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INFORMATION SYSTEMS EDUCATION JOURNAL

Introducing Big Data Concepts in an Introductory Technology Course

Mark Frydenberg
mfrydenberg@bentley.edu
Computer Information Systems Department
Bentley University,
Waltham, MA 02452, USA

Abstract

From their presence on social media sites to in-house application data files, the amount of data that companies, governments, individuals, and sensors generate is overwhelming. The growth of Big Data in both consumer and enterprise activities has caused educators to consider options for including Big Data in the Information Systems curriculum. Introducing Big Data concepts and technologies in the classroom often is reserved for advanced students in database or programming courses. This paper explores approaches for integrating Big Data into the Information Systems curriculum, and presents a sample lesson for presenting basic Big Data concepts to first year students in a general education Information Technology course. As the need for IT professionals with Big Data skills will continue to increase, including these topics in a general education technology curriculum is especially pertinent.

Keywords: Big Data, Technology Concepts, Google, Data Visualization

1. INTRODUCTION

The rise of Web 2.0 applications (2004-2009) saw the Internet evolve as a platform upon which users would generate their own content and run applications on many devices. "Data as the next 'Intel inside'," a reference to Tim O'Reilly's analogy that data powers web applications much in the same way that processors power computers, became the mantra for companies moving their products and services online (O'Reilly, 2005). In the years that followed, the growth of commerce and social applications on the web, the proliferation of mobile devices, the rise of cloud computing, the ubiquity of Internet access in consumer and enterprise activities, and the emergence of the Internet of Things has resulted in daily digital activities that generate large quantities of data. Such large databases often are kept on servers distributed across the Internet. New technologies make it possible to gather, store, query, and retrieve all of this data over the Internet.

Social networking sites, open government and healthcare databases, e-commerce transactions and automated sensors are among the many daily digital interactions that generate data to be stored online for analysis of possible trends. With these activities comes information on social interests, consumer trends, and business prospects that if understood, could provide insights into business intelligence, social trends, and organizational opportunities.

In the highly cited report *Big Data: The Next Frontier for Competition*, the McKinsey Foundation (Manyika, Chui, Bughin, Dobbs, Roxburgh, & Byers, 2011) states that the increase in the amount of information produced through these actions and transactions will provide important insights to organization that can understand such large data sets. They define Big Data as "data sets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyze." The value of Big Data "…comes from the patterns that can be derived by making connections between pieces of data, about an individual, about individuals in relation to others, about groups of people, or simply about the structure of information itself" (boyd & Crawford, 2011, p. 1). Business, education, and government sectors routinely produce and manage terabytes and petabytes of data, and rely on distributed tools to store and make sense of it all.

As the enterprise finds value from Big Data and the information it contains, introducing Big Data concepts into the undergraduate Information Systems classroom becomes a necessary curriculum addition in order to prepare tomorrow's IT professionals and knowledge workers.

This literature review describes programs for teaching big data concepts to Information Systems majors and minors, and the narrative shares a lesson for introducing basic Big Data concepts to first-year students in a general education introductory IT course. The author presents a teaching exercise that gives students an appreciation for the issues without requiring significant technology experience.

2. BIG DATA IN THE INFORMATION SYSTEMS CURRICULUM

Where and how to introduce Big Data concepts in the information systems curriculum has received much discussion. "IS programs, faculty members, and text books have so far been, in practice, somewhat lukewarm about their relationship with Big Data" (Topi, 2013, p. 12). Many degree programs in information systems are introducing courses in business analytics and data mining so Information Systems majors can develop skills in managing and interpreting large scale enterprise data sets (King & Satyanarayana, 2013), (Grossniklaus & Maier, 2012). These courses require basic database skills usually taught in the undergraduate business education curriculum.

General education courses also could expose students to Big Data concepts by presenting students with hands-on exercises involving online databases, productivity tools, and data visualization tools. Doing so offers students the opportunity to develop familiarity and skills with these tools from an enterprise perspective.
Today’s students need to understand the requirements for storage space, processing power, Internet connectivity, security, and ways to access or update information online in order to recommend solutions to their future employers (Frydenberg & Andone, 2011). Students who learn about relational databases need to understand where that technology falls short. So often, textbooks provide sample datasets, which are nicely structured, well formed, and conducive to a particular problem. In the real world, data sets are not always so clean and well-structured.

As the business education curriculum evolves, educators must consider current technology trends such as Big Data to determine where and how to integrate these topics. "Business analytics is one of the fastest growing areas of focus for Information Systems (IS) programs, particularly at the graduate level. IS departments are establishing new analytics programs at a fast pace, and companies are very interested in graduates with strong capabilities in business analytics. Within this broad topic area, Big Data continues to become increasingly important, even though the concept itself is at times confusing and continues to evolve" (Topi, 2013, p. 12).

The remainder of this paper presents a lesson for introducing big data concepts in a general education introductory technology course at a business university.

3. A LESSON FOR TEACHING BIG DATA CONCEPTS IN A GENERAL EDUCATION CONTEXT

IT 101 (Introduction to Information Technology and Computing Systems) is a first-year required general education course for all students at Bentley University, a business university in Massachusetts. The course introduces students to types of hardware and software, operating systems, cloud storage, the Internet and the World Wide Web, HTML, wireless networking, multimedia, spreadsheet and database applications, and cloud computing concepts.

Introducing Big Data in an introductory technology course allows students to apply their knowledge of several of these topics (especially databases, the Internet and World Wide Web, and cloud computing) in order to understand the technological issues required to store, search, and maintain Big Data sets, and Excel as a data analysis and visualization tool for smaller data sets.

This section describes a series of classroom demonstrations and activities piloted in seven sections of IT 101 over two consecutive semesters. The same instructor presented this material to each section. The presentation was preceded by a survey to ascertain students' familiarity with Big Data concepts. A follow-up survey captured student feedback after students completed a homework assignment on the topic.

Volume, Velocity, Variety

The terms volume, velocity, and variety have become synonymous with features of Big Data sets (Russom, 2011), (Laney, 2001; 2012) (Big Data 3 V's: Volume, Variety, Velocity (Infographic), 2013). Others have added Value and Veracity as additional V's of Big Data to suggest that data is a company's important asset, and that a company's data must be accurate.

Gartner analyst Doug Laney first described the growth of large data sets in three dimensions: volume (the amount of data generated), velocity (the rate at which data is generated), and variety (the different formats in which data can appear.) In 2001, as companies and consumers began to use the Internet for e-commerce, and nearly five years before the dawn of the Web as a social and collaborative platform, Laney (2001) wrote:

> While enterprises struggle to consolidate systems and collapse redundant databases to enable greater operational, analytical, and collaborative consistencies, changing economic conditions have made this job more difficult. E-commerce, in particular, has exploded data management challenges along three dimensions: volumes, velocity and variety.

With this historical context, students are ready to understand these concepts through examples of how their everyday interactions on the web contribute to Big Data.

Volume. Capturing student interest in Big Data is often easy to accomplish by presenting statistics about the amount of information generated by consumers and the enterprise. Companies routinely require storage in petabytes (1000 terabytes) rather than gigabytes and terabytes. For example, Facebook stores and analyzes over 30 petabytes of data generated by its users; Walmart has 2.5 petabytes of customer data. As the volume of data grows, the challenge comes in being able to store, access, and analyze it effectively.

A lesson on data volume begins by asking students to consider that Google archives all search queries from its users. Asking students the amount of storage required based on the number of queries per day, and then what information Google can determine from saved search queries is a relevant way to begin a classroom conversation about Big Data, storage required, and related issues of data privacy.

Collaborative filtering is the process of using data from the activities of many people to make decisions or offer advice. The following two demonstrations, of Google Autocomplete and Amazon.com, show the value obtained from being able to process large volumes of data.

Google Autocomplete allows the search engine to predict search queries that dynamically update with each character entered into the search bar as shown in Appendix I, Figure 1. Google Autocomplete displays search queries that reflect the search activity of the user's search history, other Google users search queries, and the content of web pages indexed by the search engine.

Google Trends "is a real-time daily and weekly index of the volume of queries that users enter into Google" (Choi & Varian, 2012). Appendix I, Figure 2 shows the volume of queries for three technology trends as search terms.

Asking students to analyze this chart develops their critical thinking skills and allows them to make informed predictions about future trends. Examining news stories associated with high and low points on a search term's trend line can give insights into why it increased or decreased in search popularity.

Amazon.com uses data from customer purchases to recommend related items for purchase. For example, Amazon recommends sunglasses, pails, and shovels to complement the purchase of beach balls, as shown in Appendix I, Figure 3.

Velocity. Real-time statistics and visualizations of social media data provide a tangible way for students to understand how quickly data is generated. For example, in 2013, Twitter received 500 million tweets per day, YouTube users uploaded 100 hours of video every minute, and Facebook users liked over 4.5 billion posts per day. National Weather Service sensors at 1800 tracking stations across the country report temperature and climate information every hour of the day. Consumers purchase 426 items per second on Amazon.com during the holiday shopping period. Google processed approximately 5,922,000,000 search queries per day in 2013 (StatisticsBrain, 2013), and saves all of them.

In a business context, it is important for organizations to be able to analyze data that changes quickly in order to make good business decisions. "The Road," an IBM-produced video describes the importance of data analytics, and poses the question:

> "If you were to stand at a road, and the cars are whipping by, and all you can do is take a snapshot of the way the road looked five minutes ago, how would you know when to cross the road? 9 out of 10 organizations still make decisions this way every day, using out of date information. The organizations that are the most competitive are the ones who are going to be able to make sense of what they learn as fast as they learn it." (IBM, 2013)

To visualize data that changes quickly, consider TweetPing.net, shown in Appendix I, Figure 4. TweetPing is a visualization that illustrates the velocity of data generated by Twitter users. The real-time map becomes denser as more Tweets are processed and plotted. The app records the location of origin, hashtags, mentions, and tracks total Tweets, words, and characters in each Tweet.

Variety. Digital information may be represented and stored in a variety of formats that can be easily read and interpreted by both humans and computer programs.

While much data is structured, stored in rows and columns, unstructured data generally is more complex, and may include items such as Tweets, social media "likes" or updates, retina scans, Wikipedia articles, fingerprints, and facial recognition features. This information usually does not originate in a format that is easily searchable or fit into relational database tables. Its growth in recent years has contributed to the development of new technologies for interacting with and processing unstructured Data.
Students can investigate these sources of unstructured data. For example, facial recognition is an up and coming technology that helps in crime fighting, advertising, and social networking. These applications process facial data points and compare them to other faces stored in a database in order to produce appropriate content. For example, Facebook's Deepface technology is accurate in recognizing faces 97% of the time, and is used to make suggestions of people to tag in photographs. In industry, digital advertising kiosks use cameras to scan the person looking at a monitor, and then display content appropriate to the person's age and gender, as determined by facial recognition software.

To show that data is not always represented in neat rows and columns, the instructor searched dbPedia, a semantic database obtained from of Wikipedia, using Relfinder (http://www.visualdataweb.org/relfinder.php). Relfinder uses data from dbPedia, an index of Wikipedia's text content stored in RDF (representational data format) format, to find relationships between seemingly unrelated topics (Exner & Nugues, 2012). RDF uses triples of values (object1, relationship, object2) to store relationships between objects. Students can see that searching for relationships produces different results than searching plain text. In Appendix I, Figure 5, Relfinder shows commonalities between Madonna and Aretha Franklin based on information in dbPedia.

Introducing Big Data Technologies
Several new technologies take advantage of the distributed nature of large databases and parallel processing needed to process them quickly. Today’s students should at least be aware of the problems that technologies such as Hadoop or MapReduce try to solve, so they might better succeed as 21st century IT professionals. "Choosing the best collaboration partners requires a good understanding of the technologies themselves, knowledge of the key solutions and solution types available in the marketplace, and general organizational skills and knowledge related to technical resource acquisition." (Topi, 2013, p. 13)

Querying large datasets can be time consuming and costly without an appropriate hardware and infrastructure. The instructor provided a lesson to students using Google BigQuery (Frydenberg, 2013). Google BigQuery is an easy to use technology that allows students to learn about distributed databases, SQL queries, and data mining. Google BigQuery is a query service for running SQL-like queries against multiple terabytes of data in seconds. It is one of Google's core technologies that has been used for data analytics tasks since 2006. Google BigQuery performs rapid SQL-like queries against online database tables, using the processing power of Google's big data infrastructure. Google provides several large sample databases for querying, including Shakespeare, birth and weather station information for use with BigQuery. Advanced users can upload their own databases (Sato, 2012).

After a short demonstration of BigQuery in the classroom, the instructor distributed a tutorial handout for students to follow (Frydenberg, Drinking from the Fire Hose: Tools for Teaching Big Data Concepts in the Introductory IT Classroom, 2013) working in small groups, where students took on the roles of reader, doer, and checker (Frydenberg, Flipping Excel, 2013) to complete the assignment.

Appendix I, Figure 6 shows details about the public natality (birth) database, which has 137,826,763 rows, and takes up 21.9 GB of storage. It provides birth information from 1969 through 2008.

Appendix I, Figure 7 shows a Google BigQuery query to display the average age of birth mothers grouped by year and state. (Programmable Web, 2012) It took Google BigQuery 2 seconds to process 2.5 GB of information when performing this query, which results in 1840 rows retrieved and summarized from the table.

After performing the query in Google BigQuery, students can use a BigQuery Connector tool from https://bigquery-connector.appspot.com/ to import the results into Excel for further analysis. Appendix I, Figure 8 shows a pivot table report in Excel summarizing average age of birth mothers grouped by state during this period. Spark lines provide a handy visualization of this data.

Examining the spark lines clarifies the trend that mother ages has increased during the years for which data is available. Performing the analytics and visualization in Excel (or any other client side data visualization tool) is not nearly as computationally intensive as processing 21.9 GB of data in the original online database.

4. METHODOLOGY

Students in seven sections of an introductory IT course received a presentation demonstrating velocity, variety, and volume as described here, as well as a hands-on activity using Google BigQuery as described in the previous section. They completed questionnaires before and after so the study could ascertain the development of their understanding of Big Data.

166 students (64 female, 102 male) voluntarily completed a survey prior to the lesson on Big Data; 160 students (64 female, 96 male) completed the survey after the lesson.

The first set of questions, shown in Appendix I, Figure 9, asked about awareness of big data and other current technology developments. It is interesting to note that while student awareness of technology developments was at about 60%, relatively few students agreed that they were familiar with "big data" before the exercise. This number nearly doubled after the lesson. Many were aware of social networking sites as a popular source of online data. Responses were provided in a 5-point Likert scale (from strongly disagree to strongly agree).

Students before and after the lesson responded similarly about their familiarity with technology news and developments, and as expected, the number of students "familiar with the phrase 'Big Data'" increased after the lesson.

After the lesson, students were asked two additional questions related to the relevance of data analysis and Big Data, as shown in Appendix I, Figure 10.

The majority of students agreed or strongly agreed that it is important to know how to analyze and interpret data, and that Big Data is a relevant topic that will impact their own lives as digital students. Students commented on aspects of the lesson that they found helpful, as shown in Appendix I, Figure 11.

The demos for velocity, volume and variety, and using Google Big Query, and instructing students about the role of Social Media in generating Big Data were the most useful elements of the lesson.
This is likely because of the hands-on experience with these tools that makes the topic relevant for students.

When asked what students learned about Big Data, in addition to their new awareness of Big Data technology concepts, their responses also touched on social and privacy concerns. Said one student: "Big Data has become a part of our everyday lives. It is tracing our locations through our phones and we constantly leave paths through various social media sites." Another student commented, "Every move we make seems to be recorded and every human being is leaving a data trail that will be there after the human being is long gone."

About learning Big Data concepts in a general education introductory technology course, one student commented, "I found the presentation quite informative, and appreciated the exposure to material, particularly the Google applications of which I was not previously aware. I believe the content was relevant, crucial and necessary in what many would consider the 'technological age,' and I have begun to realize that informing myself of news and materials in this field may prove beneficial, if not necessary." Others wrote that they "had never heard about Big Data specifically and [are] now very interested in the topic."

5. SUMMARY

Both consumers and the enterprise make use of collaborative tools, social networking sites, Internet-connected devices, and online transactions that produce large quantities of data every day. Big Data offers new challenges and technologies for storing, accessing, and processing large sets data as fast as it is being generated.

This paper presents a lesson for introductory students to learn about Big Data concepts and technologies. It offers relevant examples of Volume, Velocity, and Variety of Big Data, and outlines a hands-on experience querying an online database with Google BigQuery, and then using Excel to create a visualization of the selected data. By considering social media, commerce, and public databases, students can gain exposure to Big Data concepts and technologies in their introductory IT course.

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Editor's Note:

This paper was selected for inclusion in the journal as an ISECON 2014 Distinguished Paper. The acceptance rate is typically 7% for this category of paper based on blind reviews from six or more peers including three or more former best papers authors who did not submit a paper in 2014.

Appendix I

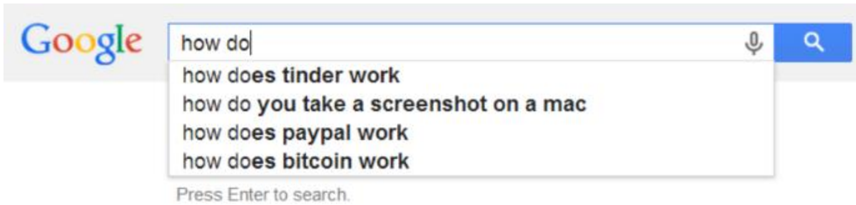


Figure 1. Google Autocomplete.

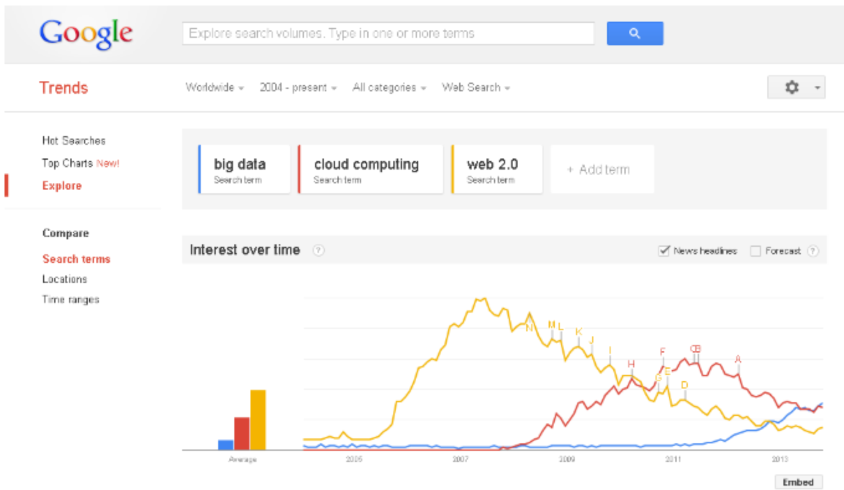


Figure 2. Google Trends.

Figure 3. Big Data allows Amazon to make purchase recommendations.

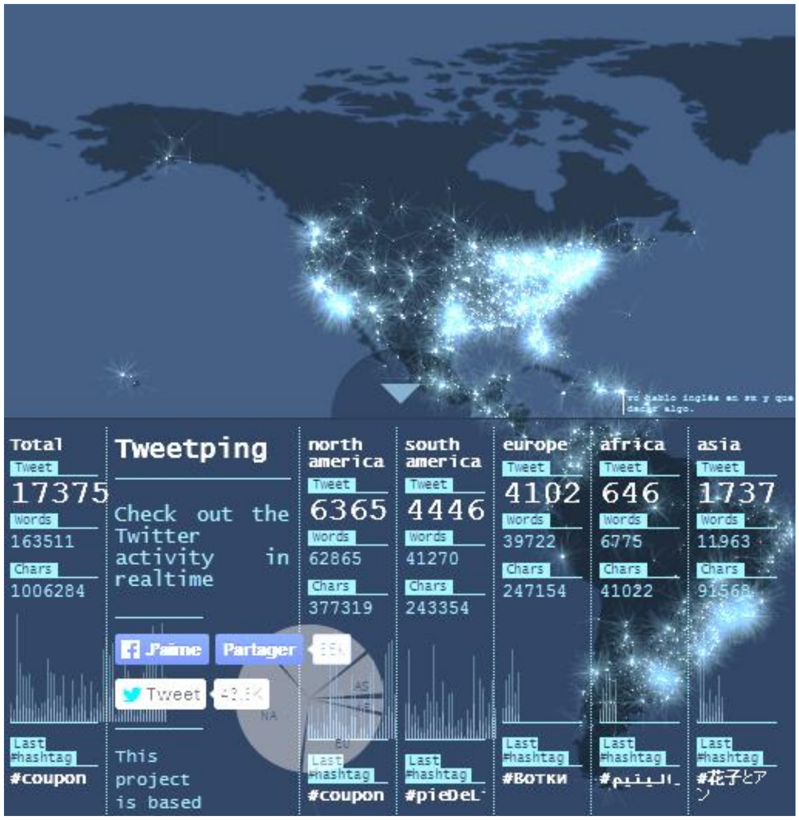


Figure 4. TweetPing is a Twitter visualization in real-time.

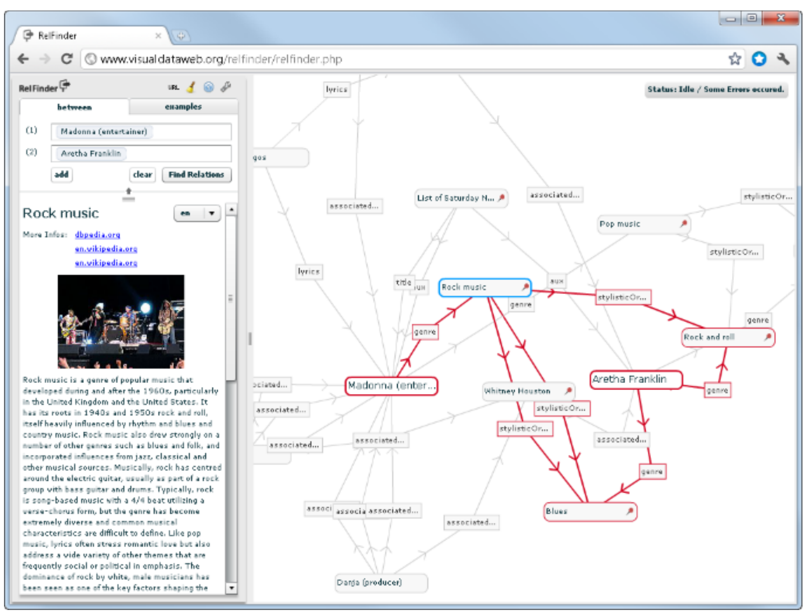


Figure 5. Relfinder determines relationships from text data stored in RDF format.

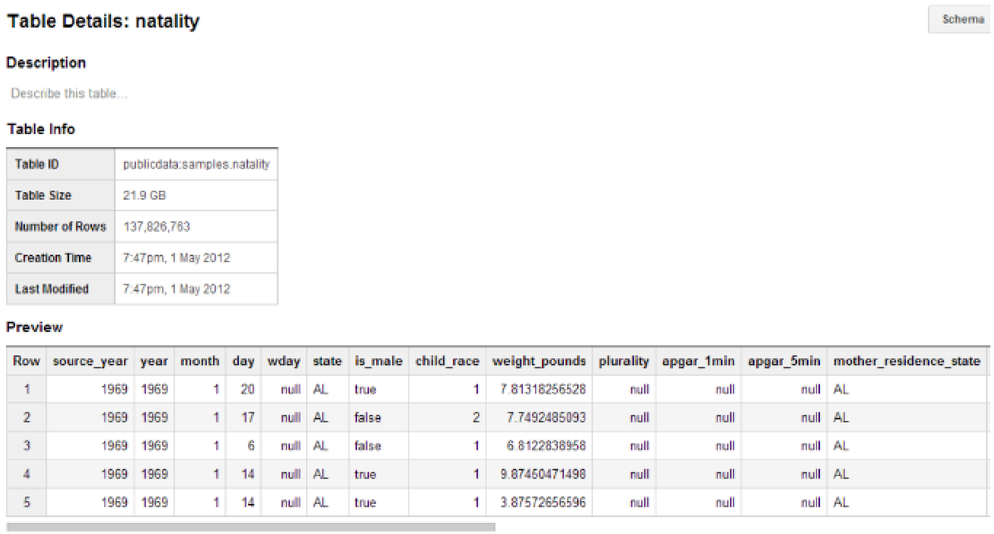


Table Details: natality

Schema

Description

Describe this table...

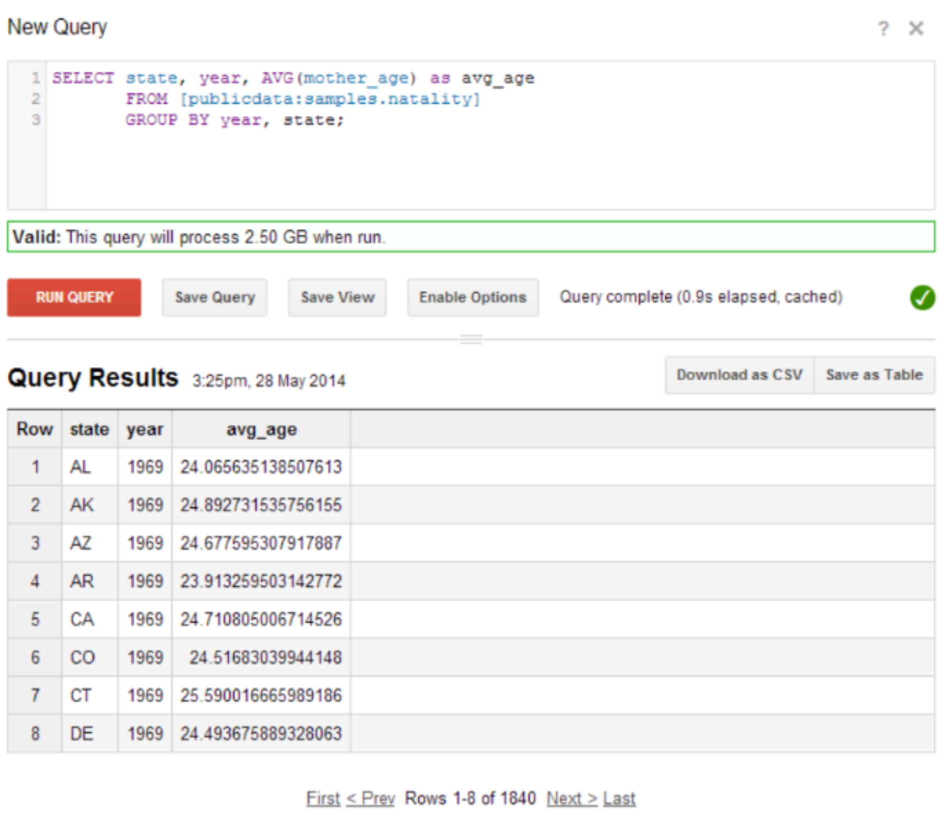
Table Info

Table ID	publicdata:samples.natality
Table Size	21.9 GB
Number of Rows	137,826,763
Creation Time	7:47pm, 1 May 2012
Last Modified	7:47pm, 1 May 2012

Preview

Row	source_year	year	month	day	wday	state	is_male	child_race	weight_pounds	plurality	apgar_1min	apgar_5min	mother_residence_state
1	1969	1969	1	20	null	AL	true	1	7.81318256528	null	null	null	AL
2	1969	1969	1	17	null	AL	false	2	7.7492485093	null	null	null	AL
3	1969	1969	1	6	null	AL	false	1	6.8122838958	null	null	null	AL
4	1969	1969	1	14	null	AL	true	1	9.87450471498	null	null	null	AL
5	1969	1969	1	14	null	AL	true	1	3.87572656596	null	null	null	AL

Figure 6. Details and sample natality information from Google BigQuery.



New Query

```
SELECT state, year, AVG(mother_age) as avg_age
       FROM [publicdata:samples.natality]
       GROUP BY year, state;
```

Valid: This query will process 2.50 GB when run.

RUN QUERY | Save Query | Save View | Enable Options | Query complete (0.9s elapsed, cached)

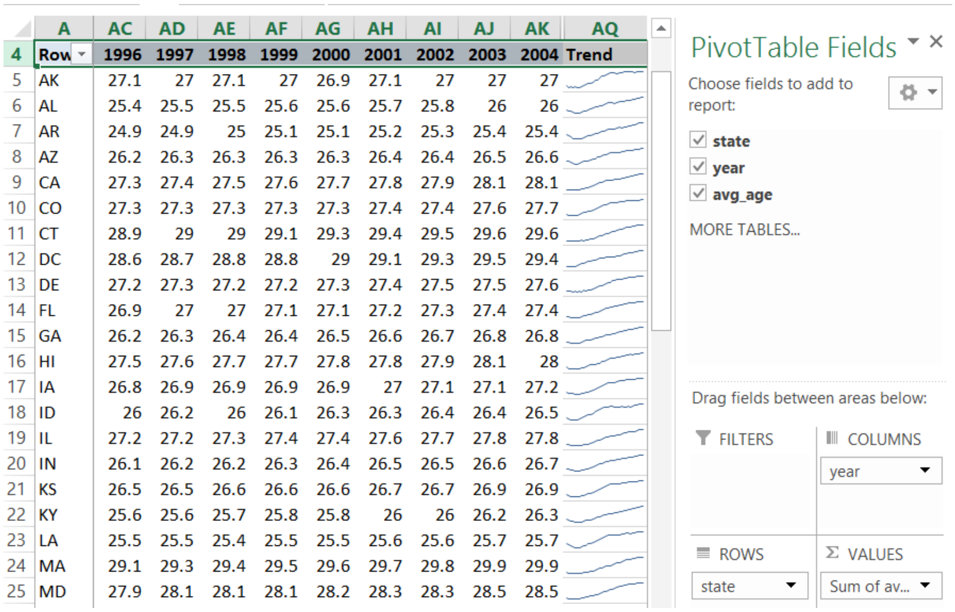
Query Results 3:25pm, 28 May 2014

Download as CSV | Save as Table

Row	state	year	avg_age
1	AL	1969	24.065635138507613
2	AK	1969	24.892731535756155
3	AZ	1969	24.677595307917887
4	AR	1969	23.913259503142772
5	CA	1969	24.710805006714526
6	CO	1969	24.51683039944148
7	CT	1969	25.590016665989186
8	DE	1969	24.493675889328063

First < Prev Rows 1-8 of 1840 Next > Last

Figure 7. Query and Results with Google BigQuery.



	A	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AQ
4	Row	1996	1997	1998	1999	2000	2001	2002	2003	2004	Trend
5	AK	27.1	27	27.1	27	26.9	27.1	27	27	27	
6	AL	25.4	25.5	25.5	25.6	25.6	25.7	25.8	26	26	
7	AR	24.9	24.9	25	25.1	25.1	25.2	25.3	25.4	25.4	
8	AZ	26.2	26.3	26.3	26.3	26.3	26.4	26.4	26.5	26.6	
9	CA	27.3	27.4	27.5	27.6	27.7	27.8	27.9	28.1	28.1	
10	CO	27.3	27.3	27.3	27.3	27.3	27.4	27.4	27.6	27.7	
11	CT	28.9	29	29	29.1	29.3	29.4	29.5	29.6	29.6	
12	DC	28.6	28.7	28.8	28.8	29	29.1	29.3	29.5	29.4	
13	DE	27.2	27.3	27.2	27.2	27.3	27.4	27.5	27.5	27.6	
14	FL	26.9	27	27	27.1	27.1	27.2	27.3	27.4	27.4	
15	GA	26.2	26.3	26.4	26.4	26.5	26.6	26.7	26.8	26.8	
16	HI	27.5	27.6	27.7	27.7	27.8	27.8	27.9	28.1	28	
17	IA	26.8	26.9	26.9	26.9	26.9	27	27.1	27.1	27.2	
18	ID	26	26.2	26	26.1	26.3	26.3	26.4	26.4	26.5	
19	IL	27.2	27.2	27.3	27.4	27.4	27.6	27.7	27.8	27.8	
20	IN	26.1	26.2	26.2	26.3	26.4	26.5	26.5	26.6	26.7	
21	KS	26.5	26.5	26.6	26.6	26.6	26.7	26.7	26.9	26.9	
22	KY	25.6	25.6	25.7	25.8	25.8	26	26	26.2	26.3	
23	LA	25.5	25.5	25.4	25.5	25.5	25.6	25.6	25.7	25.7	
24	MA	29.1	29.3	29.4	29.5	29.6	29.7	29.8	29.9	29.9	
25	MD	27.9	28.1	28.1	28.1	28.2	28.3	28.3	28.5	28.5	

PivotTable Fields
Choose fields to add to report:
state
year
avg_age
MORE TABLES...
Drag fields between areas below:
FILTERS
COLUMNS
year
ROWS
state
VALUES
Sum of av...

Figure 8. Creating a visualization using a pivot table and sparklines (column AQ) in Excel.

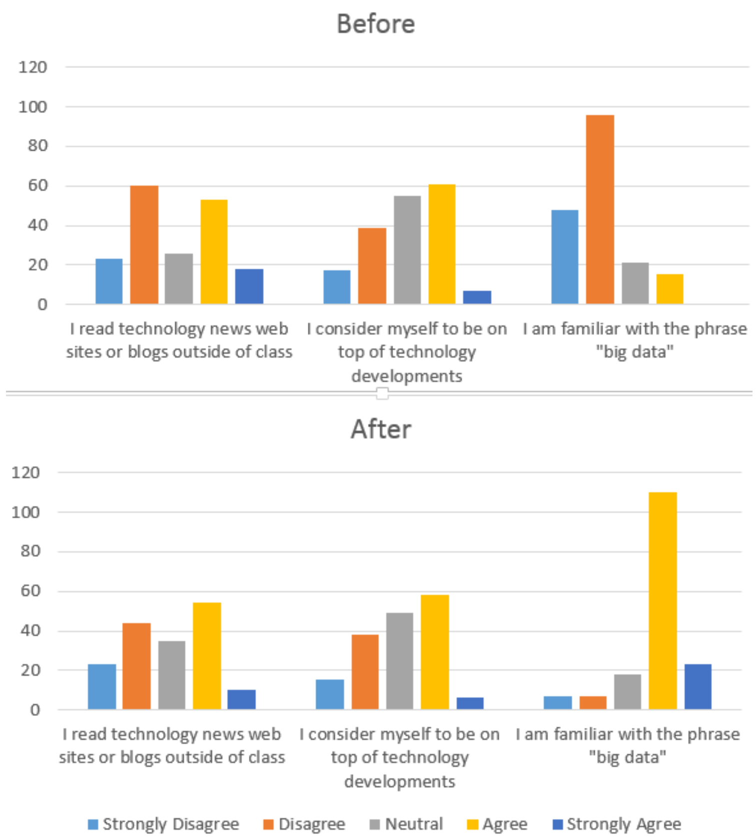


Figure 9. Big Data awareness.

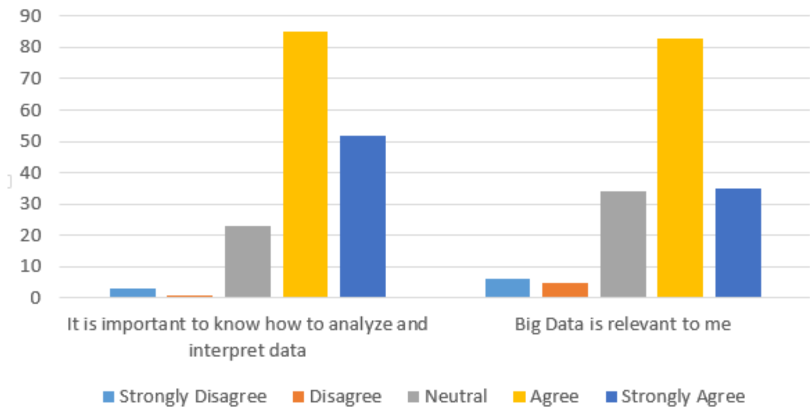


Figure 10. Student Perception of Relevance of Big Data

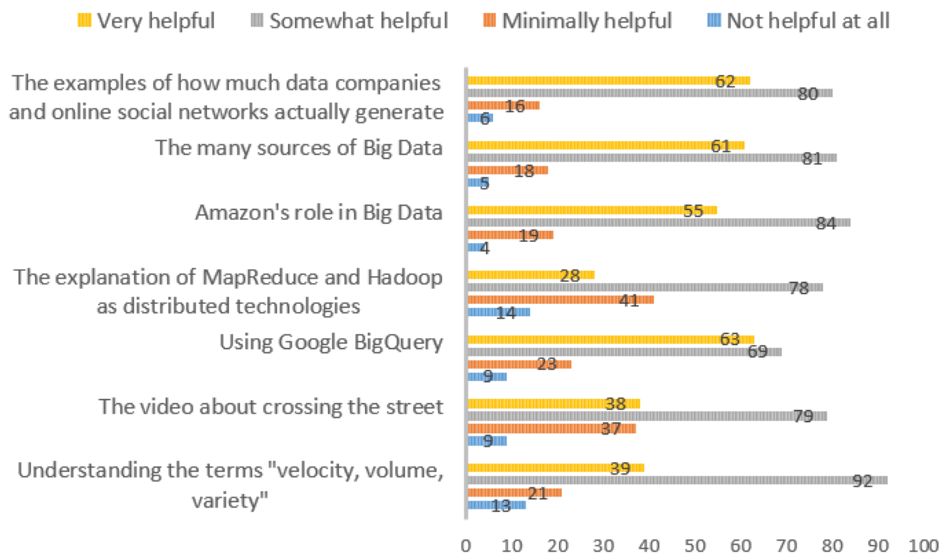


Figure 11. Student reaction to aspects of the Big Data lesson.