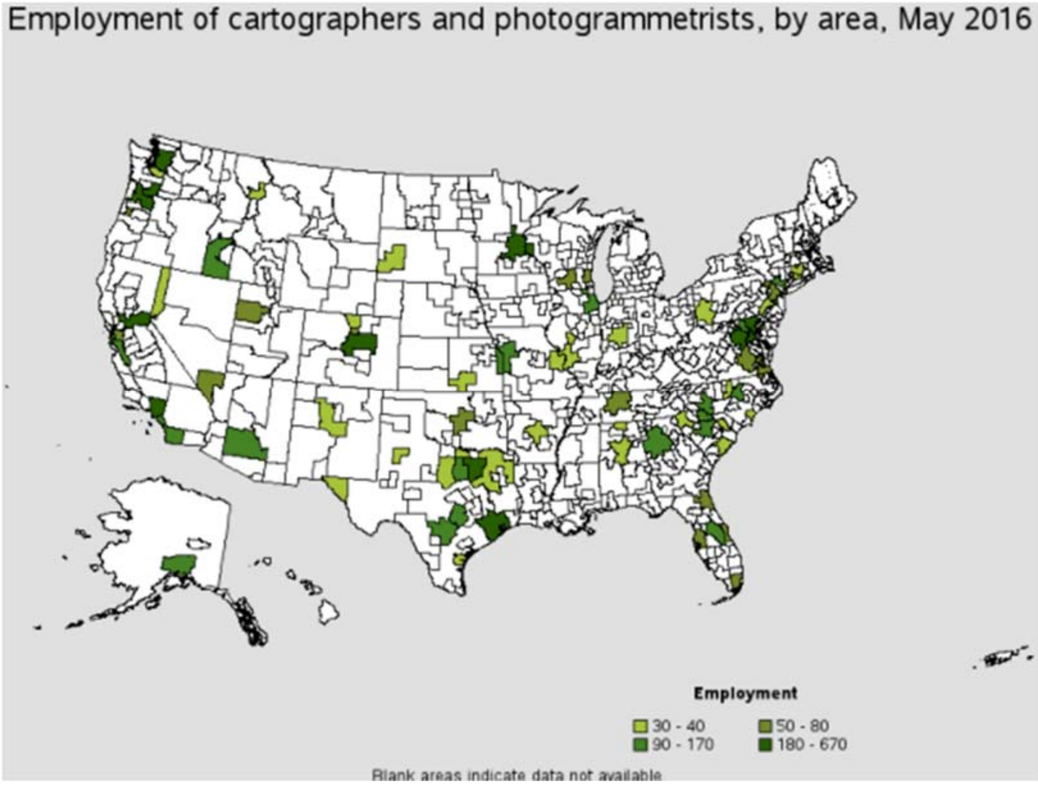


Figure 7. Number of employed cartographers and photogrammetrists by metropolitan statistical area based on the Bureau of Labor Statistics Occupational Employment Statistics survey (May 2016).

Unfortunately, employment projections are not available at the MSA level. For this project, analysis at the MSA level will not be used because many universities offering STEM majors are located in MSAs that do not have current employment data. To calculate ROI, long-term employment projections are needed for all universities.

Finally, the National Center for Education Statistics (NCES) created an interactive College Map and comprehensive tabular information on tuition rates, fields of study by degree level, and the number of degrees conferred by major at each university in the nation (NCES, 2017). Tracking the number of new graduates in a field is an additional indicator of workforce surplus or shortage for a geographic area. Although a link to the BLS Occupational Outlook Handbook is provided, projected employment and salaries by geography are not easily ascertained in this web application. However, the usability of this web application is similar to the application in this project (Figure 8).

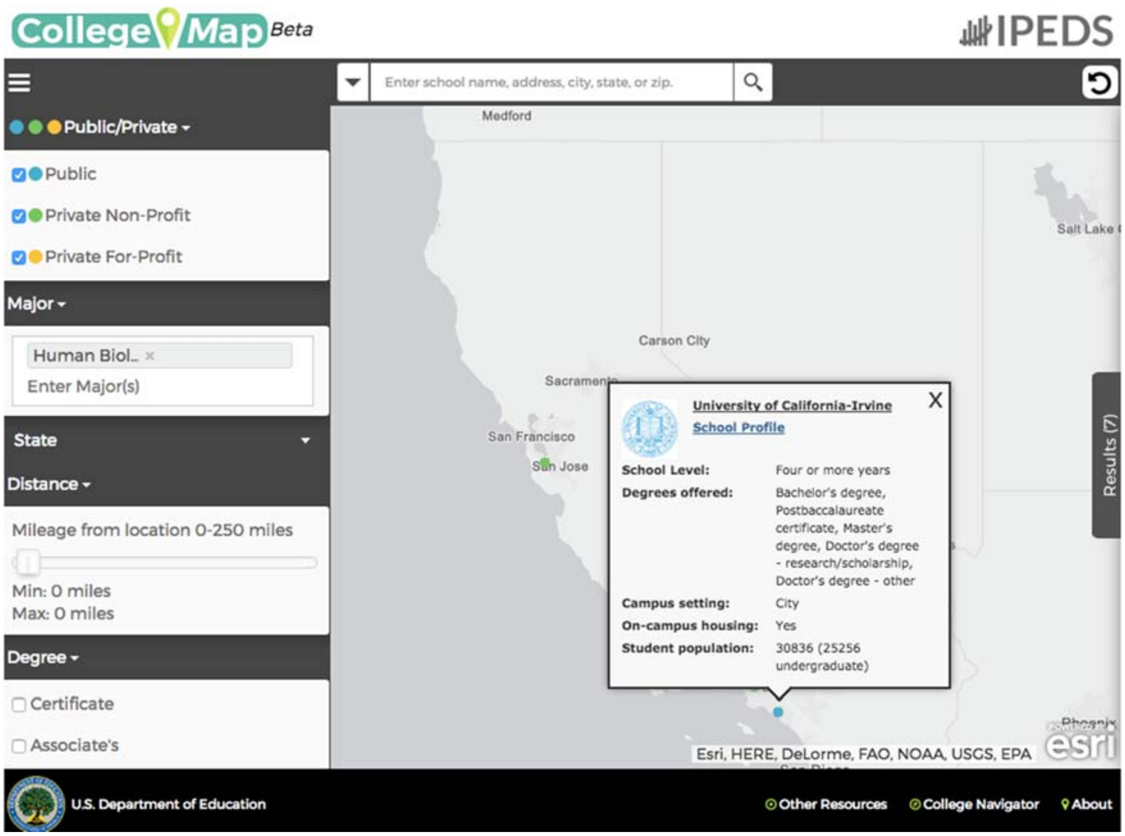


Figure 8. Example of the NCES College Map web application.

The previously discussed applications present data in a number of categories related to this project, namely tuition rates, ROI, number of conferred degrees, STEM employment figures, and STEM employment forecasts. By developing a single web application, students will be able to compare the geographic distribution of these data within a single resource. Table 1 compares the data categories addressed by each application.

Table 1. Comparison of web applications related to STEM Major ROI

	Geographic Distribution	**Annual Earnings**	**Estimated ROI**	**Cost of Tuition**	**Job Opportunities (Current/Projected)**	**Degrees Conferred by Major**
Hamilton Report	--	✓	--	--	--	--
Payscale	✓	--	✓	✓	--	--
The Economist	--	--	✓	--	--	--
Brookings Institute	✓	--	--	--	✓ (Current)	--
BLS	✓	✓	--	--	✓ (Current)	--
NCES	✓	--	--	✓	--	✓

3. Methodology

Section three describes the data sources, assumptions, and calculations used in the web application.

3.1. User Persona

As discussed in the introduction, the web application is designed for high school, college students, and career counselors interested in STEM fields. Graduate-level programs are excluded from this project because students at this level have already chosen a field of interest.

3.2. Data Sources

3.2.1. College Tuition and Conferred Degrees

Every year, the NCES tabulates undergraduate college tuition for universities nation-wide. Tuition is defined as the cost of in-state attendance for full-time, 4-year degree students living on campus. The cost includes fees, books, and on-campus room and board (NCES, 2015). Data from the 2015-2016 academic year was used as it was the most complete data set during the time of development. Data was filtered to include only those universities granting STEM degrees. Figure 9 illustrates a portion of the college tuition data available from NCES.

	A	B	C	D
1	unitid	institution name	year	DRVIC2015.Total price for in-state students living on campus 2015-16
11	222178	Abilene Christian University	2015	$ 44,740.00
13	138558	Abraham Baldwin Agricultural College	2015	$ 14,853.00
23	108232	Academy of Art University	2015	$ 40,204.00
60	126182	Adams State University	2015	$ 21,726.00
61	188429	Adelphi University	2015	$ 51,708.00
63	188438	Adirondack Community College	2015	$ 17,899.00
66	168528	Adrian College	2015	$ 48,906.00
86	133872	Adventist University of Health Sciences	2015	$ 25,944.00
91	138600	Agnes Scott College	2015	$ 50,386.00
92	134811	AI Miami International University of Art and Design	2015	$ 31,914.00
93	152822	AIB College of Business	2015	$ 23,988.00
101	100654	Alabama A & M University	2015	$ 22,896.00
105	100724	Alabama State University	2015	$ 19,137.00

Figure 9. First few records of the 2015-2016 college tuition database (NCES, 2015).

Upon inspection of the filtered dataset, approximately 27% of STEM-degree conferring colleges were missing tuition data. Tuition not provided was estimated based on information provided by CollegeCalc.org (2017). (Note: Data provided by CollegeCalc is sourced from the U.S. Department of Education and was used to estimate tuition rates after comparing similar tuition rates for known universities reported by NCES.) If on-campus housing is not available, the off-campus housing estimate will be used.

This database does not include address or coordinate location information. Addresses were obtained from an online batch geocoding service that uses the Google Maps API place search functionality (Bell, 2017).

The NCES dataset also includes the total number of conferred bachelor degrees, or graduates, for each university by major (Figure 10).

	A	B	C	E	F	G	H
1	unitid	institution name	year	C2015_A.CIP Code - 2010 Classification	CipTitle	C2015_A.Award Level code	C2015_A.Grand total
2	100654	Alabama A & M University	2015	'01'	Agriculture, Agriculture Operations and Related Sciences	Bachelor's degree	19
3	100654	Alabama A & M University	2015	'01.00'	Agriculture, General	Bachelor's degree	3
4	100654	Alabama A & M University	2015	'01.09'	Animal Sciences	Bachelor's degree	4
5	100654	Alabama A & M University	2015	'01.10'	Food Science and Technology	Bachelor's degree	9
6	100654	Alabama A & M University	2015	'01.99'	Agriculture, Agriculture Operations and Related Sciences, Other	Bachelor's degree	3
7	100654	Alabama A & M University	2015	'03'	Natural Resources and Conservation	Bachelor's degree	1
8	100654	Alabama A & M University	2015	'03.0599'	Forestry, Other	Bachelor's degree	1
9	100654	Alabama A & M University	2015	'04'	Architecture and Related Services	Bachelor's degree	4
10	100654	Alabama A & M University	2015	'04.03'	City/Urban, Community and Regional Planning	Bachelor's degree	4
11	100654	Alabama A & M University	2015	'04.0301'	City/Urban, Community and Regional Planning	Bachelor's degree	4
12	100654	Alabama A & M University	2015	'10'	Communications Technologies/Technicians and Support Services	Bachelor's degree	7
13	100654	Alabama A & M University	2015	'10.02'	Audiovisual Communications Technologies/Technicians	Bachelor's degree	7
14	100654	Alabama A & M University	2015	'10.0202'	Radio and Television Broadcasting Technology/Technician	Bachelor's degree	7
15	100654	Alabama A & M University	2015	'11'	Computer and Information Sciences and Support Services	Bachelor's degree	27
16	100654	Alabama A & M University	2015	'11.01'	Computer and Information Sciences, General	Bachelor's degree	27

Figure 10. First few records of the 2015-2016 college major database (NCES).

3.2.2. STEM Field Classification

Although a universal definition of STEM fields does not exist, STEM majors in this project were classified based on the BLS 2010 Standard Occupational Classification System (BLS, 2010) and the U.S. Immigration and Customs Enforcement STEM Designation Degree Program List (ICE, 2016). Both sources were used to create a more comprehensive list of STEM majors.

3.2.3. Salary Trends

The BLS (2015) publishes annual wage estimates for occupations in each state. Data for 2015, shown in Figure 11, was used to estimate early career starting salaries and career range salaries; annual 10th Percentile Wage and Annual 90th Percentile Wage fields, respectively. Missing data is noted as "N/A" in the web application.

	A	C	E	S	W
1	AREA	STATE	OCC_TITLE	Annual 10th Percentile Wage	Annual 90th Percentile Wage
89	01	Alabama	Aerospace Engineers	67,120	152,790
826	02	Alaska	Aerospace Engineers	67,330	147,040
1407	04	Arizona	Aerospace Engineers	65,090	128,510
2880	06	California	Aerospace Engineers	67,680	171,910
3709	08	Colorado	Aerospace Engineers	72,560	#
4476	09	Connecticut	Aerospace Engineers	80,370	144,010
5190	10	Delaware	Aerospace Engineers	65,940	134,300
5748	11	District of Columbia	Aerospace Engineers	79,410	159,980
6282	12	Florida	Aerospace Engineers	64,670	154,140
7083	13	Georgia	Aerospace Engineers	69,680	145,950
9132	17	Illinois	Aerospace Engineers	64,900	145,620
9935	18	Indiana	Aerospace Engineers	52,290	132,240
10718	19	Iowa	Aerospace Engineers	64,940	151,990
11456	20	Kansas	Aerospace Engineers	64,700	147,470
12173	21	Kentucky	Aerospace Engineers	*	*
12924	22	Louisiana	Aerospace Engineers	64,360	146,960
13673	23	Maine	Aerospace Engineers	70,560	128,690

Figure 11. First few records of the May 2015 State Occupational Employment and Wage Estimates.

3.2.4. Employment Projections

State-level employment projections are also available through the BLS (2016). The average annual job opening projections are updated every two years. For this project, the 2014-2024 time period was chosen as it most closely aligns with the 2015-2016 NCES tuition data. Using the same STEM field classifications described in Section 3.2.2, non-STEM occupations were filtered out of the database (Figure 12).

B	D	E	F	G	H	I	J	K
Area Name	Occupation Name	Base Yea	Base	Projected Year	Projection	Change	Percent Change	Average Annual Openings
Alabama	Biological Scientists, All Other	2014	170	2024	160	-10	-1.2	0
Alabama	Biological Technicians	2014	1050	2024	1130	80	7.6	40
Alabama	Biological Science Teachers, Postsecondary	2014	1820	2024	2570	750	40.9	110
Alaska	Biological Scientists, All Other	2014	490	2024	520	30	5.5	20
Alaska	Biological Technicians	2014	540	2024	540	0	-0.2	20
Alaska	Biological Science Teachers, Postsecondary	2014	140	2024	140	0	-1.4	0
Arizona	Biological Scientists, All Other	2014	550	2024	610	60	12.1	20
Arizona	Biological Technicians	2014	900	2024	1060	160	18.2	40
Arizona	Biological Science Teachers, Postsecondary	2014	860	2024	1130	270	31.1	40
Arkansas	Biological Technicians	2014	570	2024	620	50	8.5	20
Arkansas	Biological Science Teachers, Postsecondary	2014	410	2024	510	100	25.2	20
California	Biological Scientists, All Other	2014	7900	2024	9100	1200	15.2	340
California	Biological Technicians	2014	12800	2024	15200	2400	18.8	590
California	Biological Science Teachers, Postsecondary	2014	4700	2024	5800	1100	23.4	190
Colorado	Biological Scientists, All Other	2014	620	2024	660	40	5.3	20
Colorado	Biological Technicians	2014	2560	2024	3130	570	22.3	130

Figure 12. First few records of the BLS Long-Term Occupational Projections.

3.2.5. Majors to Job Comparison Table

To compare degree programs with possible occupations, the NCES in conjunction with the BLS developed the CIP-SOC crosswalk table (NCES, 2010) (Figure 13). The Classification of Instructional Programs (CIP) represents academic degree programs. Occupations are identified by the Standard Occupational Classification (SOC) codes. Each CIP code is mapped to multiple SOC codes. Likewise, each SOC code is mapped to multiple CIP codes. Generalized two- and four-digit CIP codes were matched to the equivalent six-digit CIP code provided in the crosswalk table. For example, 27.03 "Applied Mathematics" will be matched to 27.0399 "Applied Mathematics, Other". Although it is not possible to match every degree to every possible occupation, this database provides the basis for this project's analysis.

National Center for Education Statistics

Classification of Instructional Programs (CIP) - 2010

Mapped to Standard Occupational Classification (SOC) - 2010

CIP2010 Code	CIP2010Title	SOC2010Code	SOC2010Title
01.0000	Agriculture, General.	19-1011	Animal Scientists
01.0000	Agriculture, General.	19-1012	Food Scientists and Technologists
01.0000	Agriculture, General.	19-1013	Soil and Plant Scientists
01.0000	Agriculture, General.	25-1041	Agricultural Sciences Teachers, Postsecondary
01.0101	Agricultural Business and Management, General.	11-9013	Farmers, Ranchers, and Other Agricultural Managers
01.0101	Agricultural Business and Management, General.	25-1041	Agricultural Sciences Teachers, Postsecondary
01.0102	Agribusiness/Agricultural Business Operations.	11-9013	Farmers, Ranchers, and Other Agricultural Managers
01.0102	Agribusiness/Agricultural Business Operations.	25-1041	Agricultural Sciences Teachers, Postsecondary

Figure 13. First few records of the CIP to SOC crosswalk table.

3.2.6. ROI Methodology

The data described in the section above was used to calculate a simplified return on investment percentage for each university and STEM major. The following example calculates the simplified ROI for a student majoring or specializing in GIS at California State University, Northridge (CSUN).

In 2015, the 4-year tuition at CSUN was $84,652. Tuition is defined as the cost of in-state attendance for full-time, 4-year degree students living on-campus (including books and fees). Assuming the average person graduates at age 22 and works until age 65, there are 43 working years. The starting salary is estimated using the BLS annual 10th percentile wage. Likewise, the peak salary will be estimated using the annual 90th percentile wage. (These percentiles were selected because according to the BLS, "someone new to the field may expect wages near the 10th or 25th percentile, whereas those with more experience and education could expect wages near the 75th or 90th percentile" (2017).)

By calculating a straight-line interpolation for the first 10 years after graduation, it is estimated that a student majoring in GIS from CSUN would earn $66,625. By dividing the 10-year estimate by the total tuition yields a 79% ROI. (Table 2).

Table 2. Example Return on Investment (ROI) Calculation

Starting Salary for GIS majors in California	$47,675
Peak Salary for GIS majors in California	$129,155
Annual Salary Increase over 43-year Career	$1,895
Year 1	$49,570
Year 2	$51,465
Year 3	$53,360
Year 4	$55,255
Year 5	$57,150
Year 6	$59,045
Year 7	$60,940
Year 8	$62,835
Year 9	$64,730
Year 10	$66,625
4-Year Tuition at CSUN	$84,652
Simplified Return on Investment (ROI)	79%

A more complete economic ROI analysis would factor in other variables such as taxes, cost of living, student loan interest rates, and inflation. However, this simplified calculation will help students determine the approximate financial gain a decade after graduation. Perhaps after evaluating the ROI, the student may choose to attend a less expensive college, live at home and attend the first two years at a junior college, or perhaps choose a different major entirely.

4. Interface Design and Functionality

This section presents the web application interface and functionality from the user's perspective. Section 4 describes the technology used to develop the interface.

The web application is a context-sensitive interface that responds to the user's selections. When the app is first loaded, the interface shows three dropdown menus in the upper left corner and a grayscale map of state outlines in the upper right panel. To calculate the ROI for a specific university and major, the user will make three selections from the dropdown menus on the upper left side of the webpage. The user will first select a state from the top dropdown menu. This triggers two events: a) the map in the University Locations tab zooms to the geographic extent of the state and b) a bar chart in the Compare Tuition by State tab shows the tuition for every university in the state. As the user hovers over the bar chart, a pop-up window will display the 4-year tuition rate and university name (Figure 14).

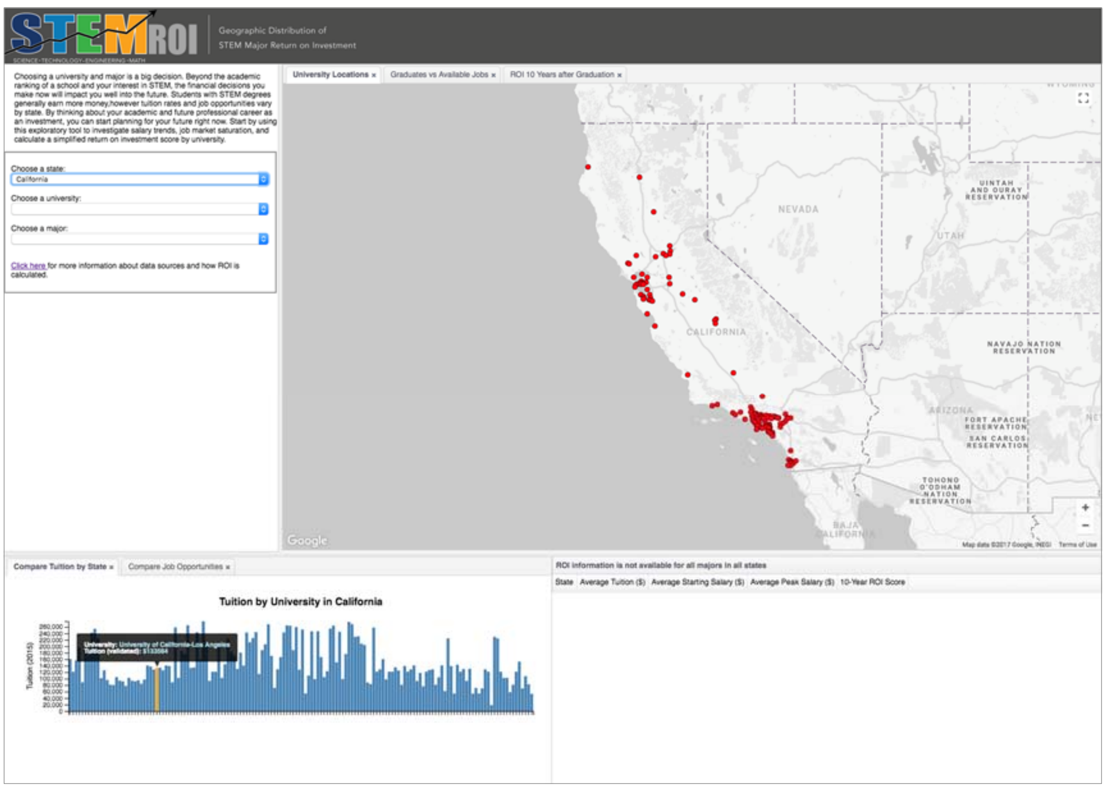


Figure 14. Web application interface once the user makes a selection from the state dropdown menu.

Next, the user will select a university from the middle dropdown menu. The list of universities is automatically filtered by state and the university location is shown in the grayscale map. As the user hovers over the red dot, the university name and tuition is displayed in a pop-up window (Figure 15).

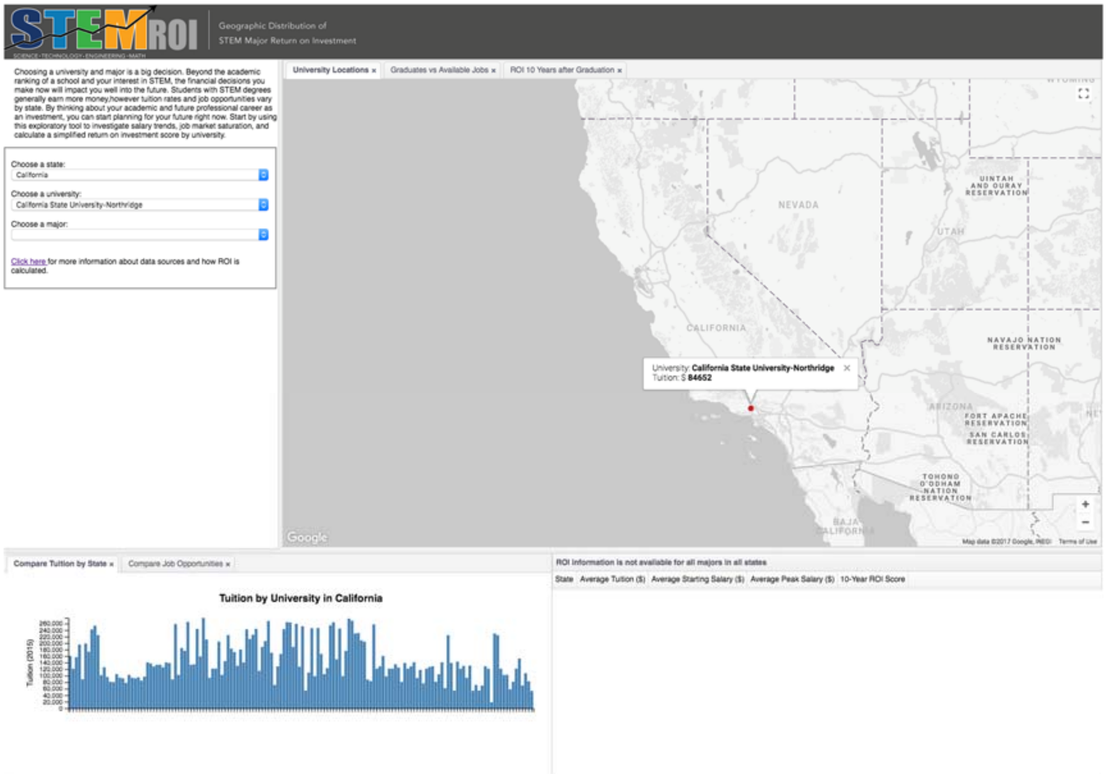


Figure 15. Web application interface once the user makes a selection from the state dropdown menu.

Finally, the user will select a major (or major specialization) from the bottom dropdown menu which loads the remainder of the webpage elements (Figure 16).

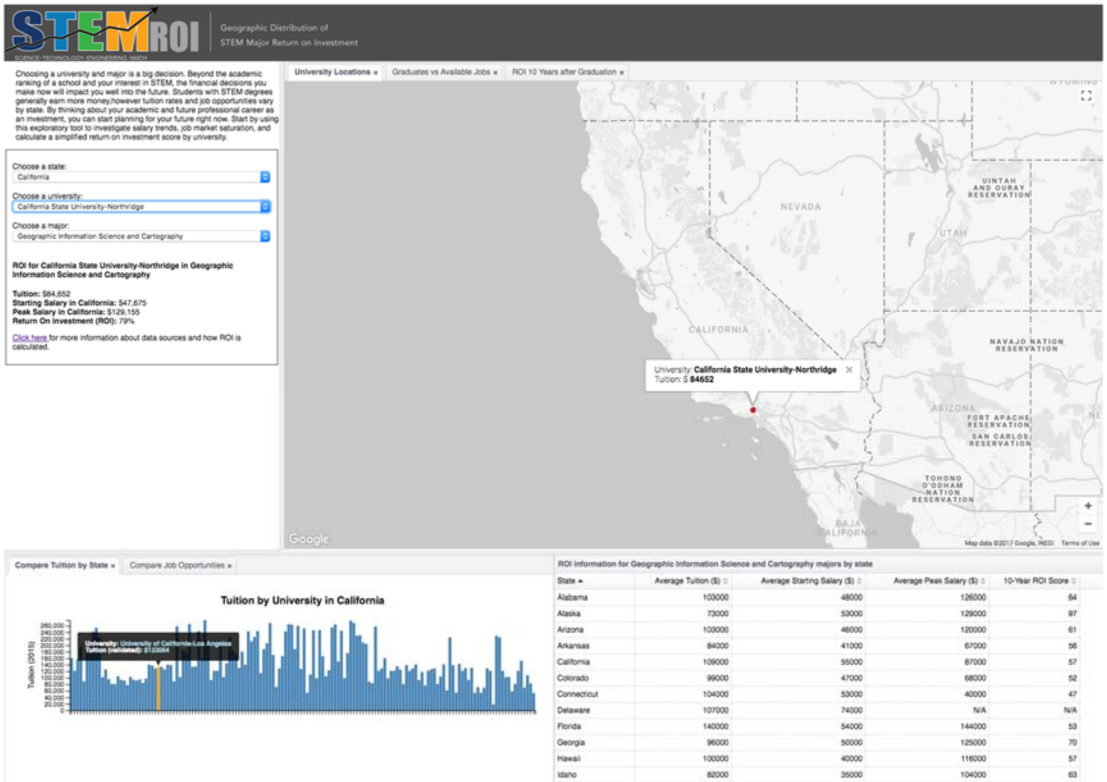


Figure 16. Web application interface once user makes a selection from each of the three dropdown menus.

Below the dropdown menus, the tuition, starting salary, peak salary, and 10-year ROI percentage calculation appears. When the user hovers over the Compare Job Opportunities tab in the bottom left panel, a bar chart displays the number of projected job openings for the selected major by state. A pop-up window provides the specific number of job openings as of 2014 (Figure 17).

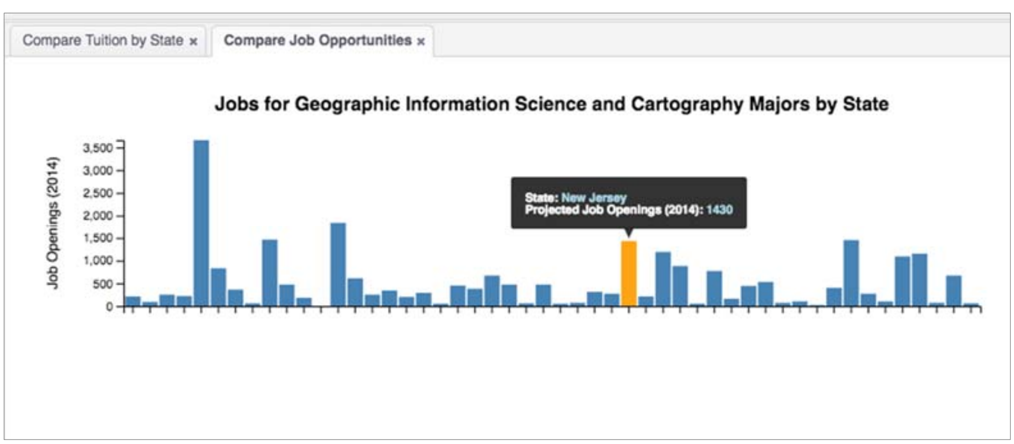


Figure 17. Example of Compare Job Opportunities tab in the bottom left panel for GIS majors.

The bottom right panel shown in Figure 18 is a sortable table with the tuition, starting and peak salaries and ROI percentage score for the selected major in other states. The ROI calculation by state uses the average tuition and average salaries to determine the ROI score. If starting or peak salary is not available for the selected major, the ROI score is not calculated and is noted as “N/A”.

ROI information for Geographic Information Science and Cartography majors by state

State	Average Tuition ($)	Average Starting Salary ($)	Average Peak Salary ($)	10-Year ROI Score
Alabama	103000	48000	126000	64
Alaska	73000	53000	129000	97
Arizona	103000	46000	120000	61
Arkansas	84000	41000	67000	56
California	109000	55000	87000	57
Colorado	99000	47000	68000	52
Connecticut	104000	53000	40000	47
Delaware	107000	74000	N/A	N/A
Florida	140000	54000	144000	53
Georgia	96000	50000	125000	70
Hawaii	100000	40000	116000	57
Idaho	82000	35000	104000	63

Figure 18. Partial example of the ROI table by state.

In the upper right side of the webpage is the map panel. The second tab in the map panel, Graduates vs. Available Jobs, shows a choropleth map of the job market saturation (Figure 19). This percentage is calculated as the total number of conferred degrees (graduates) divided by the number of annual job openings by state in 2014. (Note: Complete datasets between the NCES and BLS are not synchronized. The number of conferred degrees is based on 2015 data while the “current” job opportunity dataset is based on 2014.) The legend is color-coded and split into three categories, minimally saturated (<50%), partially saturated (50-100%), and saturated (>100%).

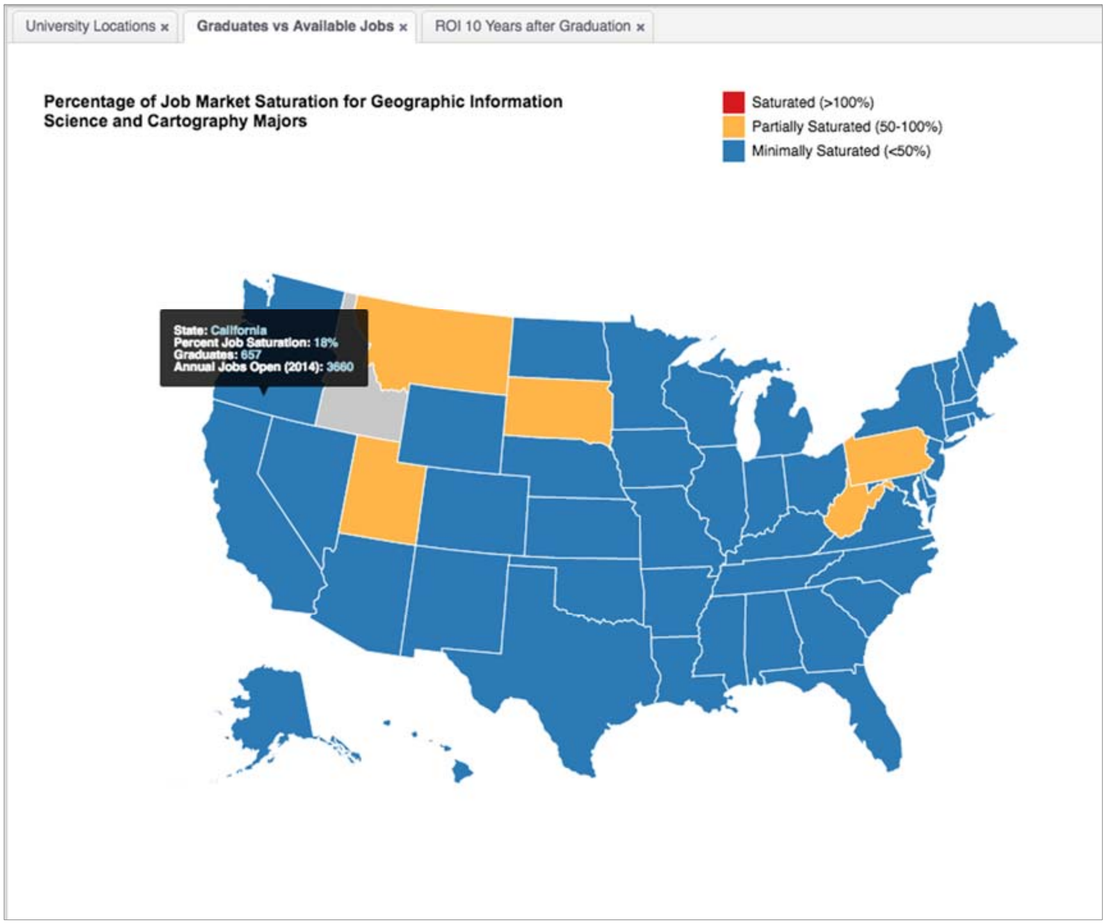


Figure 19. Job Market Saturation tab

The ROI 10 Year after Graduation tab is the third tab in the map panel. The choropleth map shown in Figure 20 displays the calculated ROI for the selected major by state. The state-level ROI score matches the table in the bottom right side of the webpage. The legend is color-coded and split into five categories: low ROI (>25%), 25-50%, 50-75%, 75-100%, and High ROI (>100%).

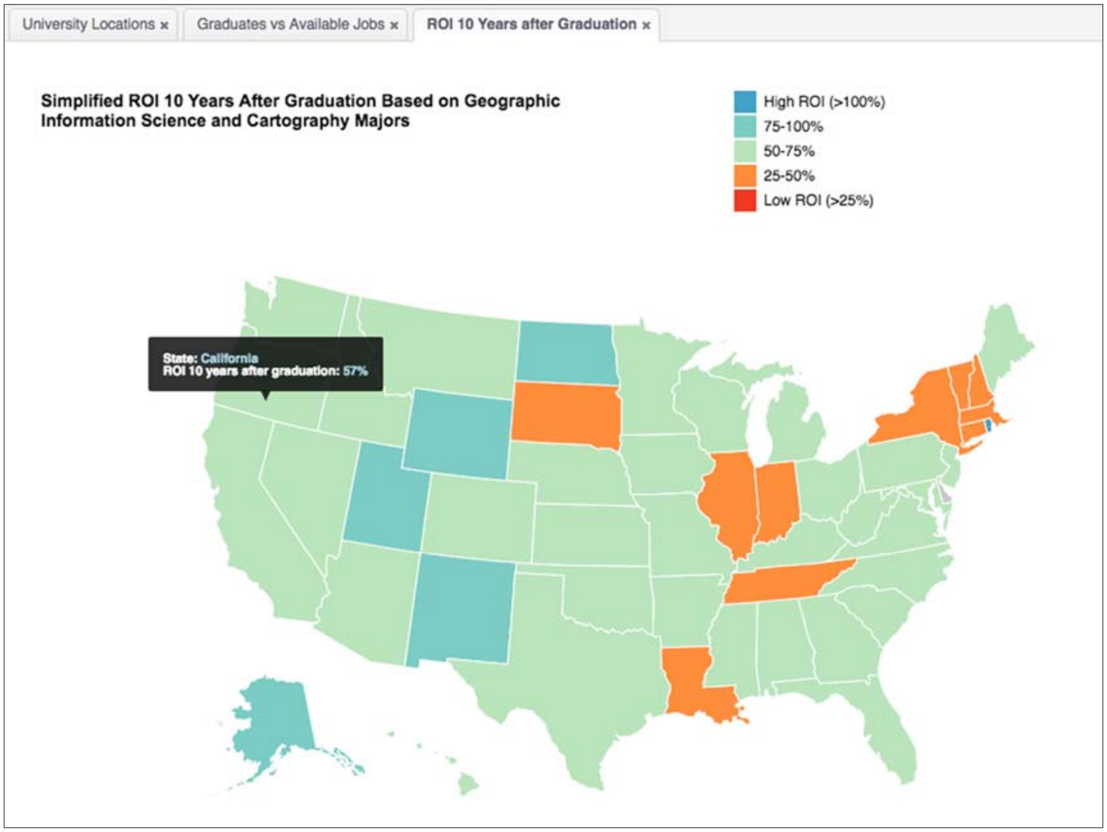


Figure 20. ROI 10 Years after Graduation tab

A summary of the data sources and methodology can be viewed by clicking on the link provided under the dropdown menus (Figure 21).

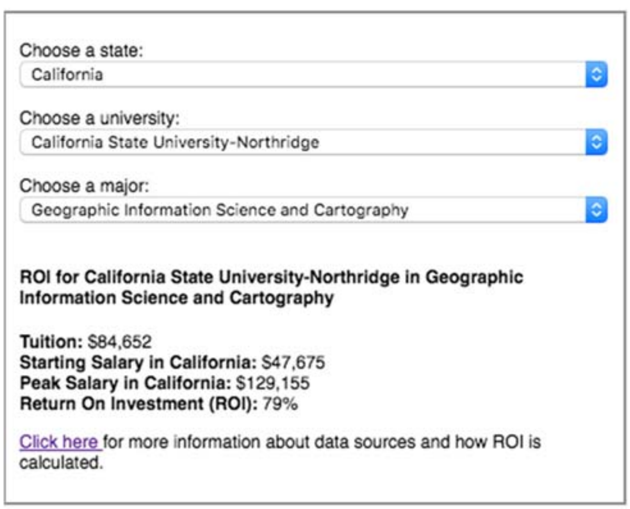


Figure 21. Link to data sources and methodology description.

5. Technology Stack and Approach

5.1. Technology Stack

Early in the development process, two key considerations determined the technology stack and approach: cost and usability.

To reduce development costs, the web app was built on a free, open-source technology stack. The front-end interface utilizes the jQuery Easy UI JavaScript framework. The grayscale map showing university locations was developed using the Google Maps JavaScript API. All other maps and the two bar charts are dynamically generated using the JavaScript library D3 (Bostock, 2017). Data is stored in a single MySQL database.

The other consideration was usability. To simplify the interface, the app was designed as a Single-Page Application (SPA) that does not require page reloading. This functionality is primarily built with jQuery that calls back-end REST web services. Because I am more versed in Python than PHP, I investigated two popular Python frameworks for building RESTful APIs: Django and Flask (Django, 2017 and Ronacher, 2017). Based on my research, Flask is recommended for beginning programmers by several experts because Django has a steep learning curve, whereas Flask allows for fine-grain control and only implements what is needed (Dwyer, 2017 and Coding Dojo, 2017). Consequently, Flask was selected as the web framework for the app. The next sections provide a high level overview of the web architecture.

5.2. Front-End

To create a front-end web application with dynamic elements, JavaScript is required. jQuery, a JavaScript library, simplifies development by abstracting the code needed for event handling (e.g., when a user hovers over a bar chart and a pop-up window appears) and transparently handles web browser differences. When an event is triggered, a jQuery method utilizes AJAX to call a REST endpoint written in Flask, which then retrieves data from the MySQL database and refreshes part of the page. A portion of the jQuery function used to populate the major dropdown menu is shown in Figure 22. The AJAX method calls to the /stemroi/api/majordd URL in Flask, which is discussed in greater detail in section 5.3.

```
// Populates 'majorlist' select list (bottom-left)
$('#unislist').change(function() {
    $("#unisroi").hide();
    $.ajax({
        url: '/stemroi/api/majordd',
        type: 'POST',
        dataType: 'json',
        contentType: 'application/json',
        data: JSON.stringify({
            unitid: $('#unislist :selected').val()
        }),
```

Figure 22. Portion of the jQuery function used to populate the major dropdown menu; based on the university selected previously.

The interactive data visualizations shown in the bar charts and choropleth maps use D3, a dynamic, data visualization JavaScript framework. The power of D3 lies in the ability to generate elements on-the-fly based on the user's selection. For example, the left axis intervals of the Compare Job Opportunities bar chart are scaled based on the data values and the size of the drawing canvas. Figure 23 illustrates the automatic interval scaling for job openings between Architecture and Computer Programing majors.

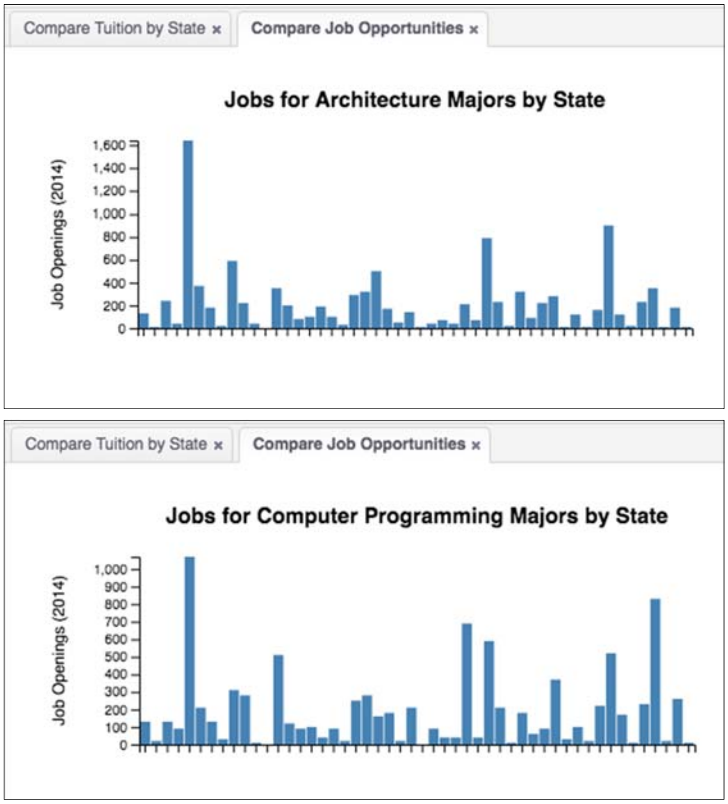


Figure 23. Compare Job Opportunities bar charts generated using D3. Note the Job Openings axis interval dynamically changes based on data values.

Using the Graduates vs. Available Jobs map as an example, the D3 workflow is as follows. When the user selects a major from the dropdown menu, the major is passed to a REST endpoint in Flask, which in turn queries the state-specific data stored in the database (e.g., ROI percentage). The data is then dynamically bound to the state outlines that are stored as a JSON object and displayed as a GeoJSON object using the Albers' equal area-conic projection (Figure 24).

```
945     <script type="text/javascript">
946         $('#majorlist').change(function() {
947             d3.select("#gradmap").selectAll("svg").remove();
948 
949             //Load in graduate data endpoint
950             var gradURL = '/stemroi/api/grads/' + $('#majorlist :selected').val();
951             $.ajax({
952                 url: gradURL,
953                 type: 'get',
954                 dataType: 'json',
955                 contentType: 'application/json',
956                 // Get major selected and convert the object to a string
957                 // https://stackoverflow.com/questions/6323338/jquery-ajax-posting-json-to-webservice
958 
959                 data: JSON.stringify({
960                     cip: $('#majorlist :selected').val()
961                 }),
962 
963                 success: function(dataG) {
964                     //Set margin surrounding SVG canvas.
965                     var marginG = {
966                         top: 20,
967                         right: 10,
968                         bottom: 20,
969                         left: 10
970                     };
971 
972                     //Width and height
973                     var w = $("#allmaps").width() * 0.75 - marginG.left - marginG.right;
974                     var h = $("#allmaps").height() - marginG.top - marginG.bottom;
975 
976                     //Define map projection
977                     var projection = d3.geoAlbersUsa()
978                         .translate([w / 2, h / 2]) // translate to center of screen
979                         .scale([w]); // scale down map to see entire US
```
Figure 24. Portion of the D3 code used in the Graduates vs. Available Jobs tab. Line 977 defines the map projection.

As discussed in Section 5.1, the Google Maps JavaScript API is used to draw the university point locations. Originally, all points displayed when the webpage first loaded in the user's browser. However, due to performance issues, the number of universities displayed were modified and filtered by state. The ability to zoom to the geographic extent of the selected state was easier using the Google Maps API, thus the university location map did not use D3. Unlike D3, the Google Maps API is accessed by registering a Google API key.

5.3. Back-End

Flask is a Python module used for building web applications. For this project, the Flask app file directory is as follows:

/stemroi

- **stemroi.py** – contains all Flask code, including REST endpoint functions
- **wsgi.py** – configuration file used only in production to import stemroi.py as a module and serve via Apache
- **/templates**
  - **index.html** – main HTML web page, with embedded Python for resolving URLs for static resources

methods.html – HTML web page describing data sources and methodology

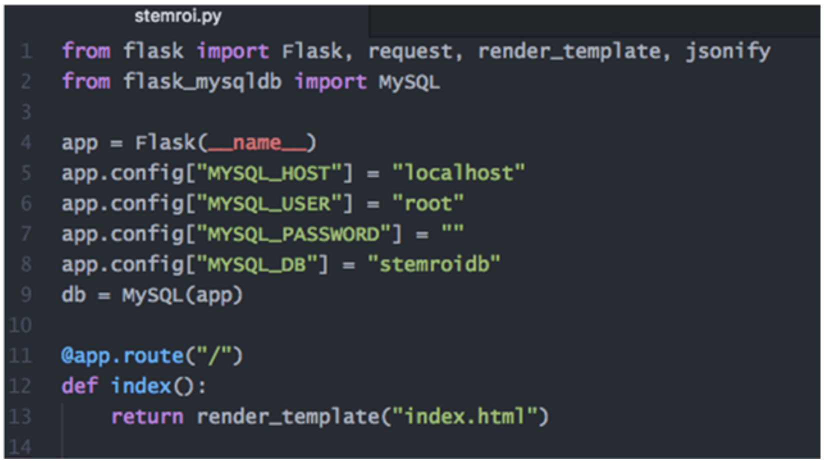
/static

/css – main CSS file and jQuery Easy UI CSS

/img – image files

/js – JavaScript files: d3.js, jQuery Easy UI.js, jQuery.js and state outline JSON

Flask is imported as a module in a file called stemroi.py (Figure 25). A Flask object is created called app. This object is then used to configure database access.



```
stemroi.py
from flask import Flask, request, render_template, jsonify
from flask_mysqldb import MySQL

app = Flask(__name__)
app.config["MYSQL_HOST"] = "localhost"
app.config["MYSQL_USER"] = "root"
app.config["MYSQL_PASSWORD"] = ""
app.config["MYSQL_DB"] = "stemroidb"
db = MySQL(app)

@app.route("/")
def index():
    return render_template("index.html")
```

Figure 25. Initial portion of the stemroi.py file.

Each function in stemroi.py has a decorator that maps the endpoint and HTTP method (e.g., GET, POST, etc.) to a function. When that endpoint is called, the function is executed. Figure 26 shows the function that is called when the user selects the major dropdown menu, as shown in Figure 22 above.

```python
# Flask function for major dropdown menu
@app.route('/api/majordd', methods=['POST'])
def selectMajor():
    if request.is_json:
        # Get JSON sent
        content = request.get_json()

        # Check to see if the field(s) we are looking for exist

        if 'unitid' in content:
            # Get the university value
            unitid = content['unitid']

            cur = db.connection.cursor()

            cur.execute("SELECT m.cip, m.cip_title \
                FROM stemroidb.university u, stemroidb.university_major um, stemroidb.major m \
                WHERE  u.unitid = um.unitid and um.cip = m.cip and u.unitid = '{0}'\
                ORDER BY m.cip_title".format(unitid))
            payload = []
            for row in cur:
                payload.append({'cip':row[0], 'major':row[1]})
        else:
            return jsonify({"errors":"Malformed JSON or incorrect format"}), 400
    else:
        return jsonify({"errors":"Malformed JSON or incorrect format"}), 400
    return jsonify(payload), 200
```

Figure 26. Flask function for the major dropdown menu. Line 2 defines the decorator function noted by @app.route().

Flask also supports templates, which like PHP, are HTML pages with special mark-ups to embed server-side Python code. The actual webpage for this SPA is a Flask template called index.html. The full request-response cycle diagram can be found in Appendix B.

Flask can run in one of two modes: development or production. In development mode, it includes an embedded web server that run on port 5000 by default. In production mode, where it runs on a web server, an Apache module called *mod_wsgi* handles redirecting requests to Flask.

At the end of the stemroi.py file, there is a block of code (starting on line 305) that runs only in development mode and maps the application to a /stemroi root directory to match production mode (Figure 27). Note that this block of code only runs in development mode and is ignored in production mode.

```python
if __name__ == "__main__":
    # Source (copied from):
    # https://stackoverflow.com/questions/18967441/add-a-prefix-to-all-flask-routes
    # and https://gist.github.com/rduplain/1705072

    # Relevant documents:
    # http://werkzeug.pocoo.org/docs/middlewares/
    # http://flask.pocoo.org/docs/patterns/appdispatch/
    from werkzeug.serving import run_simple
    from werkzeug.wsgi import DispatcherMiddleware
    APPLICATION_ROOT = '/stemroi'
    app.config.from_object(__name__)
    app.config['DEBUG'] = True
```
Figure 27. Flask code block for development mode in stemroi.py.

5.4. Database Design

Data described in Section 3.2 was normalized as shown in the entity-relationship diagram in Figure 28. The *university* table contains tuition and coordinates used to map the point locations. The estimate field notes if the tuition rate was provided by NCES or estimated from another source. The *university_major* table stores the many-to-many relationship between the universities and the majors offered. The *major* table stores the name of each major and the unique major ID (cip) as determined by the NCES. Using the same cip ID, STEM majors and related occupations are stored in the *major_job* table. The soc field is the unique identifier for occupations as determined by the BLS. Occupation names and soc IDs are stored in the *jobs* table. Information related to salaries and employment opportunities are saved in the *jobs_salaries* table. Finally, the *state_abbrev* table contains the unique state abbreviation ID and name.

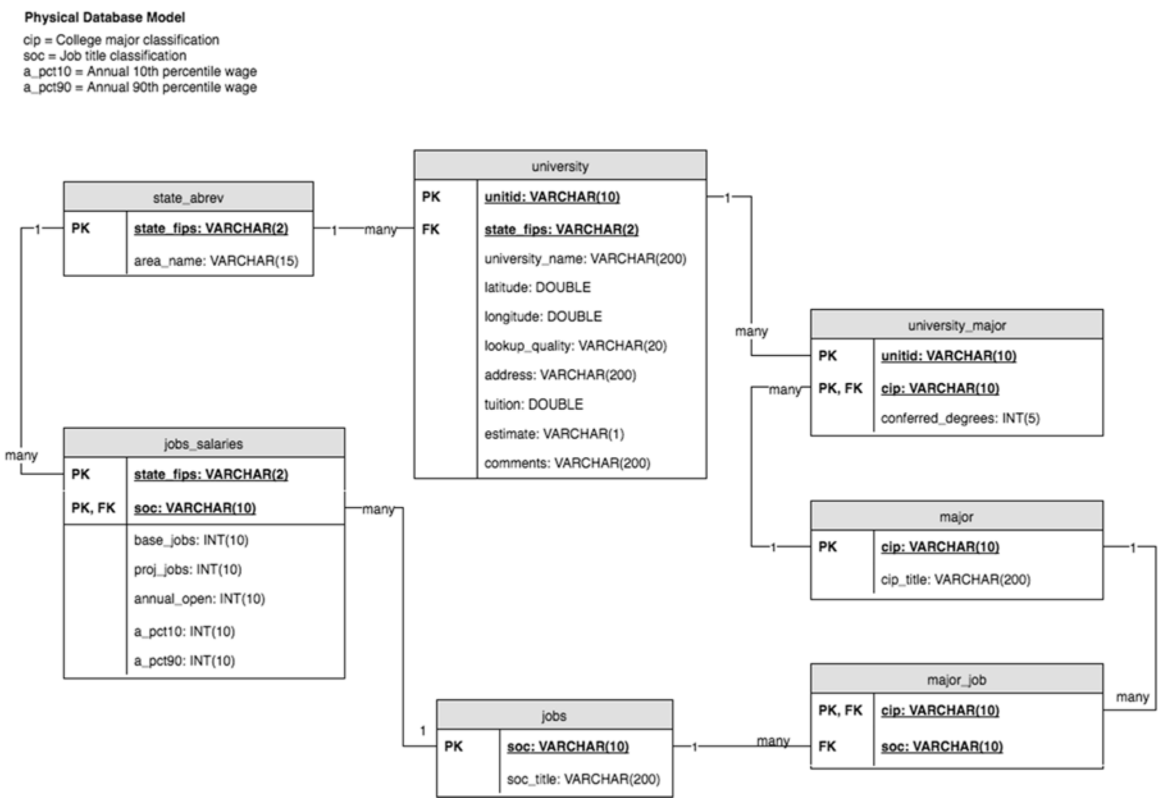


Figure 28. MySQL Entity-Relationship Diagram

5.5. Web Server Hosting

During development, the Flask environment was run on a laptop running both Python 2 and Python 3. To minimize the likelihood of conflicting Python library dependencies, virtualenv was installed on both the development and production environment (Flask, 2017). Virtualenv isolates Python environment dependencies without installing separate copies of Python.

Once completed, the web application was uploaded to a production server hosted by Digital Ocean and can be viewed at https://jackberrystudio.net/stemroi. In addition, all code is available at https://github.com/jsilber/stemroi.

6. Conclusion

6.1. User Evaluation

Once development was completed, one high school senior and two college students known to the author tested the app for usability. The test participants were sent a link to a 12-question survey hosted on Google Forms. The survey asked the following questions:

- What is the ROI for physics majors at the University of Wyoming?
- What is the tuition at University of Wisconsin-Milwaukee?
- How many students earned their degree in meteorology in Wisconsin?
- Is the tuition at University of Southern California (USC) higher or lower than the average tuition in California?
- Does the tuition change based on major?
- What is the average starting salary for chemistry majors in Texas?
- Which state has the highest number of job openings for chemistry majors?
- Did you have problems finding any of the data?
- If yes, describe what information was difficult to find.
- What did you find most helpful?
- If you were searching for a STEM major, would you use this tool? Why or why not?
- What would make this app more useful?

The students were able to answer most of the questions correctly, found the app to be useful, and ranked the app's ease of use as a high 4 out of 5 score. Results of the survey are included in Appendix A.

As a result of the high school student's feedback, the phrase "conferred degrees" was changed to "graduates" (see pop-up window in Graduates vs. Available Jobs map tab). Additionally, one of the college respondents suggested re-ordering the dropdown menus so that students could choose a major and review the data separate from university specific information.

6.2. Future Direction

This web app presents a single page resource for students interested in majoring and working in STEM fields. However, additional refinement and added functionality could increase the usefulness to a wider audience. Suggestions for future improvements include:

- Project salaries at the local level for finer-grain geographic analysis.

- Provide ability to compare programs by university rankings (e.g., Display the top ranked universities for chemistry and compare the ROI for each school).

- Calculate the ROI based on different school and job locations. Currently, the app assumes students will take a job in the same state as their alma mater. However, the number of out-of-state freshmen attending public universities has increased in the last several decades (Strayer, 2016).

- Provide an optional ROI score based on out-of-state tuition.

6.3. Conclusion

The research and data are clear – majoring in a STEM field can reap financial rewards provided college tuition costs are kept low and jobs are plentiful. Previous studies provided aspects of this information, however this web application goes a step further and enables high school and college students to explore the geographic distribution of STEM education and evaluate the financial ROI alongside employment projections.

7. Appendix A – Results of User Survey

High School Student Respondent

11/5/2017 STEM ROI Web App Survey

STEM ROI Web App Survey

Please take a few minutes to familiarize yourself with the app (https://jackberrystudio.net/stemroi/) then answer the survey questions below. Your answers will be published in the final report but your identity will remain anonymous. Thank you for your help!

What is the ROI for physics majors at the University of Wyoming? *

86

What is the tuition at University of Wisconsin-Milwaukee? *

94260

How many students earned their degree in meteorology in Wisconsin? *

I didn't understand where to find this.

Is the tuition at University of Southern California (USC) higher or lower than the average tuition in California? *

higher

Does the tuition change based on major? *

- Yes
- No (selected)
- Don't Know

https://docs.google.com/forms/d/1aLk-hJeOvOWGC6td5RmhyldHd3i8ZB4P7RrFruJOzO0/edit#response=ACYDBNhG0gBbD4KpwTyYOIROEIkWqeMM6Ffg8k... 1/3

What is the average starting salary for chemistry majors in Texas? *

33610

Which state has the highest number of job openings for chemistry majors? *

Texas

How difficult was it to find answers to the questions above? *

	1	2	3	4	5	
Very Difficult	○	○	○	◉	○	Easy

Did you find this app useful? *

Yes

Any other comments? *

I liked it, I just didn't understand where to find question 3.

Are you in high school or college? *

◉ High School

○ College

College Student Respondent 1

STEM ROI Web App Survey

Please take a few minutes to familiarize yourself with the app (https://jackberrystudio.net/stemroi/) then answer the survey questions below. Your answers will be published in the final report but your identity will remain anonymous. Thank you for your help!

What is the ROI for physics majors at the University of Wyoming? *

86%

What is the tuition at University of Wisconsin-Milwaukee? *

$94260

How many students earned their degree in meteorology in Wisconsin? *

9

Is the tuition at University of Southern California (USC) higher or lower than the average tuition in California? *

higher

Does the tuition change based on major? *

- (●) Yes
- ( ) No
- ( ) Don't Know

What is the average starting salary for chemistry majors in Texas? *

$43,000

Which state has the highest number of job openings for chemistry majors? *

Texas

How difficult was it to find answers to the questions above? *

	1	2	3	4	5	
Very Difficult	○	○	○	◉	○	Easy

Did you find this app useful? *

Yes!

Any other comments? *

It was very well put together and organized.

Are you in high school or college? *

○ High School

◉ College

College Student Respondent 2

STEM ROI Web App Survey

Please take a few minutes to familiarize yourself with the app (https://jackberrystudio.net/stemroi/) then answer the survey questions below. Your answers will be published in the final report but your identity will remain anonymous. Thank you for your help!

What is the ROI for physics majors at the University of Wyoming? *

86%

What is the tuition at University of Wisconsin-Milwaukee? *

94260

How many students earned their degree in meteorology in Wisconsin? *

9

Is the tuition at University of Southern California (USC) higher or lower than the average tuition in California? *

higher

Does the tuition change based on major? *

- ○ Yes
- ◉ No
- ○ Don't Know

What is the average starting salary for chemistry majors in Texas? *

43,000

Which state has the highest number of job openings for chemistry majors? *

Texas

How difficult was it to find answers to the questions above? *

	1	2	3	4	5	
Very Difficult	○	○	○	◉	○	Easy

Did you find this app useful? *

Very useful! Data was extremely in depth, and is great for prospective undergraduates or high school graduates.

Any other comments? *

Very easy to use, just took a couple minutes and I was familiar with it. Perhaps there may be a way to allow for the "choose" dropdown menus to behave independently: e.g., if you'd like to search only for Chemistry degrees for national/state data from the map and graphs, "then" select State/University for school costs and other school-specific data.

Are you in high school or college? *

○ High School

◉ College

8. Appendix B – Request-response Cycle

To understand how these technologies work together, Figure B1 illustrates the request-response cycle in a Flask application. When a user enters a URL for the web application, the browser will send a request to a file called stemroi.py (step 1). This Flask script maps the URL to the appropriate function and processes the GET request. The stemroi.py file calls the appropriate database function (step 2), which then queries the MySQL database and returns the results back to stemroi.py (step 3). stemroi.py then locates the index.html file inside the templates folder (step 4). The index.html page retrieves the necessary files from the static folder in step 5 (i.e., css, jQuery, JavaScript, D3, images and stateOutlines.json). The rendered index.html is then sent back to stemroi.py (step 6), which is forwarded back to the user's browser (step 7). This is how the web application is initially loaded in the user's browser.

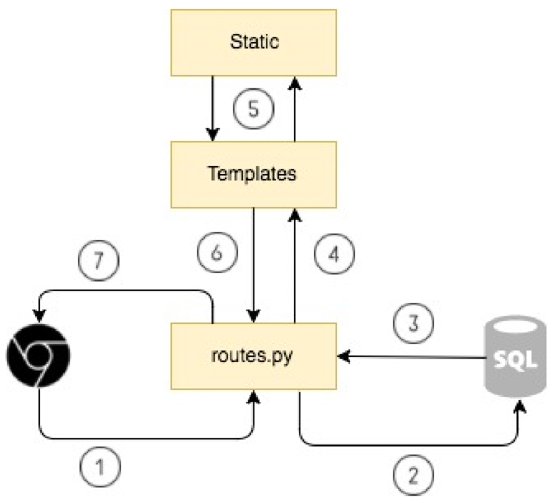


Figure B1. Initial Request-Response Cycle

Once index.html is loaded in the user's browser, jQuery is used to make REST web service calls without reloading the page; a user triggers an event based on what form element they click (Figure B2). The jQuery code in index.html makes an AJAX call to stemroi.py (step 1), where the request is parsed and processed. The stemroi.py file then calls the appropriate database function, which then queries the MySQL database (step 2). The results of the query are returned to stemroi.py (step 3), and then converted from Python dictionaries to JSON and returned to index.html in the user's browser (step 4). The index.html page in the user's browser applies the new data based on what the user triggered.

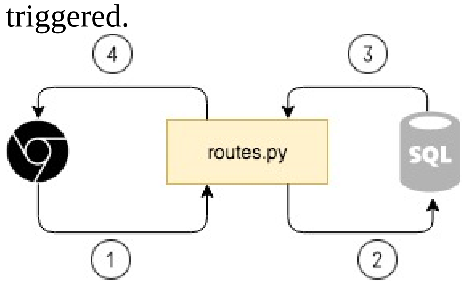


Figure B2. REST Request-Response Cycle

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