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Do Undergraduate Data Science Program Competencies Vary by College Rankings?

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1.0 Introduction

In recent years the data science domain has increased exponentially due to advances in technology including in infrastructure, storage, and analytical tools and techniques[1][2][3]. The demand for the data science field can be seen in various industries including retail, health care, finance and in all areas of economy and society [3]. Data science careers are the top careers in the U.S. across many disciplines[3]. It is predicted that this demand will continue to increase in the near future [2][3]. The rise in demand for data science technology has created a demand for graduates who have the skill set needed to support the data science field [1][2][3]. To meet this demand in the data science industry, many colleges are revising current programs or developing new programs geared for the data science industry[1][2]. A recent study [4] has shown that many colleges across the United States have already adopted undergraduate data science curriculum and programs.

In 2021, the Association for Computing Machinery (ACM) Data Science Task Force published the results of their 4 year research study which identified eleven data science competencies vital to all data science programs. These competencies are 1) analysis and presentation, 2) artificial intelligence, 3) big data systems, 4) computing and computer fundamentals, 5) data acquisition, management and governance, 6) data mining, 7) data privacy, security, integrity, and analysis for security, 8) machine learning, 9) programming, data structures and algorithms, 10) software development and maintenance, and 11) professionalism. The results of a study [4] that examined 136 data science college programs across the United States showed that all of the 136 data science college programs examined contained two or more of the ACM data science competencies. The goal of this research study is to further examine the 136 data science programs identified in [4] for similarities and differences in data science competency offerings among the programs. College/university were placed in ranking categories based on U.S. News ranking categories (national ranking, national liberal arts ranking and regional ranking) and programs were compared within and among categories. In addition, colleges not ranked by the U.S. News ranking service were also examined and compared. The research questions answered as a result of this study are:

RQ1. Do undergraduate Data Science program profiles vary by college ranking?
RQ2. Do undergraduate Data Science program competencies vary by college ranking?

2.0 Literature Review

Economic and industry trends and demands influence the decisions made by universities to revise and develop program offerings [5] as universities are challenged by the need to keep programs current [6]. Some universities have developed relationships with regional businesses to ensure that their programs are aligned with the needs of the local business community[7]. By increasing involvement of local employers in updating and developing university programs, these universities have been better able to target their programs to the needs of the local business

and ultimately better prepare their graduates [7][8][9][10]. Employer involvement in university programs range from participation in curriculum design to work-based learning opportunities for students [7][8][9][10]. In addition to employer involvement, many universities have engaged in activities such as identifying the regional industries and the regional economic growth in order to ensure students understand the career pathway options available to them once they have completed the academic path taken[7][8][9][10]. Universities realize the important relationship between economic growth and well prepared graduates who can meet the demands of local businesses[10]. Students are also cognizant of the important relationship between university program and job opportunities [11]. Offering programs that are in high demand attracts more students and ultimately increases the economic benefits for the university [11].

The development and revision of program offerings to meet the demand of the economic market is a key focus of most universities [12][13]. Some universities have adopted industry developed competency models that define performance in that specific industry [12][13]. These competencies help to identify the skills, abilities and knowledge required and are used as a framework for measuring performance in that particular industry[12][13]. Universities use these models to identify the skill set required by the industry and to provide a framework for developing learning objectives[12][13]. Aligning curriculum with industry developed competencies is a key aspect in the development or revision of new programs as without such alignment, employability is affected[14] [15]. In the past 40 years, the incorporation of industry competencies has become an important aspect of curriculum development and revision[14][15].

Highly-ranked colleges and universities have lucrative connections with industry [16] [17]. Hiring institutions consider high-ranking colleges and universities prestigious [18], [19], [16] and are willing to pay higher wages to secure students who have graduated from these colleges and universities [16]. Hiring institutions consider a high rank as an indicator of the quality of student [18], [19], 16] and often base their hiring decisions on ranking, ultimately reducing the uncertainty associated with the process of hiring [18] [19], [16]. For potential students, the decision to attend a specific college or university is influenced by several factors including the college's or university's ranking, prestige, program offerings and employability [20] [16]. Highly ranked colleges are sought after as students at these colleges tend have a higher graduation rate, have more prestigious careers and therefore earn higher salaries and are more likely to continue their studies [21][22][23]. The robustness of programs offered by these high-ranking colleges contributes greatly to the success of the institution [21][22][23] and to its ranking. A high ranking for a college impacts its admission rates [21][22][23] ultimately increases its financial standing and its academic growth.

3.0 Method

3.1 Data Source

Original Data Source

The screening criteria for the academic programs provides the degrees in Data Science in the categories: AS, AA, AAS, BA, BS, BA and BS, and Certificate. The 136 college programs

utilized in this study are derived from an earlier study [4] in which the following websites were crawled and college program data was recorded:

- Associate Degree Programs:
  - https://www.discoverdatascience.org/programs/associate-in-data-science/
  - https://ryanswanstrom.com/colleges/
  - https://community.amstat.org/blogs/steve-pierson/2017/04/25/data-scienceanalytics-coursesprograms-in-two-year-colleges

- Undergraduate Degree Programs:
  - https://www.mastersindatascience.org/specialties/bachelor-degrees-in-data-science/
  - https://ryanswanstrom.com/colleges/
  - https://www.datasciencedegreeprograms.net/rankings/affordable-bachelors/
  - https://blog.collegevine.com/the-list-of-all-u-s-colleges-with-a-data-science-major/
  - https://www.usnews.com/best-colleges/rankings/computer-science/data-analytics-science

College ranking data used in this study was derived from the U.S. News college ranking data available in the U.S. News website (https://www.usnews.com/best-colleges?int=top_nav_Colleges). An analysis of the U.S. News college ranking website was conducted to identify which of the 136 colleges identified in [4] were ranked. U.S. News national ranking, regional ranking (north, west, south and east), and national liberal arts ranking data was collected for each of the colleges identified.

3.2 Datasets

Twenty six (26) of the 136 colleges[4] were not ranked by U.S. News. The final total of 110 colleges were grouped into three ranking categories 1) national ranking, 2) regional ranking and 3) national liberal arts ranking. Table 1 shows the U.S. News college ranking categories and the number of colleges ranked for each of these categories.

U.S. News Ranking Category	**Number of colleges ranked**	
National	66	1: 1-75 2: 76-150 3: 151-225 4: 226-297 5: 298-389
Regional	36	1: 1-16 2: 17-75 3: 76-150
National Liberal Arts	8	1: 15 2: 84 3: 102 4: 113, 5: 113 6: 120 7: 127

		8: 140
TOTAL	**110**	

Table 1: U.S. News ranking categories, the number of colleges in each category and the rank ranges for each category

For the 110 colleges ranked, the US News rank category (National, Regional, National Liberal Arts) and the ranking number was recorded. For the purpose of this study, 5 rank ranges were created for the national category to facilitate the analysis of the data. The 5 rank ranges are: 1-75, 76-150, 151-225, 226-297 and 298-389. The 298-389 category was created to capture the lower ranked colleges who were not ranked by US News with a single rank number but rather a range. For colleges categorized under "Regional," we strived to create a more even distribution of colleges by creating three rank ranges: 1-16, 17-75, and 76-150. Again these ranges were created to facilitate the analysis of the data. There were only 8 colleges categorized under the "National Liberal Arts" category and we therefore used the US News rank number assigned and did not create a rank range for this category.

3.4 Data Science Competencies

The data science competencies used in this study were derived from [4] and are based on the findings of the Association of Computing Machinery (ACM) Data Science Task Force who identified the 11 Data Science competencies shown in Table 2.

ACM Data Science Task Force Report Competencies	
1. Analysis and Presentation ● Foundational considerations ● Visualization ● User-centered design ● Interaction design ● Interface design and development	**7. Data Privacy, Security, Integrity, and Analysis for Security** ● Data privacy ● Data security ● Data integrity ● Analysis for security
2. Artificial Intelligence ● General ● Knowledge representation and reasoning – logic based ● Knowledge representation and reasoning – probability based ● Planning and search strategies	**8. Machine learning** ● General ● Supervised learning ● Unsupervised learning ● Mixed methods ● Deep learning
3. Big Data Systems ● Problems of scale ● Big data computing architectures ● Parallel computing frameworks ● Distributed data storage ● Parallel programming ● Techniques for Big Data applications ● Cloud computing ● Complexity theory ● Software support for Big Data applications	**9. Programming, data structures and algorithms** ● Algorithmic thinking and problem solving ● Programming ● Data structures ● Algorithms ● Basic complexity analysis ● Numerical computing
4. Computing and Computer Fundamentals ● Basic computer architecture ● Storage systems fundamentals ● Operating system basics ● File systems ● Networks ● The web and web programming ● Compilers and interpreters	**10. Software development and maintenance** ● Software design and development ● Software testing
5. Data Acquisition, Management, and Governance	**11. Professionalism**

● Data acquisition ● Information extraction ● Working with various types of data ● Data integration ● Data reduction and compression ● Data transformation ● Data cleaning ● Data privacy and security	● Continuing professional development ● Communication ● Teamwork ● Economic considerations ● Privacy and confidentiality ● Ethical considerations ● Legal considerations ● Intellectual property ● On automation
6. Data Mining ● Proximity measurement ● Data preparation ● Information extraction ● Cluster analysis ● Classification and regression ● Pattern mining ● Outlier detection ● Time series data ● Mining web data ● Information retrieval	

Table 2: ACM Data Science Task Force identified Data Science Competencies and sub-topics

In [4] the 11 ACM Data Science Competencies were clustered into seven competencies as follows 1) Computing fundamentals, 2) Data management, governance and privacy, 3) Data visualization, 4) Machine learning, 5) Data mining, Big data, 6) Data Science in context, and 7) Math and Statistics. This bottom up approach was used after a careful evaluation of the curriculum requirements for the Data Science programs in the 136 colleges examined an to more directly align the 2021 ACM Data Science Task Force competencies [4][22] with current Data Science degree programs. These seven competencies are used in the current study. Table 3 displays the mapping of the seven competencies and corresponding eleven ACM Data Science Task Force Competencies.

Competencies	**ACM Data Science Task Force Report Competencies**	**Sample Courses**
Computing Fundamentals	4, 9, 10	SQL Programming, Introduction to Programming, Algorithms, Data Structures, Object Oriented Programming, Software Engineering, Systems Analysis and Design, Human-Computer Interaction
Data Management, Governance, Privacy	5, 7, 11	Data Warehousing, SQL, Databases, Security, Fraud Detection, Network Security, Ethics
Data Visualization	1	Data Visualization
Machine Learning	2, 8	Machine Learning, Data Modeling, Artificial Intelligence, Deep Learning
Data Mining, Big Data	3, 6	Data mining, Data modeling, systems analysis, Big Data, Data munging
Data Science in Context	11	Capstone, Internship, Senior Project, courses in disciplines such as physics, biology, chemistry, the humanities, or other areas
Math and Statistics		Calculus, discrete structures, probability theory, elementary statistics, advanced topics in statistics, and linear algebra.

Table 3: Mapping of 7 competencies to 11 ACM Data Science Task Force Competencies

3.5 Data Analysis

Pearson's Correlation Coefficient Analysis was conducted. Pearson correlation coefficient is used to measure the vigor of the linear association between two variables [24]. For

the purposes of this study, Pearson's correlation coefficient analysis was used to reveal the possible relationship between college ranking and competencies. Excel Pivot tables and graphs were used to analyze undergraduate college program profile data and visualize the results.

4.0 Results

4.1 National US Ranking Category

In this section, colleges ranked in the US Ranking Category "National" will be examined. First an analysis of these colleges' profiles (number of colleges, majors, departments/schools) will be conducted, followed by an analysis of the data science competencies offered by these colleges.

4.1.1 RQ1 – Analysis of college profiles

US Ranking category "National" and number of colleges in each rank range

Rank Range	No. of Colleges
1-75	24
76-150	20
151-225	12
226-297	5
298-389	5

Table 2: National ranking category and the number of colleges in each rank range

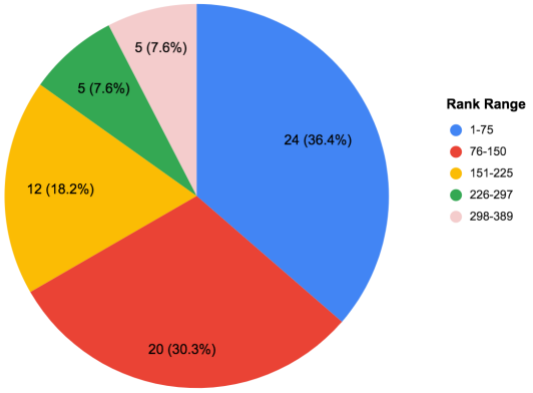

Figure 2: National ranking category and the number of colleges in each rank range

The top two rank ranges (1-75 and 76-150), contain the largest number of colleges in the National category. The bottom two rank ranges (226-297 and 298-389), contain an even distribution of colleges in the National category.

US Ranking Category "National" and majors in each rank range

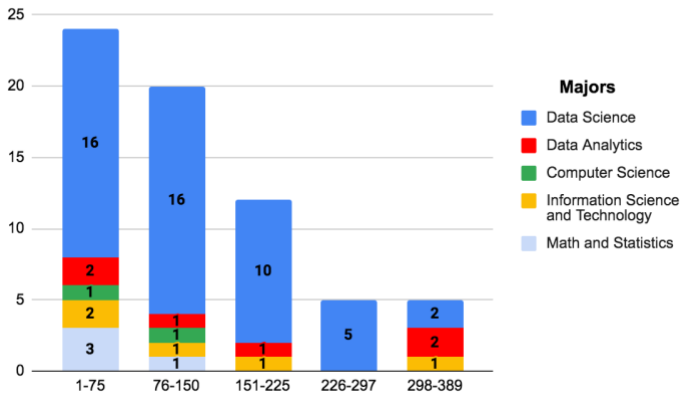

Figure 3: National ranking category and majors in each rank range

Rank Range	Data Science	Data Analytics	Computer Science	Information Science and Technology	Math and Statistics
1-75	16	2	1	2	3
76-150	16	1	1	1	1
151-225	10	1	0	1	0
226-297	5	0	0	0	0
298-389	2	2	0	1	0

Table 3: National ranking category and majors in each rank range

The majority of the top ranking National colleges (1-75 and 76-150) offer data science programs in the Data Science major. A few of these top ranking National colleges also offer data science programs in four additional majors; Data Analytics, Computer Science, Information Science and Technology and Math and Statistics. Lower ranking National colleges (151-225 and 226-297) offer the majority of data science programs in the data science major. National colleges ranked in the 151-225 rank range also offer data science programs in the Data Analytics major and in the Information Science and Technology major. The lowest ranking National colleges (298-389) offer data science programs equally in the Data Science major and in the Data Analytics major, with one college in this rank range offering their data science program in the Information Science and Technology major.

US Ranking category "National" and departments/schools in each rank range

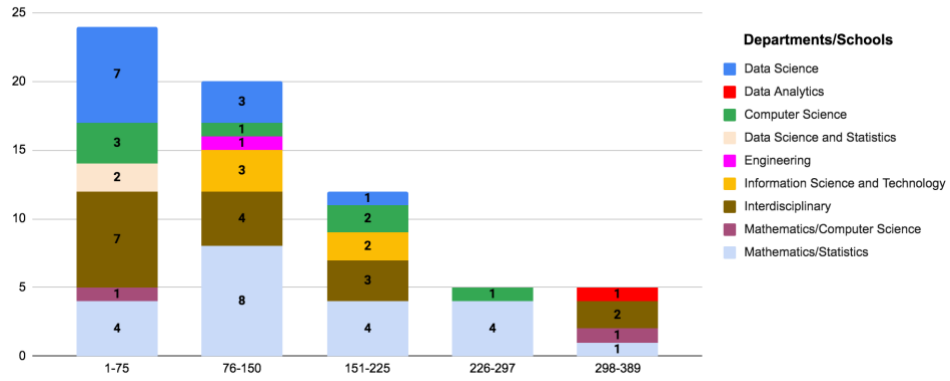

Figure 4: National ranking category sand departments/schools in each rank range

Rank Range	Data Science	Data Analytics	Computer Science	Data Science and Statistics	Engineering	Information Science and Technology	Interdisciplinary	Mathematics/ Computer Science	Mathematics/ Statistics
1-75	7	0	3	2	0	0	7	1	4
76-150	3	0	1	0	1	3	4	0	8
151-225	1	0	2	0	0	2	3	0	4
226-297	0	0	1	0	0	0	0	0	4
298-389	0	1	0	0	0	0	2	1	1

Table 4: National ranking category and departments/schools in each rank range

The top ranking National colleges (1-75 and 76-150) offer data science programs in the Data Science, Interdisciplinary and Mathematics/Statistics departments. Across all rank ranges, data science programs are more often offered by the Mathematics/Statistics department.

4.1.2 RQ2 – Analysis of competencies

US Ranking category "National" and Data Science competencies in each rank range

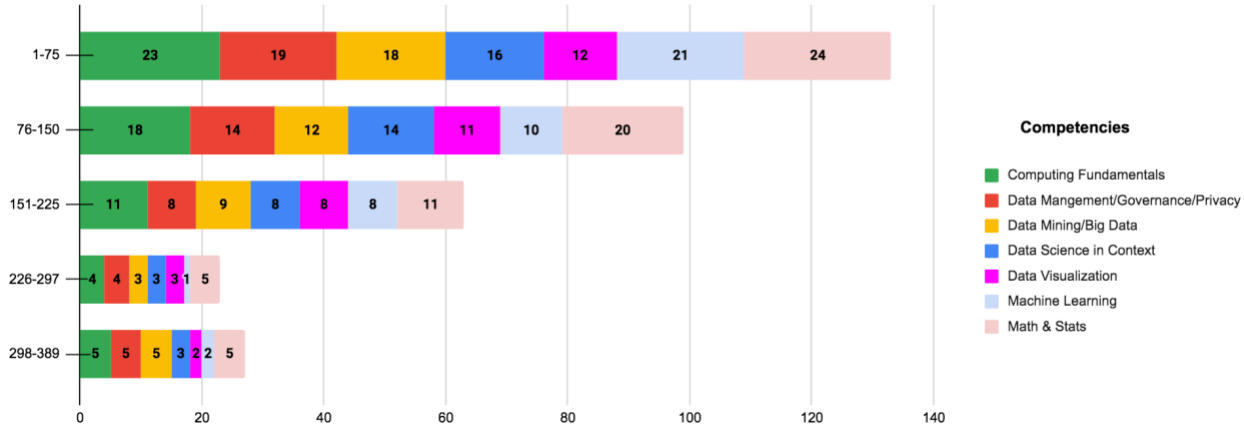

Figure 1: National ranking category and data science competencies in each rank range

Rank Range	Computing Fundamentals	Data Mangement/ Governance/ Privacy	Data Mining/Big Data	Data Science in Context	Data Visualization	Machine Learning	Math & Stats
1-75	23	19	18	16	12	21	24
76-150	18	14	12	14	11	10	20
151-225	11	8	9	8	8	8	11
226-297	4	4	3	3	3	1	5
298-389	5	5	5	3	2	2	5

Table 1: National ranking category and data science competencies in each rank range

All Nationally ranked colleges regardless of their ranking, offer all the Data Science competencies. The most prevalent Data Science competencies offered by National colleges across all rank ranges are; Math & Statistics, Computing Fundamentals, Machine Learning, Data Management/Governance and Privacy and Data Mining/Big Data.

4.2 Regional US Ranking Category

In this section, colleges ranked in the US Ranking Category "Regional" will be examined. First an analysis of these colleges' profiles (number of colleges, majors, departments/schools) will be conducted, followed by an analysis of the data science competencies offered by these colleges.

4.2.1 RQ1 – Analysis of college profiles

US Ranking category "Regional" and number of colleges in each rank range

Rank Range	No. of Colleges
1-16	13
17-75	13
76-150	10

Table 6: Regional ranking category and number of colleges in each rank range

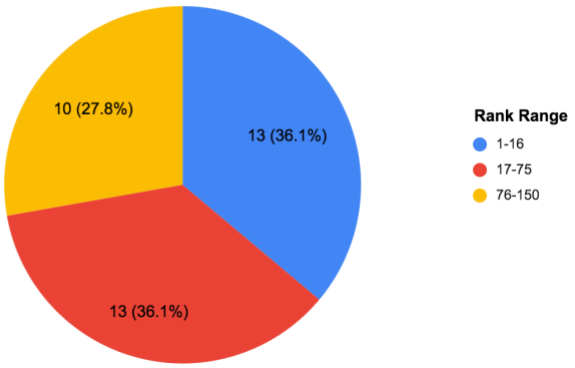

Figure 6: Regional ranking and number of colleges in each rank range

All the colleges in the Regional ranking category are pretty much evenly distributed among the three ranking ranges 1-16, 17-75 and 76-150. The two top rank ranges (1-16 and 17-75) contain 13 Regional colleges each, while the bottom rank range (76-150) contains 10 Regional colleges.

US Ranking Category "Regional" and majors in each rank range

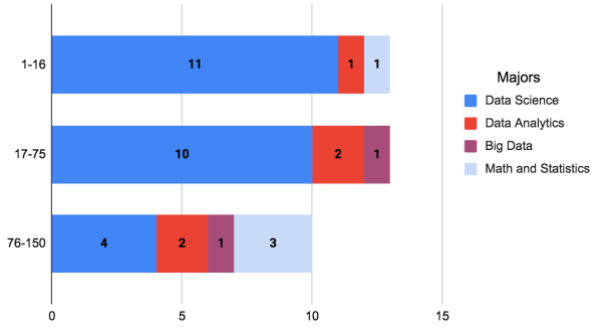

Figure 7: Regional ranking category and majors in each rank range

Rank Range	Data Science	Data Analytics	Big Data	Math and Statistics
1-16	11	1	0	1
17-75	10	2	1	0
76-150	4	2	1	3

Table 7: Regional ranking category and majors in each rank range

Similar to the National ranked colleges, the top ranked Regional colleges (1-16 and 17-75) offer data science programs in the Data Science major. The lower ranked Regional colleges (76-150) offer data science programs in all four majors; Data Science, Data Analytics, Big Data and Math and Statistics.

US Ranking category "Regional" and department/schools in each rank range

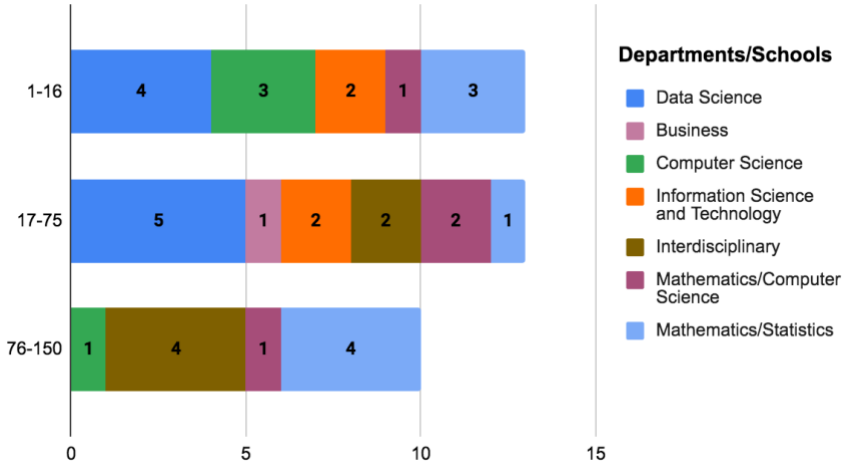

Figure 8: Regional ranking category and departments/schools in each rank range

Rank Range	Data Science	Business	Computer Science	Information Science and Technology	Interdisciplinary	Mathematics/ Computer Science	Mathematics/ Statistics
1-16	4	0	3	2	0	1	3
17-75	5	1	0	2	2	2	1
76-150	0	0	1	0	4	1	4

Table 8: Regional ranking category and departments/schools in each rank range

Top ranked Regional colleges (1-16 and 17-75) offer data science programs in the Data Science departments. Regardless of rank ranges, the Mathematics/Computer Science department and the Math/Statistics department offer data science programs.

4.2.2 RQ2 - Analysis of competencies

US Ranking category "Regional" and Data Science competencies in each rank range

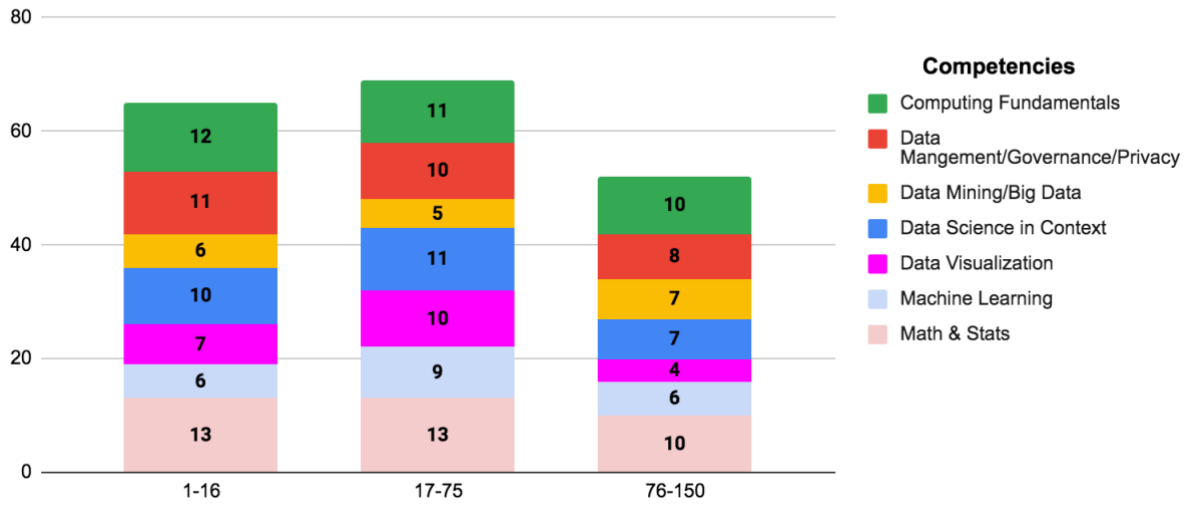

Figure 5: Regional ranking category and Data Science competencies in each rank range

Rank Range	Computing Fundamentals	Data Mangement/ Governance /Privacy	Data Mining/Big Data	Data Science in Context	Data Visualization	Machine Learning	Math & Stats
1-16	12	11	6	10	7	6	13
17-75	11	10	5	11	10	9	13
76-150	10	8	7	7	4	6	10

Table 5: Regional ranking category and Data Science competencies in each rank range

Much like the National ranked colleges, all Regional ranked colleges, regardless of ranking, offer all the data cience competencies. The most prevalent Data Science competencies for the Regional ranked colleges are: Math & Statistics, Computing Fundamentals, Data Management/Governance/Privacy, Data Science in Context, and Data Visualization.

4.3 National Liberal Arts US Ranking Category

In this section, colleges ranked in the US Ranking Category "National Liberal Arts" will be examined. First an analysis of these colleges' profiles (number of colleges, majors, departments/schools) will be conducted, followed by an analysis of the data science competencies offered by these colleges.

4.3.1 RQ1 – Analysis of college profiles

US Ranking category "National Liberal Arts" and number of colleges in each rank

Rank Range	No. of Colleges
15	1
84	1
102	1
113	2
120	1
127	1
140	1

Table 10: National Liberal Arts ranking category and number of colleges in each rank range

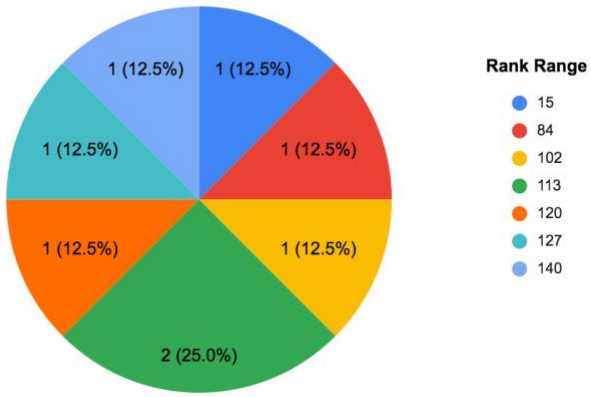

Figure 10: National Liberal Arts ranking category and number of colleges in each rank range

The eight colleges in the US Ranking "National Liberal Arts" category are almost evenly distributed across the ranks.

US Ranking category "National Liberal Arts" and majors in each rank

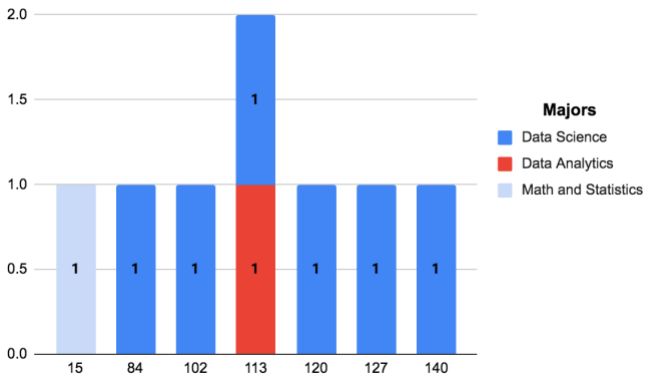

Figure 11: National Liberal Arts ranking category and majors in each each rank range

Rank Range	Data Science	Data Analytics	Math and Statistics
15	0	0	1
84	1	0	0
102	1	0	0
113	1	1	0
120	1	0	0
127	1	0	0
140	1	0	0

Table 11: National Liberal Arts ranking category and majors in each rank range

The top ranking National Liberal Arts college (rank 15) offers the data science program in the Math and Statistics major. The remainder of the National Liberal Arts colleges in the ranks: 84, 102, 113, 120, 127, 140 offer the data science program in the Data Science major. One National Liberal Arts college in the rank 113 offers the data science program in the Data Analytics major.

US ranking category "National Liberal Arts" and departments/schools in each rank

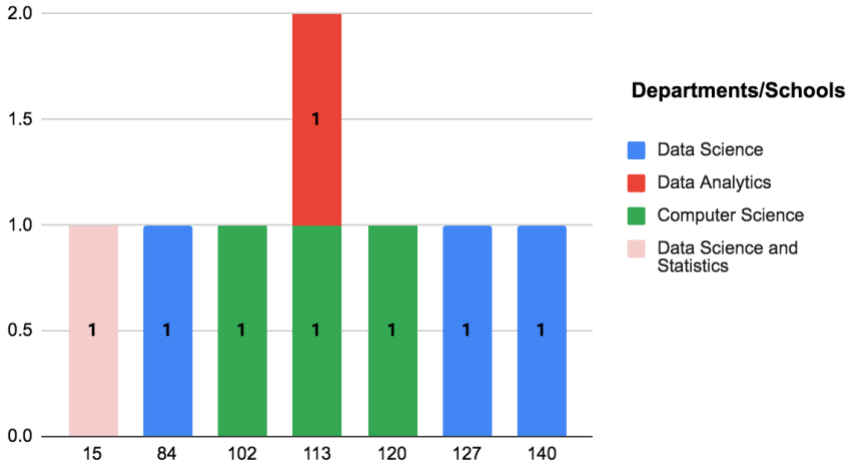

Figure 12: National Liberal Arts ranking category and departments/schools in each rank range

Rank Range	Data Science	Data Analytics	Computer Science	Data Science and Statistics
15	0	0	0	1
84	1	0	0	0
102	0	0	1	0
113	0	1	1	0
120	0	0	1	0
127	1	0	0	0
140	1	0	0	0

Table 12: National Liberal Arts ranking category and departments/schools in each rank range

The top ranked National Liberal Arts college (rank 15) offers the data science program in the Data Science and Statistics department. The second top ranked National Liberal Arts college (rank 84) offers the data science programs in the Data Science department. The remainder of the National Liberal Arts colleges ranked as 102, 113, 120, 127 and 140 offer

data science programs in four departments; Data Science, Data Analytics, Computer Science and Data Science and Statistics departments.

4.3.2 RQ2 – Analysis of competencies

US Ranking Category "National Liberal Arts" and Data Science competencies in each rank

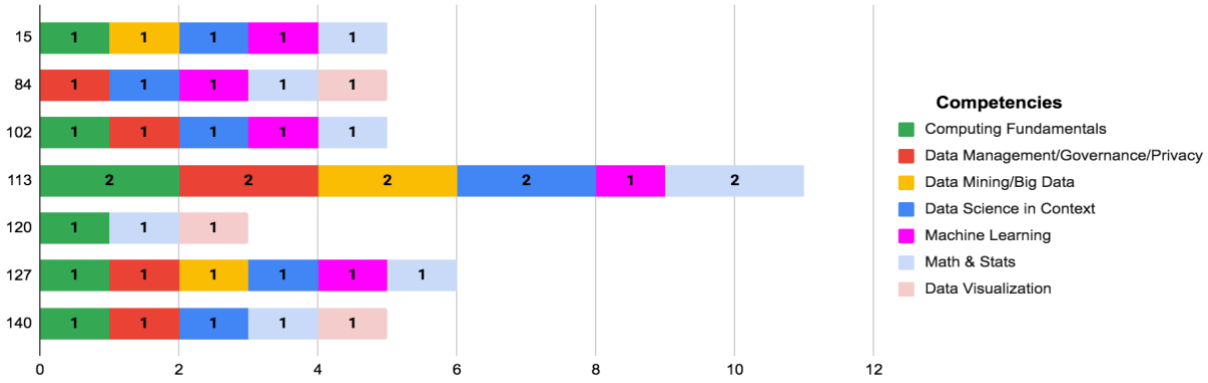

Figure 9: National Liberal Arts ranking category and Data Science competencies in each rank range

Rank Range	Computing Fundamentals	Data Management/ Governance/ Privacy	Data Mining/Big Data	Data Science in Context	Machine Learning	Math & Stats	Data Visualization
15	1	0	1	1	1	1	0
84	0	1	0	1	1	1	1
102	1	1	0	1	1	1	0
113	2	2	2	2	1	2	0
120	1	0	0	0	0	1	1
127	1	1	1	1	1	1	0
140	1	1	0	1	0	1	1

Table 9: National Liberal Arts ranking category and Data Science competencies in each rank range

None of the colleges in the National Liberal Arts category offer all 7 of the Data Science competencies. National Liberal Arts colleges ranked 113 and 127, offer the most data science competencies (6 out of 7). Colleges ranked 15, 84, 102, and 140 offer 5 out of 7 competencies. The college ranked 120 offers the least amount of competencies (3 out of 7). The Math and Statistics competency is offered by all the National Liberal Arts colleges regardless of their ranking.

5.0 Discussion and Conclusion

Our findings showed that 67% of the top ranking National colleges (rank ranges: 1-75 and 76-150) offer data science programs. In terms of majors, the top ranking National colleges (1-75 and 76-150) offer the data science programs in the Data Science major

Based on study findings we can conclude that a majority of colleges that offer data science programs are in the top ranking tiers. mainly located in the top 150 colleges and count for 72%. In terms of majors, the top ranking colleges mainly offer the Data Science program in the Data Science major. However, these colleges also show a diversity of majors in which the Data Science programs are offered such as Computer Science or Math and Statistics majors. Future studies can help identify the reason behind such diversity in these colleges. In terms of which departments/schools the Data Science programs are being offered, the study findings revealed a small portion of colleges have a separate data science department/school. The root of Data Science programs are in the Math and Statistics departments/schools or in the Interdisciplinary departments/schools. The latter is justified as the application of data science is far reaching with branches that touch upon finance, health, technology, engineering and more. In terms of the data science competencies, the study findings revealed that regardless of US News ranking categories and ranking ranges, a large majority of colleges offer all seven data science competencies.

The results of the Pearson's Correlation Coefficient Analysis showed that overall, the top ranking colleges in any of the U.S. News Ranking categories (National, Regional, National Liberal Arts) are the only colleges that offer the Machine Learning competency. Also, the top ranking colleges in the North and Midwest regions offer more data science programs than those in the South and West regions.

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