Embracing the Liberal Arts in an Interdisciplinary Data Analytics Program

Jessen Havill
Department of Mathematics & Computer Science
Data Analytics Program
Denison University
Granville, Ohio
havill@denison.edu

ABSTRACT

In 2016, we launched an interdisciplinary, undergraduate Data Analytics major that extends the definition of "interdisciplinary" beyond computer science, mathematics, and statistics to the natural and social sciences, humanities, and fine arts. Our program was conceived, and continues to be administered, as an independent academic unit by a Committee of faculty representing ten disciplines. Students majoring in Data Analytics complete four or more mathematics and computer science courses, four project-oriented Data Analytics courses, three to four courses in one of seven applied domains, and a required summer internship. Data Analytics courses are taught by both dedicated Data Analytics faculty and other faculty from the Committee. Partnerships with campus offices, alumni, businesses, and nonprofits have enhanced both coursework and internship opportunities. The major's popularity has exceeded our expectations, and has succeeded in attracting students with a variety of academic interests, many of whom would not have otherwise pursued a computational or quantitative major.

CCS CONCEPTS

• **Social and professional topics → Computing education**;

KEYWORDS

Data Science, Data Analytics, Curriculum, Liberal Arts

ACM Reference Format:
Jessen Havill. 2019. Embracing the Liberal Arts in an Interdisciplinary Data Analytics Program. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education (SIGCSE '19), February 27–March 2, 2019, Minneapolis, MN, USA.* ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3287324.3287436

1 INTRODUCTION

With the growing availability of huge amounts of data and their increased application in a variety of sectors, undergraduate Data Science and Analytics programs (majors and minors) are on the rise. Anecdotally, it appears that most of these new programs, especially at smaller colleges, are growing out of Computer Science, Mathematics, Statistics, and/or Business departments as alternatives to their established majors [3, 4, 20].

At Denison University, we created an interdisciplinary Data Analytics program, administered as a standalone entity, that takes a more holistic approach to integrating this new discipline into an undergraduate curriculum. Now in its third year, enrollment in the major has grown well beyond our expectations. We believe that our program is unique in at least two ways. First, we recognize the value of Denison's liberal arts curriculum, and actively promote liberal arts values both through the structure of the major and in the content of unique, interdisciplinary core courses. Second, the major is designed to appeal to students with a broad array of interests and backgrounds. This is achieved by intentionally integrating disciplines beyond the quantitative sciences from the outset and establishing a low barrier to entry into the major.

In the following sections, we describe in detail the structure of the major, recount how the major originated and was developed, discuss our goals and the principles we followed in designing the program, and share our results and plans for the future.

2 THE DATA ANALYTICS MAJOR

Denison University is a highly selective liberal arts college located about 30 miles east of Columbus, Ohio that enrolls approximately 2300 undergraduate students. Among peer institutions, our student body is fairly diverse: 20 percent are first-generation college students, 23 percent are domestic students of color, and 16 percent are international. The college offers 50 undergraduate majors and has no graduate programs.

Denison's Data Analytics (DA) major requires 11–12 courses, plus an internship. These requirements are divided into four components, color coded in Figure 1:

(1) computer science and mathematics foundation (yellow),
(2) project-oriented Data Analytics courses (blue),
(3) courses in an applied domain (green), and
(4) summer internship or research project (pink).

The first and third components, and to a lesser extent the fourth, are similar to other Data Science programs. The second component, however, and the way in which the program is administered and staffed, differentiates it from most, if not all, existing programs. In the remainder of this section, we will describe each component in more detail.

SIGCSE '19, February 27–March 2, 2019, Minneapolis, MN, USA

ACM ISBN 978-1-4503-5890-3/19/02…$15.00
https://doi.org/10.1145/3287324.3287436

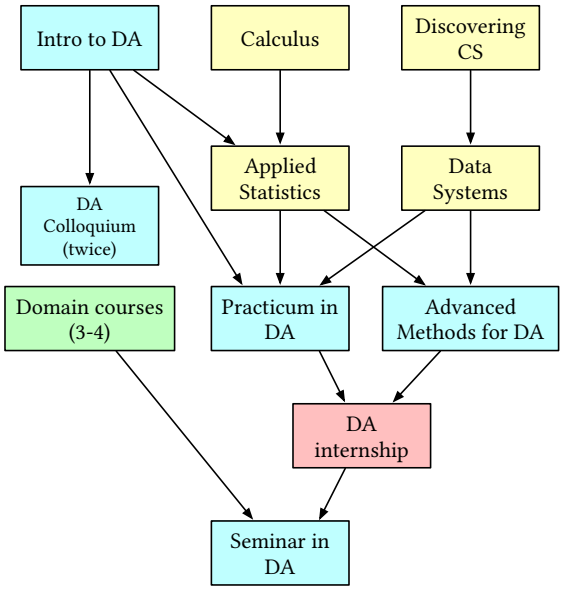

Figure 1: Components and course flow in the Data Analytics major. Computer science and mathematics foundation courses are shaded yellow, Data Analytics courses are shaded blue, domain courses are shaded green, and the internship is shaded pink.

2.1 Computer science and mathematics foundation

DA majors take a minimum of two computer science courses: *Discovering Computer Science* and *Data Systems*. *Discovering Computer Science* is a project-oriented course that teaches computational problem solving and the principles of computer science through simulations and data-oriented problems in the natural or social sciences [5, 12]. *Data Systems* is a novel new course that teaches introductory students, with only one previous CS course, how to work with tabular, relational and hierarchical data models, and interact with data sources via web APIs. Both courses are also required for our major in Computer Science, and utilize the Python programming language. *Data Systems* also introduces SQL.

DA majors also take at least two mathematics courses: *Calculus* (single variable or multivariable, depending on placement) and *Applied Statistics*. *Applied Statistics* covers calculus-based probability, experimental design, data collection, statistical inference, hypothesis testing, and regression analysis. Students are introduced to programming in the R language in both this course and *Introduction to Data Analytics* (below).

Students who wish to deepen their technical knowledge, or who are interested in pursuing data science in graduate school, are encouraged to take additional mathematics (e.g., linear algebra and differential equations, statistical modeling, operations research) and/or computer science (e.g., data structures, database design, artificial intelligence, high performance computing) courses. Some students choose to further pursue a major or minor in Computer Science or Mathematics.

2.2 Project-oriented Data Analytics courses

The core of the DA major consists of four interdisciplinary courses, plus a once-weekly colloquium, that are administered by the DA program. All of these courses engage students in active learning through work on applied, interdisciplinary projects and emphasize communication and teamwork in lab environments.

Introduction to Data Analytics has no prerequisites and is intended to give new students a broad introduction to the data analysis cycle and applications thereof. Through a sequence of projects, the course introduces students to different types of data, basic data collection, programming with data (in R), wrangling data into a tidy format, and elementary descriptive and predictive statistics. The projects are intentionally drawn from a diversity of application areas (e.g., political science, economics, sociology, biology, city planning, psychology, entertainment, sports). Crucially, the course also emphasizes how to effectively visualize and present, orally and in writing, the results of data analysis to a nontechnical audience. Throughout, students are challenged to confront ethical issues arising from the collection, interpretation, presentation, and application of data about human beings.

Practicum in Data Analytics is taken by DA majors in the fall semester of their junior year. In this course, students, in small groups, synthesize, hone, and translate their data analytics skills in the context of semester-long consulting projects with real clients. The clients so far have primarily been campus offices — the Registrar (room utilization), Sustainability (energy usage and carbon neutrality), the library (reference desk usage), Athletics (player metrics for men's basketball), and the Annual Fund — but we are also starting to work with businesses (e.g., a west coast insurance company) and local non-profits (e.g., a local affordable housing coalition). Each student group starts with a project prospectus and works with its client over the course of the semester to produce the desired product. Emphasis is placed on the iterative nature of the data analysis cycle, dealing with ambiguity, effectively working with clients, developing professional visualization and presentation skills, and ethical/social implications of policy recommendations on end users. Students are free to use whatever tools are best for the task at hand (e.g., Python, R, SQL, Tableau, Stata). Overall, the course provides students with a valuable "real world" experience in a safe environment that tolerates failures, and challenges students to learn from them. The course also acts as a prelude to students' summer internships (more below).

Advanced Methods for Data Analytics develops students' understanding of cutting-edge algorithms for data analytics, and how they can be used to answer questions about real-world problems. The emphasis is on modern machine learning methods (both supervised and unsupervised), but also covers topics such as missing data, optimization, dimensionality reduction, and network analysis. As with other DA courses, these techniques are learned through work on projects from a variety of domains (e.g., fraud detection, movie recommendations, online ad placement, a soup kitchen optimization, Egyptian hieroglyphic recognition).

Seminar in Data Analytics is the senior major capstone experience. Each student undertakes an independent consulting or research project over the course of the semester. The project is expected to synthesize each student's accumulated skillset, applied to

a problem in their chosen domain (more below). Weekly seminar meetings provide opportunities to share updates, get critical feedback, and discuss other topics of interest. The course culminates in significant individual research papers and oral presentations.

Finally, starting next year, the *Data Analytics Colloquium* will be a 1-credit (full courses are normally 4 credits) once-weekly opportunity for DA majors to gather to hear from guest speakers and discuss data analytics topics of interest. The overarching theme of the colloquium will be "Data Analytics Across the Liberal Arts." The course must be taken twice by majors: once as a sophomore, and again as either a junior or senior. For sophomore students, the colloquium will provide an initial exposure to advanced methods, wicked problem solving, and possible career paths in the field. For upper-level students, the colloquium will build on their course and/or work experiences, and allow them to share these connections with less experienced students. Because sophomore and junior/senior students will be enrolled in the class together, and faculty from across campus will be invited to give presentations, this course will help to build community among students across levels and with faculty with diverse interests and expertise.

2.3 Courses in an applied domain

Because no data exists in a vacuum, each DA major must choose an applied domain in which to specialize. The goal of this specialization is to understand the types of questions that data are used to answer in that discipline, and how data are collected and interpreted in this context. There are currently seven available domains:

- Anthropology and Sociology,
- Biology,
- Economics,
- Philosophy,
- Physics,
- Political Science, and
- Psychology.

In each domain, students take 3–4 prescribed courses. (Some disciplines allow elective choices.) Included in each set of courses is an "analytics-intensive" course (often that discipline's research methods course). Alternatively, students are invited to design their own domain; these proposals are evaluated based on their coherence and whether they satisfy the goals laid out above.

Our embrace of the liberal arts is perhaps most exemplified by the newly added Philosophy option. Students choosing this domain take one course each in ethics, philosophy of science, and logic. These courses equip students with an appreciation of the history and complexity of moral issues and normative theories so they can investigate and address the ethical challenges that arise in solving analytical problems. They are also a natural way to deepen students' appreciation of what is distinctive about data analytics and to sharpen their critical assessment of its tools and applications. We anticipate that DA students focusing in Philosophy may also pursue questions being addressed in experimental philosophy [10].

2.4 Summer internship or research project

Finally, every DA major is required to undertake a DA-focused internship or research project during the summer between their junior and senior year. The internship experience places students in authentic situations in which to apply their skills and learn more about their particular interest areas. The summer internship (or research project) is intentionally situated between the practicum and the senior seminar; the former prepares students to effectively navigate the internship and be an effective contributor, while the latter gives students an opportunity to reflect on their experience and further investigate problems they encountered.

While students are ultimately responsible for securing their own internship, we have been able to facilitate a number of opportunities through relationships with alumni and local organizations, and a close partnership with our career exploration center.

3 ORIGIN AND DEVELOPMENT

The germination of the Data Analytics major officially began in late 2014, but seeds had been planted over the last decade. During this time, with the growing availability of large datasets, our Mathematics and Computer Science department began to increasingly lean toward data-oriented content in our introductory and elective courses. Across campus, some natural and social science departments were also moving in more data-oriented directions, both in faculty and student research and in their research methods courses. Taken as a whole, it was becoming increasingly clear that data analytics was developing into a new fundamental mode of inquiry that is not specific to any one discipline.

Echoing this sentiment, in response to a call for new academic programs in Fall 2014, two new data analytics/science majors were proposed. These proposals led to conversations among a group of like-minded faculty from seven disciplines in the social and natural sciences (Biology, Computer Science, Economics, Mathematics, Political Science, Psychology, and Sociology/Anthropology). This enlightening and fruitful dialogue stretched over all of 2015. At the time, we were aware of very few model undergraduate Data Analytics/Science programs [3, 4, 13], and none that were appropriate for our liberal arts curriculum. As we discuss in more detail below, we paid particular attention to designing a broad and inclusive program that would create synergy with our liberal arts mission and leverage strengths that were already present. We submitted our consensus proposal for the Data Analytics major in late 2015, and it was approved by the Faculty in Spring 2016. The program officially began in Fall 2016, with the first majors eligible to graduate in May 2019.

4 PRINCIPLES AND GOALS

Since the inception of our program, a handful of curricular guides for data science majors have been published [9, 14, 19].[1] The structure of our major is mostly consistent with these recommendations with two notable differences. First, our program more intentionally integrates the liberal arts and disciplinary perspectives outside of computer science and mathematics into its core. Second, our program has fewer mathematics and computer science requirements than other programs in data science. In what follows, we explain our rationale behind these decisions by highlighting two main principles upon which we designed the major: the centrality of the liberal arts and broadening participation in the program.

[1] Three Denison DA faculty contributed to the PCMI report [9].

4.1 Embracing the liberal arts

The Data Analytics program embraces, rather than competes with, Denison's liberal arts curriculum. In an oft-cited article, William Cronon describes ten qualities of a liberally educated person. He sums them up with this description of the tenth quality, that liberally educated people "Only connect…:"

> More than anything else, being an educated person means being able to see connections that allow one to make sense of the world and act within it in creative ways. Every one of the qualities I have described here—listening, reading, talking, writing, puzzle solving, truth seeking, seeing through other people's eyes, leading, working in a community—is finally about connecting. [8]

The value of these qualities to science education in general has long been recognized. In 1999, Nobel Laureate Thomas Cech wrote that,

> …in history, literature, and the arts one is presented with diverse, often mutually contradictory "data"—different points of view due to incomplete knowledge or the different backgrounds of those doing the viewing. One learns to distill the critical elements from the irrelevant, synthesize seemingly discordant observations, and develop a strong argument. …Scientists need the same skills as humanists to cut through misleading observations and arrive at a defensible interpretation, and intellectual cross-training in the humanities exercises the relevant portions of the brain. [6]

More recently, multiple authors [7, 11, 15, 17, 22] have expounded on the values that the liberal arts bring to Data Science education in particular. They warn of reducing data science to a set of techniques, ignoring the benefits that cultural knowledge and empathy can bring, skills that are best learned through the humanities and arts. For example, Andy Cotgreave, Senior Technical Evangelist at Tableau, writes, "Liberal arts skills are needed at every level of data science, from storytelling and communication of insights through to the training and interpreting of the most advanced machine learning applications in your business." [7] *Data ethnographers* [18, 21] with diverse cultural perspectives are needed to critically evaluate both the data that goes into an analysis and the policies it recommends. Insufficient attention to these issues has caused many well-documented machine learning failures in recent years [16]. Finally, DJ Patil, former Chief Data Scientist of the United States, recently remarked, "If you want to be great, make sure you have a good dose of liberal arts in your training. That is fundamental." [17]

Denison's Data Analytics program promotes the values of the liberal arts both in the structure of the major and within its courses. With regard to the former, each student's 3–4 course domain specialization gives them meaningful exposure to data methodology and concerns grounded in a particular discipline. Notably, we encourage students to approach this experience as a bidirectional exchange. Our emphasis is not simply on applying data analytics techniques to domain-specific data; rather, we recognize the oft-overlooked value that quantitative methodologists bring to our students' education. These domain connections are reinforced through the individual research projects that students complete in their senior seminar. In addition, to afford students the freedom to pursue a well-rounded education, the size of the major is consistent with the College's "rule of thirds" for students' typical 32-course degree: one third major, one third general education requirements, and one third electives. The general education requirements ensure that students acquire a broad education and their freedom with electives allows them to explore further, pursue a second major, or deepen their quantitative skills.

Within the Data Analytics courses described above, liberal arts values are emphasized in a variety of ways. First, the introductory and *Advanced Methods* courses are organized around a sequence of projects that are drawn from a diverse set of disciplines. Through these projects, students explore the rich diversity of the ways in which information is collected, understood, analyzed, and communicated. Effective communication and ethics are two themes common to all Data Analytics classes. They include instruction on, and repeated practice with, clear and concise communication of results—visual, oral, and written—to both technical and nontechnical audiences. And they force students to reflect on and address ethical and fairness concerns arising from the collection and handling of human (and other sensitive) data, and interpreting and reporting inferential conclusions based on them. In addition, in the *Practicum*, students grapple with real problems which force them to become more comfortable with ambiguity and uncertainty. In their communication with clients, students must learn to listen, question their assumptions, and see issues from other points of view. And, in this environment, gaps in students' domain and/or technical knowledge inevitably arise during the semester, pushing students to become independent learners and adopt a growth mindset.

4.2 Broadening student participation

In designing the Data Analytics major, we wanted to welcome a more diverse pool of students than is typically attracted to a quantitative major like computer science. Notably, we intentionally left the word "science" out of the name of the program, opting for "Data Analytics" over "Data Science," to signal that this course of study is not geared exclusively to science-oriented students. For the same reason, we proposed to administer Data Analytics as a standalone interdisciplinary program that is independent of (but collaborates with) the Mathematics and Computer Science department. To staff the program, we hired three new faculty — a quantitative ecologist, an applied mathematician, and a statistician — whose home department is Data Analytics. The program continues to be administered by a diverse Committee that includes the three DA faculty and faculty from several other departments. The directorship of the program will rotate among these departments moving forward. In addition, *Introduction to Data Analytics* has thus far been taught by faculty with primary expertise in mathematics, statistics, biology, psychology, and political science. These decisions serve to position Data Analytics as a discipline that spans a range of application areas and is not "siloed" in any one department or division of the College.

For the same reasons, we designed the curriculum to provide sufficient technical skills without over-emphasizing them relative to

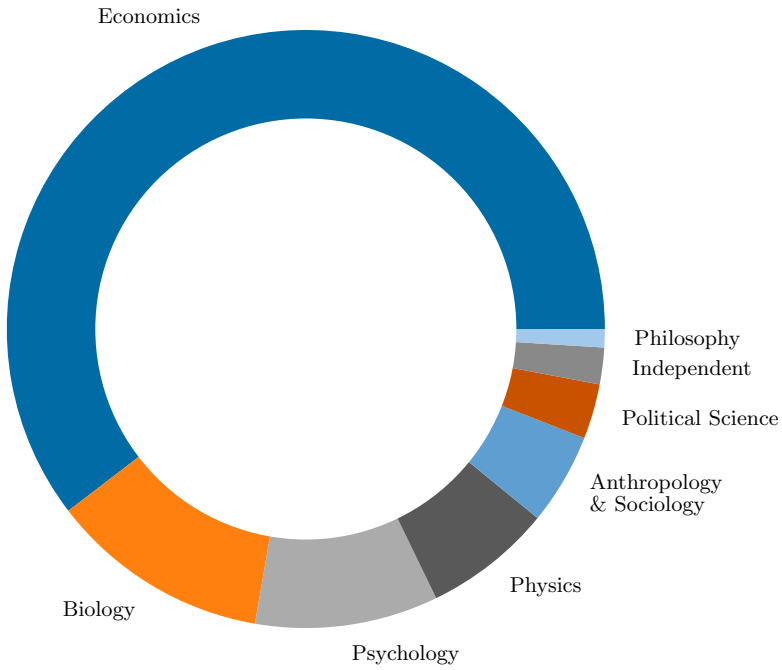

Figure 2: Distribution of Data Analytics majors' chosen domains.

other skills and points of view inherent in this interdisciplinary field. Only requiring four computer science and mathematics courses makes the major more welcoming to students who are apprehensive about quantitative subjects or who have less mathematical preparation. And none of these courses is a prerequisite for our *Introduction to Data Analytics* course, which gently orients students to the field. Additional technical skills are taught in the core DA courses, but in a more holistic way, integrating them with topics like project management, visualization, and communication. (As stated above, students who want to delve more deeply are encouraged to pursue additional courses or a minor/major in computer science or mathematics.) Simultaneously emphasizing the importance of expertise in another discipline (i.e., the domain) appeals to students' existing interests and gives them a "hook" into the major. In these ways, we want to provide a relatively low barrier to entry while meeting students where they are with respect to academic interest.

5 RESULTS

Our novel Data Analytics curriculum has been even more successful than we anticipated. Over the first four semesters of the program, we have offered 13 sections of Introduction to Data Analytics, enrolling approximately 240 students in total. At the end of the program's second academic year (2017–2018), there were already about 100 declared DA majors among the first year, sophomore, and junior classes. Overall, 37% of our majors are women, and this percentage has been rising with each class year.

At the end of the 2018–2019 academic year, our first year with graduating seniors, we anticipate that we will enroll approximately 130 total declared majors, and that we will graduate 27. This would make DA the fifth or sixth largest major at the College in only its third year. Although comparison data is hard to come by, the outdated data that is available [1–3] suggests that our enrollments may be higher than other undergraduate Data Science programs, even at much larger institutions.

We have DA majors with a variety of interests, and are finding that students are coming to DA from a variety of different directions. As illustrated in Figure 2, about half of the majors have chosen to focus in Economics (one of the largest majors at the College), and the remaining half are approximately evenly distributed among the remaining domains. 58% of our majors are currently double majors; 17% are double majoring in Mathematics or Computer Science.

One year into the program, in Fall 2017, we sought insight into introductory students' interest in Data Analytics by asking them, "What aspect of the Data Analytics major is the most appealing or exciting to you?" Their replies generally fell into three categories. About half wrote about integrating data analytics with other interests, for example:

> I love the idea of being able to use both my love for math/analytics and my love of humanities/social sciences in the same career.

> It is a very applicable skill in the workforce today and I can pair it with another interest of mine, psychology.

Another 40% wrote about the broad career opportunities, for example:

> The most appealing aspect is that Data Analytics can take you in many different directions, meaning there are a lot of fields you can go into with a DA major.

> I am interested in being fluent in computer languages such as R as a skill set and working with nonprofits and other humanitarian organizations.

And the final 15% cited their interest in statistics and/or computing, for example:

> I love being able to create graphs out of code, I find it absolutely fascinating!

> The statistics aspect, as well as finding patterns and deciphering what it means in the grand scheme of things.

During the summer of 2018, all 27 rising seniors were successful in securing a DA-oriented internship or research experience. Students worked in a wide variety of sectors, including health care, pharmaceuticals, logistics, criminology, animal care, nonprofits, consulting, dining, retail, insurance, finance, energy, e-commerce/billing, transportation, physics, and athletics. Most students secured these opportunities on their own, with the help of our career exploration center, but we were also able to facilitate some exclusive opportunities by actively pursuing relationships with alumni and local businesses and nonprofits. These relationships have also led to class visits and panels in which our students have the opportunity to learn from practitioners.

6 FUTURE PLANS

Based on student feedback, we are currently exploring additional domains in sports analytics, data journalism, and geosciences. In the future, we would also like to open up possibilities in linguistics, humanistic macroanalysis, and the arts. In the latter vein, we are looking forward to welcoming later this year an artist who creates data-inspired sculpture and a pianist who also works in AI.

We are also likely to propose in the immediate future a Bachelor of Science in Data Science program to better accommodate our students with deeper technical interests. As mentioned previously, these students are currently pursuing a double major or minor in Computer Science or Mathematics. This new option would streamline their requirements, providing for more room in their schedules for other electives.

ACKNOWLEDGEMENTS

I would be remiss in not acknowledging the good work of my colleagues in creating and maintaining the Data Analytics program: Anthony Bonifonte (Data Analytics), Laura Boyd (Economics), Michael Brady (Political Science), Thomas Bressoud (Computer Science), Paul Djupe (Political Science), Mine Dogucu (Data Analytics), Fareeda Griffith (Anthropology and Sociology), Erin Henshaw (Psychology), Ashwin Lall (Computer Science), Andy McCall (Biology), Matthew Neal (Mathematics), Sarah Supp (Data Analytics), and David White (Mathematics).

REFERENCES

[1] American Statistical Association. New Undergraduate Data Science Programs. Amstat News, July, 2015, http://magazine.amstat.org/blog/2015/07/01/new-undergraduate-data-science-programs/, accessed August 30, 2018.

[2] American Statistical Association. New Undergraduate Data Science Programs. Amstat News, August, 2015, http://magazine.amstat.org/blog/2015/08/01/new-undergraduate-data-science-programs-2/, accessed August 30, 2018.

[3] Paul Anderson, James Bowring, Renée McCauley, George Pothering and Christopher Starr. An Undergraduate Degree in Data Science: Curriculum and a Decade of Implementation Experience. In *Proceedings of the 45th ACM Technical Symposium on Computer Science Education*, pages 145–150, 2014.

[4] Paul Anderson, James McGuffee, and David Uminsky. Data Science As an Undergraduate Degree. In *Proceedings of the 45th ACM Technical Symposium on Computer Science Education*, pages 705–706, 2014.

[5] Douglas Baldwin, Valerie Barr, Amy Briggs, Jessen Havill, Bruce Maxwell, and Henry M. Walker. CS 1: Beyond Programming. In *Proceedings of the 48th ACM SIGCSE Technical Symposium on Computer Science Education*, pages 677–678, 2017.

[6] Thomas R. Cech. Science at Liberal Arts Colleges: A Better Education? Daedalus 128:1, pages 195–216, 1999.

[7] Andy Cotgreave. Your analytics team needs a liberal arts major. InfoWorld, April 4, 2018, http://www.infoworld.com/article/3267998/analytics/your-analytics-team-needs-a-liberal-arts-major.html, accessed August 30, 2018.

[8] William Cronon. "Only Connect...": The Goals of a Liberal Education. The American Scholar 67:4, 1998.

[9] Richard D. De Veaux, et al. Curriculum Guidelines for Undergraduate Programs in Data Science. Annual Review of Statistics and its Application 4:2.1–2.16, 2017.

[10] Experimental Philosophy. http://experimental-philosophy.yale.edu/ExperimentalPhilosophy.html, accessed August 30, 2018.

[11] Scott Hartley. The Fuzzy and the Techie: Why the Liberal Arts Will Rule the Digital World. Houghton Mifflin Harcourt, 2017.

[12] Jessen Havill. Discovering Computer Science: Interdisciplinary Problems, Principles, and Python Programming. *Chapman & Hall/CRC Press*, 2016.

[13] Aparna Mahadev and Karl R. Wurst. Developing Concentrations in Big Data Analytics and Software Development at a Small Liberal Arts University. Journal of Computing Sciences in Colleges 30:3, pages 92–98, 2015.

[14] National Academies of Sciences, Engineering, and Medicine. Data Science for Undergraduates: Opportunities and Options. The National Academies Press, doi.org/10.17226/25104, 2018.

[15] JM Olejarz Liberal Arts in the Data Age. Harvard Business Review, July–August, 2017, http://hbr.org/2017/07/liberal-arts-in-the-data-age, accessed August 30, 2018.

[16] Cathy O'Neil. Weapons of Math Destruction: How Big Data Increases Inequality and Threatens Democracy. Crown Publishing Group, 2016.

[17] DJ Patil. Big Data, and How It Can Solve the World's Most Pressing Problems. Lecture presented at The Ohio State University, September 19, 2018, https://livestream.com/WOSU/DJPatil/videos/180512174, accessed November 26, 2018.

[18] Sarah Pink, Deborah Lupton, Martin Berg, Paul Dourish, Adrian Dyer, Vaike Fors, Edgar Gómez Cruz, Heather Horst, Pilar Lacasa, John Postill, Shanti Sumartojo, and Emma Witkowski. DATA ETHNOGRAPHIES (1): personal data in an uncertain world. Data Ethnographies Lab, 2016, https://dataethnographies.com/paper-i-personal-data-in-an-uncertain-world/, accessed November 26, 2018.

[19] Renata Rawlings-Goss. Keeping Data Science Broad: Negotiating the Digital and Data Divide Among Higher Education Institutions. South Big Data Innovation Hub, 2018, https://southbigdatahub.org/programs/keeping-data-science-broad/, accessed August 30, 2018.

[20] Ryan Swanstrom. College and University Data Science Degrees. http://datascience.community/colleges, accessed August 30, 2018.

[21] Tricia Wang. Why Big Data Needs Thick Data. https://medium.com/ethnography-matters/why-big-data-needs-thick-data-b4b3e75e3d7, accessed November 26, 2018.

[22] Adam Weinberg. Data Analytics and the Liberal Arts. Huffington Post blog, April 19, 2016, http://www.huffingtonpost.com/adam-weinberg/data-analytics-and-the-li_b_9721312.html, accessed August 30, 2018.