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A Proposed Concentration Curriculum Design for Big Data Analytics for Information Systems Students

John C. Molluzzo
jmolluzzo@pace.edu

James P. Lawler
jlawler@pace.edu

Pace University
One Pace Plaza
New York, New York 10038

Abstract

Big Data is becoming a critical component of the Information Systems curriculum. Educators are enhancing gradually the concentration curriculum for Big Data in schools of computer science and information systems. This paper proposes a creative curriculum design for Big Data Analytics for a program at a major metropolitan university. The design emphasizes expanded learning of business, mathematical and statistical, and presentation skills, in projects of teams, in addition to skills in technology. This paper will be beneficial to educators considering improvement of the curriculum for Big Data Analytics and to students desiring a more contemporary program.

Keywords: analytics, big data, computing curricula, data mining, data science, privacy, security.

1. BACKGROUND AND DEFINITION

"Data is the New Oil" (Smolan and Erwitt, 2012).

Big Data is defined as "bigger and bigger and bigger" (Aiden, & Michel, 2013) aggregates of data that challenge business firms in analyzing business benefit with common software. Big Data dimensions are defined in a diverse variety of structured data, such as traditional transaction data, and non-structured data, such as mobile sensor and social media networking data; in a velocity as to rapid sensitivity to real time timeliness of the data; in a veracity as to the purity of sizable volume; and in sheer streaming volume (Ohlhorst, 2013). Big Data is essentially a data management paradigm shift (Borkovich, & Noah, 2013). Big Data is estimated to be in dozens of terabytes to multiples of petabytes (IBM, 2014), growing 50% each year and 100% every 2 years in business firms (Lohr, 2012); and is estimated to be further impacted by increased information from the "internet of things" (Morozov, 2014), such as consumer wearables (Minsker, 2014a). Firms in the retail industry, such as Walmart, store 2.5 petabytes or 1 quadrillion bytes of data (McAfee, & Brynjolfsson, 2012). The storing of data however is less important than the business benefit to be acquired from the analysis of the data, in cost control, decision improvement and design improvements in processes, products and services (Davenport, 2014), especially from the cross-fertilization of customer social networking and transaction data streaming into firms (Brustein, 2014). The accessibility of such data is apparently a "big deal" (eWeek, 2013), as firms exploit the potential of data analytics in

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this perceived revolution of technology (Freeland, 2012).

The benefits of Big Data Analytics (henceforth referred to as BDA) are cited frequently in firms (IBM, 2014). Amazon is analyzing data for competitive customer micro-segmentation of products to customize its products and services; Google is analyzing messaging to improve its services (Rosenblatt, 2014); and Tesco and Walmart are analyzing demographics to lower inventory pricing of products and services at their stores. Twitter is analyzing hashtags for more patterns of potential sales from subject trends. Firms are clearly interested in BDA to optimize the outcomes of processes, products and services. Even the government and the health industry (Kim, Trimi, & Chung, 2014) are commencing initiatives in efficiency, decision improvement and cost control from BDA to optimize the outcomes of processes and services (Liyakasa, 2013). Though firms may be storing increased data without increased insight (Minsker, 2014b), the potential of BDA as a profitable attribute, beyond the benefits of Business Intelligence and Operations Research, is evident in the literature (King, 2014). This potential invites consideration of BDA as a differential feature of learning in schools of computer science and information systems.

Graduates from schools of computer science and information systems can contribute to the field of data analytics if the curricula of the schools include BDA. Though firms are investing in BDA, they do not have enough data scientists or specialists (May, 2013) for extracting the potential of their data (McCafferty, 2013). Graduates can contribute to the field if they have analytical business skills (Janicki, Cummings, & Kline, 2013) and content domain expertise skills (Poremba, 2013) to critically evaluate the business (Pratt, 2013) of Big Data. They can contribute to this evaluation if they have computational mathematical and statistical skills (Hulme, 2013), can interpret in a high performance environment the complex event significances of structured and non-structured data, and evaluate potential problem solutions or proposed strategies (Pratt, 2013). They can contribute further if they have privacy and security sensitivity skills in standards for Big Data housed by organizations, especially given intrusion issues as discussed in the literature (Lohr, 2013, Sengupta, 2013, & Angwin, 2014). Moreover, they can contribute notably to the field if they have persuasive presentation skills (Miller, 2013), as individual contributors or members of teams, in proposing solutions and strategies; and they can contribute powerfully if they have skills in visualization (Rao, & Halter, 2013). These skills are beyond the data base analysis, design and development skills in technology (King, 2013). Though few graduates, or even practitioners in industry (MacSweeney, 2013a), have all of these skills to be data scientists, a creative curriculum design in Data Science may improve the breadth of ensemble learning for students currently enrolled in schools of computer science and information systems.

2. FOCUS OF PAPER

"The Big Data [R]evolution holds the promise of empowering all of us with knowledge" (Smolan and Erwitt, 2012).

The proposed concentration of Data Science at Pace University is the focus of this paper. The focus is apt, as firms desire BDA personnel but do not have enough expertise for initiatives on projects (Davenport, 2014). Many firms have a BDA expertise gap (Olavsrud, 2014), despite the hype of pundits. The literature indicates that industry needs 140.0 – 190.0 thousand BDA professionals if not data scientists in 2014 (Manyika, Chui, Brown, Bughin, Dobbs, Roxburgh, & Byers, 2011) and even a high of 4.4 million scientists in 2015 (IBM, 2014). Even though a concentration of Data Science is not enough for an immediate solution, the convergence is current to the expectations of industry and organizations, as they initiate investment in Big Data strategies (Messmer, 2014). The focus of this paper on the Data Science curriculum will benefit educators and students desiring a foundation for an immediately marketable program.

3. CONCENTRATION METHODOLOGY – DATA SCIENCE

"Having the data is only the beginning "(Smolan and Erwitt, 2012).

Pace University is anticipating beginning a concentration in Data Science in 2015 with the offering of the Concepts of Big Data Analytics course. The concentration covers descriptive, predictive and prescriptive analytics (Camm, Cochran, Fry, Ohlmann, Anderson, Sweeney, & Williams, 2015) for data-driven decision making. The concentration is designed for undergraduate students to learn business, mathematical and statistical, presentation, team-playing and high-level technology skills. In the concentration**,** projects are assigned to incubating pseudo data scientist teams (O'Neil, & Schutt, 2014) consisting of different skilled students (Schmerken, 2013) of 3–5 individuals. The projects are focused on the design of processes, products or services in a discrete industry, such as energy, entertainment, finance, health and life sciences, or retail. The projects are to be focused on BDA problems in the industries and are to be furnished with data sets of a massive scale from non-proprietary Web sites and systems, such as www.data.gov, www.enigma.io (Singer, 2014) and www.openwebanalytics.com. The projects are to include internship and mentoring of the student teams from a few firms in the industry that are partnered with the school and even have data analytics employment positions (ITBusinessEdge, 2014). In 2016–2017 a few boutique data scientist firms may be partnered with the school. Technologies in the concentration include, but are not limited to, Apache, Hadoop, MapReduce, NLP for text, NoSQL, Python tools (Knorr, 2013) and SAS tools. The concentration in Data Science is planned to begin in 2016–2017 after the Concepts of Big Data Analytics course, by expanded learning of mathematical, statistical and technology skills that will involve other faculty (King, 2013) in the school. Few schools of computer science and information systems have curriculum design initiatives in Data Science (MacSweeney, 2013b) as envisioned in this paper.

The generic learning objectives of the Data Science concentration are defined below:

- Analyze a business process, product or service for experimental improvement in an organization that can benefit by BDA;

- Collaboratively design a discovery and exploratory method for interpreting the customer data domain dynamics of the process, product or service that include structured and unstructured data sources;

- Collaboratively develop a conceptual data business model for the process, product or service problem and for the solution, infused by intelligence learned in the discovery and exploratory process and by leveraging of a BDA tool(s), integrating a data service process prototype scenario(s) – *what can the firm do better now with the information that it could not do before it had it?* (Provost, & Fawcett, 2013);

- Collaboratively develop a governance plan for the new product or service or a process solution for the firm, informed by customer data privacy rights and security sensitivity standards; and

- Formulate an organizational production plan for integrating the data sources, systems and technologies for the proposed process, product or service solution and for integrating BDA as an overall business strategy.

The proposed courses in the concentration are 3 credits. The outcomes of the concentration are in analytical business skills, creative problem-solving skills, Big Data modeling skills, fundamental mathematical and statistical skills, and presentation and team-playing skills, and also privacy and security sensitivity skills. The goal of the concentration is for its graduates to be business data scientists, not mere scientist technologists. The curriculum is a foundation from which there may be employment postings of BDA specialties for the students upon graduation from the university.

Pending approval by an internal curriculum committee of the school, the concentration of Data Science will begin in fall 2015 with the offering of Concepts of Big Data Analytics, as discussed in this paper. The plan is to rollout the full concentration during 2015–2017 with the following courses.

Concept Courses

- Concepts of Big Data Analytics, a course on critical Big Data modeling of a process, product or service in industry;
- Big Data Maturity Model, a conceptual course on benchmarking of best Big Data organizational practices in industry; and
- Customer Relationship Management (CRM) and Big Data, a conceptual course integrating BDA and household priority relationship strategy in industry.

Domain Courses

- Big Data Analytics in Energy, a domain course integrating BDA projects for decision-making in the energy industry;
- Big Data Analytics in Entertainment, a domain course integrating BDA projects for decision-

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making in the entertainment and sports industries;
- Big Data Analytics in the Financial Industry, a domain course integrating BDA projects for decision-making in the international financial services industry;
- Big Data Analytics in Health and Life Sciences, a domain course integrating BDA projects for decision-making in the health and life sciences industry, including ObamaCare initiatives; and
- Big Data Analytics in Retail Industries, a domain course integrating BDA projects for decision-making in the retail industries.

Enabling Courses
- Big Data Ethical Framework, an integrative course on BDA privacy, regulatory and security standards governing analytics professionals in industries and organizations; and
- Big Data Foundation Technology, an integrative course on required BDA high performance infrastructure platform and storage technologies and tools.

The concentration of Data Science is depicted in Figure 1. The concentration is fulfilled in the three conceptual courses, three of the five domain courses, and the two enabling courses of the plan. The concentration is currently designed for the undergraduate students of the school but may be expanded in 2017 for graduate students of the School and of the School of Business of the university.

Table 1 lists courses that can give the student requisite skills in business, mathematics, statistics, and presentation, team-playing and high-level technology. The descriptions are fairly generic and reflect existing courses in most institutions that have a business major.

4. COURSE MODEL – BIG DATA ANALYTICS

" … Big Data is much more than big data" (Smolan and Erwitt, 2012).

The field of data science or data analytics is relatively new, with few consistencies in the content or names of introductory courses.

During January-February, 2014, a scan of the Internet disclosed the following names for introductory courses:

- Advanced Big Data Analytics
- Analytics and Decision Analysis
- Applied Data Science
- Big Data Analytics
- Business Analytics
- Business Intelligence and Analytics
- Data Analytics
- Data Analytics for Information Systems
- Data and Decision Analytics
- Data Warehousing and Analytics
- Elements of Data Analysis
- Introduction to Business Analytics
- Introduction to Data Analytics
- Introduction to Data Science
- Large-scale Data Analysis

For this paper, the Concepts of Big Data Analytics course is outlined in Table 2 of the Appendix.

Table 2 contains five columns corresponding to the online syllabi of five university introductory Data Science or Analytics courses. Over the period of February – March 2014, the authors reviewed the online syllabi of 21 introductory courses that contained Data Analytics or Data Science in their titles, all from Tier I and Tier II universities. The courses represented in Table 2 are a representative sample of the 21 courses. The five columns can be used to compare the Concepts of Big Data Analytics course of this paper to those at these other universities. Note that the omission of a checkmark does not mean the topic is not covered in that course. The checkmarks indicate what was available on the Web sites of the universities. Table 2 does not name the universities corresponding to the five columns**,** in order to avoid any criticism of the universities - table is for comparison only.

The Concepts of Big Data Analytics course emphasizes the concepts behind modern Data Science. The course is conceptual in the sense that the principles behind Data Science are emphasized rather than the tools with which to implement them. Therefore, topics such as R and Python programming, Hadoop, MapReduce, and so on are not covered to any extent in this course. Instead, they are covered as they are needed in the domain courses to solve industry-specific problems. Some topics in the course require knowledge of probability and statistics. Therefore, the basic statistics course required of all computing majors is a prerequisite for this course. Because the course has no programming requirements, it is accessible to any student in the university who has the statistics prerequisite, which thus includes all business majors in the university.

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The course emphasizes the strategic value of data and the use of Data Science teams in an organization, and the use of data-driven decision making. It introduces students to data-analytic thinking and Data Science principles to facilitate communication between business stakeholders and the Data Science teams. The course also discusses the limitations and pitfalls (e.g., overfitting) of Data Science and the necessity of human involvement in choosing the right data and evaluating the processes and results of the Data Science projects. The ultimate goal of this course is to enable students to participate in the development and proper evaluation of a Data Analytics solution to a business problem.

The text will be Provost, F., & Fawcett, T. (2013), Data Science for Business: What You Need to Know about Data Mining and Data-Analytic Thinking. Supporting texts will be Davenport, T.H. (2014), Big Data at Work: Dispelling the Myths, Uncovering the Opportunities. Alternately the following can be used as the text: Davenport, T.H., & Harris, J.G. (2007), Competing on Analytics: The New Science of Winning. The text will supplemented by Analysis INFORMS Magazine.

The course will also discuss in detail several recent case studies of the application of BDA to real business situations. There are many online resources to obtain such cases, (e.g., BDA sites of IBM [2014] and HP Vertica [2014])

5. IMPLICATIONS

"Big Data started as a series of small waves but is morphing into the greatest tsunami of information that humans have ever seen" (Smolan and Erwitt, 2012).

The terms "Big Data", "Data Science", "Data Analytics" are so ubiquitous in the practitioner press that it seems that they are just the next hyped fad that will fade into oblivion in a few years. However, with the ability to process and store the many kinds of data collected by firms and organizations, and the need to use these data to strategic advantage, the field of Data Science will not disappear soon. Several studies, such as Brynjolfsson, Hitt, and Kim (2011), and Tambe (2014), have shown that the more data-driven a firm, the more successful is the firm. Therefore, more and more organizations will be hiring data scientists to take advantage of their ever-growing store of data. There is, however, a problem – our universities are not keeping up with the demand.

> There will be a shortage of talent necessary for organizations to take advantage of big data. By 2018, the United States alone could face a shortage of 140,000 to 190,000 people with deep analytical skills as well as 1.5 million managers and analysts with the know-how to use the analysis of big data to make effective decisions. (Manyika, et al, 2011).

Therefore, it is important for universities to begin developing data scientists who have the requisite technical skills, and the business and content domain knowledge to leverage the data that organizations are now accumulating for advantage (Gillespie, 2014). The program in Data Science proposed in this paper helps to fill this need.

6. LIMITATIONS AND OPPORTUNITIES

The concentration of Data Science and the course on Big Data Analytics are beginning as a program in fall 2015, but evaluation of the impact of the initial program on the students may not be finished until fall 2016.

The curriculum for Data Science with Big Data Analytics is not clearly defined in the literature (Dietrich, Newton, & Corley, 2013), and the field is immature in instruction. Within the next year**,** the authors plan to survey instructors of introductory Data Analytics and Data Science courses with a view towards determining which topics are essential for such courses, and which topics are less so. The authors hope that this future research will help create a common core of topics for an introductory course in Data Analytics/Data Science.

The curriculum design in this paper furnishes important input to instructors in schools of computer science and information systems who want to have an initial program in tandem with trends. The literature indicates BDA as a desirable norm in organizations (Ohlhorst, 2013), an opportunity for the response of schools of computer science and information systems. The model of this paper provides a first step.

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7. CONCLUSION

This paper posits a curriculum design of Big Data Analytics in the proposed concentration of Data Science at Pace University. The design includes a discovery and exploratory method of critical Big Data modeling and the improvement of a process, product or service in industry. The design provides for inclusion of an organizational plan for process, product or service solutions, and a production strategy integrating non-traditional and traditional technologies and BDA tools. The design further provides privacy rights and security sensitivity standards. The design is ideal as firms and organizations pursue BDA projects. Few organizations have the full prerequisite skills for BDA projects and strategies. Throughout this paper, the design of BDA proposes the relevance of business, mathematical and statistical, and presentation and team-playing skills, augmenting prerequisite skills in the traditional data base management technologies and in the new non-traditional BDA tools. Overall, this paper provides a beneficial proposal to instructors desiring to initiate BDA and Data Science programs to be in tandem with industrial and organizational trends, and to undergraduate students intending to be in tandem with technological trends.

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APPENDIX

Figure 1: Data Science Concentration

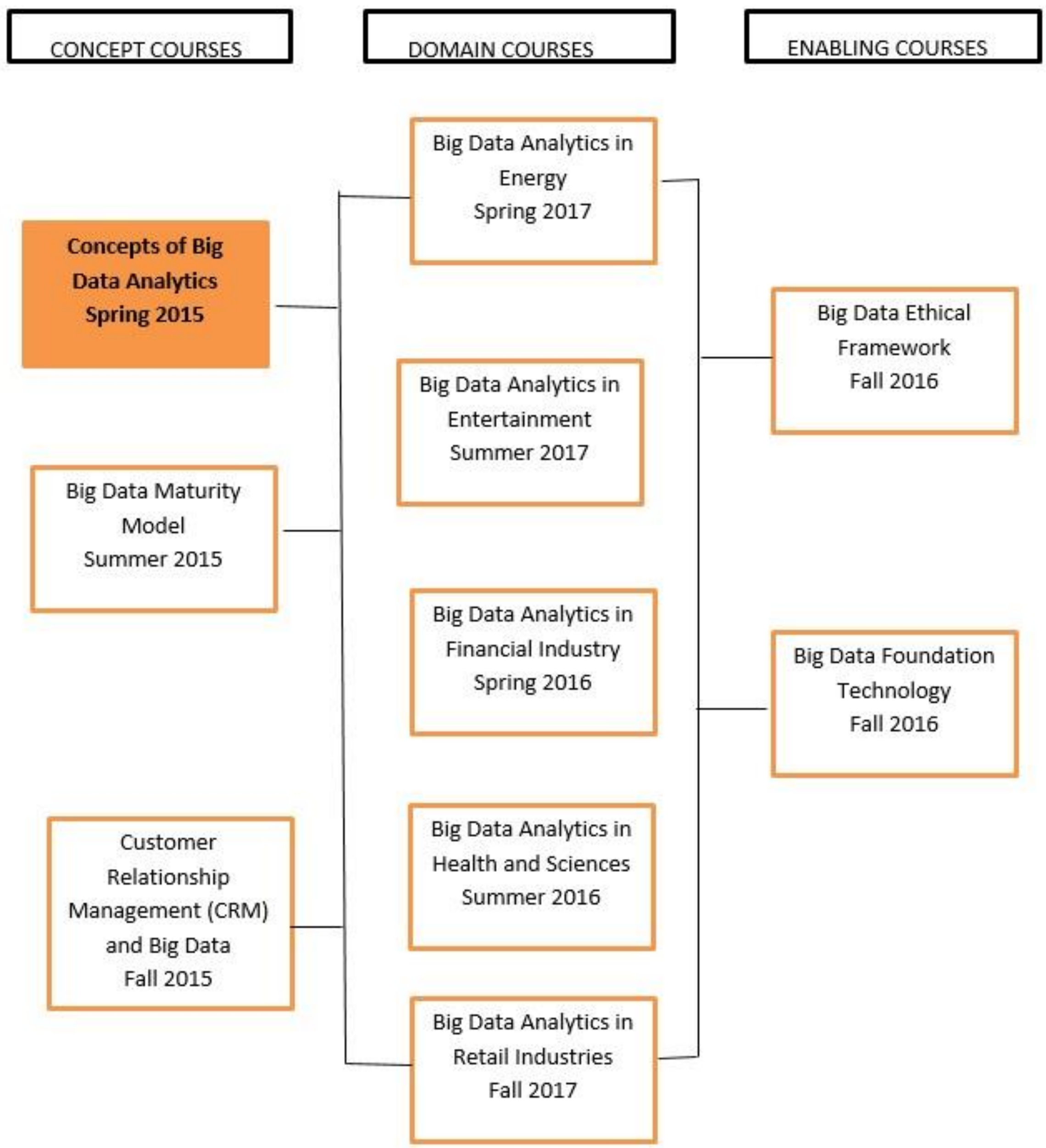

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Table 1 - Possible Support Courses	
Course	**Description**
Contemporary Business Practice	The functions of business and their interrelationships. Students work in teams to run simulated companies. Development of business writing and speaking, presentation, and data analysis skills are emphasized.
Calculus I	Limits, continuity, derivatives of algebraic, exponential and logarithmic functions, optimization problems, introduction to integral calculus, the fundamental theorem of integral calculus. Business and economic applications are stressed throughout.
Probability and Statistics	Random processes; finite sample spaces, probability models, independent events, and conditional probability. Bayes' theorem, random variables, mathematical expectation; statistical applications of probability, introduction to sampling theory, confidence intervals and hypothesis testing.
Public Speaking	The mechanics of writing and presenting one's own material. This includes outlining, addressing varied audiences, styles, and appropriate techniques of delivery, as well as the use of technology to enhance one's presentation.
Introduction to Computer Systems	The basic components of a computer, how they are organized, and how they work together under the control of an operating system. Students examine theoretical concepts underlying hardware functions, troubleshooting and preventative maintenance techniques, safety precautions, system procurement, and upgrades, and discuss networking and software as it pertains to hardware functionality.
Financial Accounting	Accounting's role in satisfying society's needs for information and its function in business, government, and the non-profit sector. Students learn from a user-oriented perspective about the accounting cycle, the nature of financial statements and the process for preparing them, and the use of accounting information as a basis for decision making.
Managerial Accounting	A study of the fundamental managerial accounting concepts and techniques that aid in management decision-making, performance evaluation, planning and controlling operations. The emphasis is on the use of accounting data as a management tool rather than on the techniques of data accumulation. The course includes such topics as cost behavior patterns, budgeting and cost-volume-profit relationships. Quantitative methods applicable to managerial accounting are studied.
Managerial and Organizational Concepts	This course examines basic managerial functions of planning, organizing, motivating, leading, and controlling. Emphasis is also given to the behavior of individual and groups within organizations.
Principles of Marketing	This course examines marketing's place in the firm and in society. Considered and analyzed are marketing research and strategies for product development, pricing, physical distribution and promotion, including personal selling, advertising, sales promotion and public relations.
Microeconomics	Theory of demand, production and costs, allocation of resources, product and factor pricing, income distribution, market failure, international economics, and comparative economic systems.
Macroeconomics	National income determination, money and banking, business cycles and economic fluctuations, monetary and fiscal policy, economic growth, and current microeconomic issues.

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Table 2 - Syllabus for Concepts of Big Data Analytics

Week	Topic	Schools				
		A	B	C	D	E
1	**Data-Analytic Thinking**					
	Data Science and Data-Driven Decision Making	X	X	X	X	X
	Data as a Strategic Asset Executive Firm Mentor Presentation	X	X	X	X	X
	Data-Analytic Thinking	X	X	X	X	X
2	**Data Science Solutions to Business Problems**					
	The Data Mining Process	X	X	X		X
	Other Analytics Techniques	X	X	X		
3	**Predictive Modeling**					
	Models		X	X	X	X
	Supervised Segmentation		X	X	X	X
	Visualizing Segmentations		X	X	X	X
	Trees		X	X	X	X
	Probability Estimation					
4	**Model Fitting**					
	Classification Using Mathematical Functions		X		X	X
	Linear Discriminant Function	X				
	Regression		X		X	X
	Logistic Regression		X		X	X
	Non-linear Functions, Neural Networks					X
	Principle Component Analysis					
5	**Overfitting**					
	Overfitting Examples					
	Overfitting Avoidance					
	Complexity Control					
6	**Similarity, Neighbors and Clusters**					
	Similarity and Distance		X	X	X	X
	Nearest Neighbor		X	X	X	X
	Clustering		X	X	X	X

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7	**Decision-Analytic Thinking – Creating a Model**					
	Evaluating Classifiers		X			
	Generalizing Beyond Classification					
	Expected Value					
	Outlier Detection					
8	**Visualizing Model Performance**					
	Ranking		X	X		
	Profit Curves					
	ROC Graphs and Curves					X
	Area Under the ROC Curve					X
	Lift Curves					
9	**Evidence and Probabilities**					
	Combining Evidence Probabilistically	X	X			
	Bayes Rule	X	X			
	Evidence Lift	X				
10	**Representing and Mining Text**					
	The Importance of Text				X	
	Text Representation				X	
	N-gram Sequences				X	
	Named Entity Extraction				X	
	Topic Models				X	
11	**Decision-Analytic Thinking – Analytical Engineering**					
	Selection Bias		X			
	Expected Value Decomposition		X			
12	**Other Data Science Techniques**					
	Co-occurrence and Associations					
	Profiling Optional Scientist Firm Mentor Presentation					
	Link Prediction					
	Data Reduction					
	Bias, Variance, the Ensemble Method					X
	Data-Driven Causal Explanation Optional Scientist Firm Mentor Presentation					

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	Time Series		X			
13	**Data Science and Business Strategy**					
	Achieving Competitive Advantage with Data Science				X	
	Sustaining Competitive Advantage with Data Science				X	
	Attracting Data Scientists and Teams Optional Scientist Firm Mentor Presentation				X	
	Evaluating Data Science Proposals				X	
	The Kaggle Model		X			
14	**Ethics and Data Science**					
	Data Security	X				
	Privacy	X	X		X	
	ACM Code of Ethics					