Journal of Forensic & Investigative Accounting
Volume 10: Issue 1, January–June 2018

Toward the Integration of Big Data into Forensic Accounting Education

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Introduction

Information technology (IT) advances (e.g., cloud computing, electronic social media, analytics) in the recent decades provide organizations of all types and sizes with an unprecedented amount of data and information availability. These organizations are progressively moving into the age of Big Data that is described by Gartner (2014) and Vasarhelyi et al., (2015) as high-volume, high-velocity, and high-variety information, that is typically processed electronically and intended to improve decision making. A recent survey of Fortune 1,000 firms conducted by Vantage Partner (2016) indicates the increasing use of Big Data. Approximately fifty-four percent of these firms have established roles of Chief Data Officers to increase investment in Big Data, faster time-to-answer, faster time-to-decision, faster speed-to-market, and obtain greater insights into business and customers. Forensic accounting also has emerged as an important practice for accounting firms, which include various practices such as fraud examination, investigation of corruption and bribery, business valuation, being an expert witness, cybercrime management/cyber security, and litigation support (Crumbley et al., 2015). This article examines the integration of Big Data into forensic accounting education by: (1) reviewing prior literature to identify a list of Big Data topics or courses that could be incorporated into forensic accounting education; (2) investigating the forensic accounting syllabi of universities worldwide in their coverage of Big Data topics; and (3) presenting suggestions for the development of forensic accounting curriculum with Big Data and data analytics focus.

Forensic accountants are now facing the huge amount of both structured (e.g., general ledger or transaction data) and unstructured data (e.g., e-mail, voice, or free-text fields in a database), together with an increasing amount of nontraditional data sources such as third-party watch lists, news media, free-text payment descriptions, email communications, and social media. Data analytics with the use of Big Data has been employed to transform unstructured data into useful, structured, and relevant information for decision making.

Forensic accounting services are often performed by individuals with multidisciplinary knowledge and experience in accounting, technology, and laws who are professionally skeptical in asking right questions, utilizing data science, and data management expertise to translate questions into meaningful analytics and use systems and IT infrastructures (EY, 2014; EY, 2016). EY (2016) documents two factors which increase the use of data analytic tools by forensic accountants in their investigations. First, cyber breaches cause illicit transferring of funds, disrupt critical operations, steal intellectual property/confidential personal data, and other critical digital assets. Second, fraud risks increase because of insider threats triggered by malicious insiders to manipulate or destroy data, perpetrate fraud, steal intellectual property, engage in unauthorized trading, espionage, or information technology sabotage.

Prior research suggests that the supply of Big Data professionals is inadequate despite an increasing use of Big Data in forensic accounting practices. For example, Dong Laney (2012) forecasts a shortage of data specialists as it is anticipated that the need for data scientists is growing fast, and there is a predicted shortage of about 100,000-plus-person analytic talents by 2020 in the U.S. McKinsey Global (2011) predicts significant shortage of 1.5 million professionals with analytical expertise and the skills to understand and use Big Data in decision-making processes. Wixom et al., (2014) find growing market demand for students with Business Intelligence (BI) and Business Analytics (BA) skill sets with the anticipation that demand for Big Data professionals will rise in the future. Recently, PwC (2017, p 5) estimates "the market analysis calls for annual job openings to rise steadily to 2.72 million postings for data science and analytics roles in 2020." In China,

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Acknowledgement
The authors appreciate the support given by Tung Wah College in Hong Kong. This research is funded by a research grant provided by the University Grant Committee (Project Reference: UGC/FDS17/B02/14).

there is an estimated demand of 1.8 million Big Data professionals in the next three to five years, 1.5 million more than current supply (Global Times, 2017).

A short supply of Big Data professionals raises the question as to whether there is adequate training related to Big Data at the undergraduate/graduate level in the forensic accounting education. This article addresses this question by (1) investigating the status of the Big Data integration into forensic accounting courses and programs; and (2) examining the topical coverage of Big Data in forensic accounting courses/programs. Our analyses show that the coverage of Big Data courses in forensic accounting education in China currently lags behind the United States (U.S.), Canada, and other English-speaking countries. Anecdotal evidence from Wang et al., (2016) shows that there are only nineteen universities in China with forensic accounting courses or forensic accounting programs, and only three universities have a standalone Big Data course out of the nineteen universities. This situation contrasts dramatically with the U.S., where among ninety-seven universities offering forensic accounting programs, forty-three have a standalone Big Data course (Seda and Kramer, 2014). As a response to the increasing demand, an accreditation body such as Association to Advance Collegiate Schools of Business and accounting firms proposed to incorporate Big Data related skills and knowledge to prepare students in their career (AACSB A7, 2014). PricewaterhouseCoopers (2015) recommended a data-driven accounting curriculum as part of its effort to facilitate the curriculum design and delivery with challenges of IT, Big Data, and data analytics. The results suggest more resource input into the forensic accounting programs, particularly at undergraduate level, to incorporate Big Data/data analytics into the curriculum. This research makes an important contribution to the forensic accounting education literature by examining the issue of integration of Big Data/data analytics into forensic accounting courses and thus the business curriculum.

Literature Review

Several studies (e.g., Chen, Chiang, and Storey, 2012; Cao, Chychyla, and Stewart, 2015) provide an overview of Big Data and its implications in audit analytics. Chen, Chiang, and Storey (2012) argue that Big Data analytics can improve the effectiveness of financial fraud detection. For example, a meta-learning framework, which is based on a business intelligence and design science approach, can achieve a 79.2 percent detection rate of test instances in most legitimate and fraud cases. This detection is higher than the less than seventy percent detection rate of financial frauds with traditional methods. Cao, Chychyla, and Stewart (2015) propose that Big Data/analytics can improve the efficiency and effectiveness of financial statement audits. Auditors are currently accessing the increasing amount of various information such as news, audio and video streams, cell phone recordings, social media comments, because of digitalization and the ability to store petabytes of data. This increase in data provides auditors with an opportunity to use Big Data analytics in risk assessment, substantive analytical procedures, collection of audit evidence, as well as obtaining audit confirmation of events, transactions, and reporting elements. Auditors can use analytics to process the voluminous information of clients' past activities or outcomes of past audits to identify fraud risks and to direct audit effort towards fraud detection. For example, auditors including forensic accountants can use statistical relationships between business elements and processes to detect irregular events or frauds.

Businesses and regulators are also using Big Data and data analytics in detecting irregularities, non-compliance with applicable law, rules, regulations, and standards. For example, internal audit staff of two insurance firms, BlueCross and BlueShield, use data analytics to detect duplicate insurance claims among millions of claims each month. (Cao, Chychyla, and Stewart, 2015). With the voluminous time-stamped data from thirteen national equity exchanges, which are around one billion records each day, the SEC uses Big Data and data analytics, labeled "RobotCop," to identify securities law violations, and irregularities in the preparation of financial statements, issuer reporting, and audit failures (Forbes, 2013). Brown-Liburd, Issa, and Lombardi (2015) discuss the challenges in incorporating Big Data and audit analytics into audit strategies and present the behavioral implications of Big Data for audit judgments that affect audit quality. The use of both Big Data and Data Science methods are changing the way auditors gather and assess audit evidence. Big Data is expected to grow exponentially and thus, forensic accountants should proactively search for patterns, including irregularities, in Big Data and assess and manage their risk profile in detecting fraud.

Issa and Kogan (2014) point out the challenge of use of Big Data and data analytics by auditors. Use of data analytics can be overwhelming for auditors because of the voluminous output of data resulting from analysis. On the one hand, irrelevant information can potentially limit the value of use of Big Data and data analytics for auditors. On the other hand, auditors need the knowledge and skills to clearly understand the quality and relevance of the data to make professional judgments. Predictive analytics can help auditors overcome the cognitive limitations associated with ambiguity commonly derived from

voluminous data to identify meaningful patterns. Russom (2011) categorized Big Data and data analytics into four groups and made predictions of an increasing use of the following: predictive analytics, machine learning, artificial intelligence, visualization techniques (dashboards), data warehouses, dedicated database management systems, and Big Data technology (e.g., Hadoop, distributed file system). Kelly (2016) describes the use of Big Data in forensic accounting practices. Traditionally, forensic accountants rely on domain-knowledge-driven approach, including knowledge of specific fraud/crime schemes and expertly defined notions of red flags in detecting and discovering fraud. Progressive forensic accountants use data analytics and unsupervised machine learning to "figure out the hidden patterns within the data on their own, thus exposing unknowns" to improve the chances of uncovering unanticipated frauds (Kelly, 2016, p 15).

Big Data enables technological, cultural, analysis, and methodology opportunities in capturing and analyzing both structured financial information and unstructured non-financial information. The use of Big Data and data analytics enables forensic accountants in incorporating non-traditional sources of financial information and non-financial information into audit processes (Vasarhelyi, Kogan, and Tuttle, 2015). The growing volume, velocity and variety of the data as well as computational complexity in accounting and auditing processes (Moffitt and Vasarhelvi, 2013) demands the use of data processing systems that can capture, process, and analyze financial and non-financial data automatically (Romero, Gal, Mock, and Vasarhelyi, 2012). Thus, the currently used Computer Assisted Audit Techniques (CAATs) may have limitations of capabilities to import and use advanced statistical techniques to analyze non-financial and unstructured information, such as social networks, blogs, company emails, and newspaper articles.

Big data and data analytics need to be integrated with traditional audit evidence and evidence gathering processes. Yoon, Hoogduin, and Zhang (2015) argue challenges for integration of Big Data with traditional audit evidence and suggest that auditors obtain audit evidence through audit of accounting records or other corroborative information. Moreover, non-financial and unstructured information are ambiguous and often result in incorrect audit judgments. Big Data and data analytic tools can overcome the weakness of existent CAATs and incorporate structured (e.g., general ledger or transaction data) and unstructured (e.g., social media, blogs), patterns of behavior (e.g., split payments to bypass transaction limit), and trends (e.g., increased fraudulent transactions before a holiday). Use of Big Data/analytics can extract relevant information from large volumes of data so that auditors can identify high-risk areas and focus their investigative efforts. For instance, auditors use Big Data/analytics to detect suspicious cash transactions in anti-money laundering compliance. Auditors also can use correlations between nonfinancial and financial performance measures, pattern recognition from unstructured data to find exceptions, outliers of transactions, and indications of manipulation of financial information.

Status of Big Data Integration into Forensic Accounting Courses and Programs

To determine the status of integration of Big Data into forensic accounting education, we synthesize several published articles that provide information about forensic accounting education in China, the U.S., and other countries. Table I shows that only three out of nineteen universities with the forensic accounting program in China have a standalone course on Big Data (Wang et al., 2016). This situation indicates that China achieves sixteen percent on the integration percentage of Big Data courses into their forensic accounting programs, which is much lower compared to the U.S. (seventy-four percent) and other foreign English-speaking countries (sixty percent). Table I supports this fact by reporting that of fifty-eight U.S. colleges and universities with forensic accounting (certificate or degree) programs, forty-three have standalone Big Data courses (Seda and Kramer, 2014); among twenty-three foreign colleges and universities with forensic accounting (certificate or degree) programs, fourteen have standalone Big Data courses (Seda and Kramer, 2014).

Table I: Global Integration of Big Data into Forensic Accounting Courses/Programs

Country	Forensic Accounting courses/programs (Number)	Big Data Courses (Number)	Percentage	Description
China	19	3	16	Integration of Big Data, quantitative methods, data analytics, cybersecurity for e-business into forensic accounting.
Unites States of America	58	43	74	Infusion of digital forensics, cybersecurity, data and image file security, database design and application, network security and cloud forensics into forensic accounting.
Other Countries	23	14	60	Incorporation of data analytics, internet risk and security, information technology, data mining security, electronic crime into forensic accounting.

Name of universities and their forensic accounting courses/programs and related Big Data courses can be obtained from the authors.

In the U.S., a survey conducted jointly by the Teaching and Curriculum Committee of the American Accounting Association International Accounting Section and KPMG in 2014 finds that fifty-eight percent of 349 respondents (AAA members) report that their schools have taken measures to incorporate data analytics into the curriculum (Beckman et al., 2016). Rezaee and Wang (2017) survey both academics and practitioners and find that both groups agree that there is an increasing demand for Big Data education at both undergraduate and graduate level. Given the increasing demand for Big Data skills and knowledge, Chinese universities may need to open a new Big Data course and incorporate their existing Big Data course into their forensic accounting programs. Moreover, there is little prior evidence on Big Data topics being covered in a standalone course or Big Data courses being covered in forensic accounting education. This research makes an important contribution to advance forensic accounting education by proposing Big Data topics/courses to be incorporated into the forensic accounting curriculum. This suggestion is a response to Cao et al., (2015), which advocate changes of accounting education so that accounting students can be prepared in the use of Big Data in future accounting practices. The study extends this line of research and further investigates the incorporation of data analytics into forensic accounting programs in China.

In 2015, PricewaterhouseCoopers (PwC) published the white paper on data-driven accounting curriculum with purpose of helping accounting students to succeed in a rapidly changing business world. The white paper presents new skills needed by future accounting graduates and recommends courses to incorporate analytics technical skills in the undergraduate and graduate accounting programs. Table II reports the new desired skills relevant to Big Data and data analytics in two related areas of audit and risk management as recommended in the PwC report (PwC, 2015). In the audit area, the Big Data and data analytics are changing the audit evidence-gathering procedures at both the transaction and general-ledger levels by using new tools to extract and visualize data. In the risk management area, auditors are using Big Data and data analytics in assessing and managing audit risk and its components of inherent, internal control, and detection risks through testing for automating compliance monitoring activities. The 2015 PwC report suggests computing and statistics courses to incorporate analytics technical skills into the accounting undergraduate and graduate programs as described in Table II.

Table II: PwC Recommendations for Analytical/Big Data Skill Sets and Related Curriculum Education

Business Specialty	Core skills	New Skills likely to be needed
Audit	An understanding of all forms of accounting and taxation Expertise in GAAP and audit standards Matching of accounting and regulation	How to: 1. Research and identify risk 2. Mine data and improve insight 3. Understand relational databases 4. Use various tools and techniques (predictive, machine learning, etc.) 5. Mine using new analysis techniques
Risk management	Under analysis of business using data science. An understanding of data science, business domain, and analytical techniques Third-party assurance and vendor risk management knowledge, which entails understating how companies can mitigate risk that is introduced when an organization contracts work with outside vendors	How to: 1. Use simple risk to minimize human error 2. Perform mapping to improve regulation and risk management 3. Apply languages such as R, SAS, and more
Statistical analytics course	Tools used for different types of analysis (cluster, conjoint, etc.)	1. Skills in Python, Java, or other languages 2. Skills in Microsoft Excel and Access 3. Skills with SQL, MongoDB, Hadoop, etc.
Computational analytics course	Texting and HTML manipulation with Python ad Java Optimization Predictive analysis and machine learning Advanced database and data methods	1. Programming with R 2. Skills in gathering and cleaning data with R. 3. Tableau, SpotFire, or Qlikview 4. Data analysis such as descriptive statistics
Data analytics practicum	Solve real or instructor-developed business issues using data analytics	1. Documenting analysis with R 2. Use of GitHub 3. Advanced topics such as machine learning and omission of data

Big Data and Forensic Accounting Integrated Education

We examine Big Data and forensic accounting education integration by searching the websites of universities and colleges in both the U.S. and China in 2017. We find twelve universities and colleges in China that offer forensic accounting

programs including three-year diploma, bachelor degree and master degree programs. We also identify nineteen universities in the U.S. that either offer forensic accounting courses or Big Data/data analytics courses or both. Panel A of Table III present forensic accounting and Big Data courses and their course description in the U.S.; whereas Panel B presents such courses in China.

Table III: Big Data and Forensic Accounting Education Integration
Panel A: U.S. Universities

Name of school	Big data Courses	Description	Forensic Accounting Courses	Description2
Bentley			AC 773 Fraud and Forensic Accounting	Tax fraud, financial fraud, and fraudulent engagements
Bentley			AC772 Principles of Fraud Investigation	Cyber fraud, fraud prevention, and misappropriation
UT Dallas	BUAN 6346 Big Data Analytics	Learn about big data concepts, tools, analytics, and environment	ACCT 6383 Fraud Examination	Investigating, solving, and prosecuting financial crimes
UT Dallas	CS 6350 Big Data Management and Analytics	Included topics are: MapReduce, NoSQL systems, large data sets, data mining		
Purdue	CNIT 58100 Big Cyber Infrastructure for Big Data Analytics	Hadoop, MapReduce, and analysis of large data sets from companies like Facebook and Twitter		
Carnegie Mellon	MISM 95-869 Big Data and Large-scale Computing	Use of Spark, SparkSQL, MapReduce, Apache, and other big data tools		
Carnegie Mellon	MISM 95-885 Data Science and Big Data	Problem solving using Python. Prior knowledge is recommended.		
Missouri University of Science and Technology	IST 5420: Business Analytics and Data Science	Use decision trees, mining, clustering, and regression on big data sets		
Georgia Tech	MGT 6203: Big Data Analytics in Business	Big data analytics and algorithms		
USC	CSCI 686 Advanced Big Data Analytics	Large-scale data analytics with time-series analysis and modeling techniques		
Nebraska at Lincoln			ACCT 401 Fraud Examination and Internal Audit	Detect and deter fraud using investigative skills
Northwestern	Cis 436-DL Big Data Management/Analytics	Database systems and administration		
Pace University	CS 662 Big Data Warehousing	Inman and Kimbel approaches to data	ACC 366 Forensic Accounting	Fraud detection and fraud investigation techniques and litigation support services
Auburn	BUAL 6656 Big Data I	Use large data sets for analysis		
Auburn	BUAL 6666 Big Data II	How to load and cleanse data for analysis		
Dakota State	INFS 774 Big Data Analytics	Understanding Big Data today and its main pillars of- volume, variety, velocity, and veracity		
American	ITEC-670 Database and Big Data	Data warehousing, data analysis and mining, and data visualization	ACCT-551 Forensic Accounting: Fraud Examination and Litigation Support	Examines financial fraud and detection along with the litigation process
American			ACCT-680 Advanced Forensic Accounting and Fraud Investigation	Cyber fraud, detective techniques, and other advanced methods to detect and prevent fraud

DePaul	IS 452 Big Data and the Internet of Things (Iot)	Machine to Machine (M2M), Internet of Things (IoT), and Internet of Everything (IoE)		
DePaul	IPD 447 Big Data Using Hadoop Program	Apache Hadoop framework and how it fits with Big Data. Learn about Hadoop, MapReduce, Hive, Pig, HBase		
DePaul	IPD 451 Big Data and NoSQL Program	Focus on NoSQL programs and technology, such as MongoDB and Cassandra		
CUNY	DATA 622 - Machine Learning and Big Data	Hadoop framework and Mahout implementation		
Seattle	IS 5315 Big Data Analytics	Hadoop and MapReduce, data warehousing. Also review big data cases		
UCONN	OPIM5502 Big Data Analytics with Hadoop	Techniques for ETL and big data tools for mining		
Chicago	MSCA 32011 Big Data and Text Analytics	HDFS, Hadoop clustering, web analytics, and classification. Text analytics also included with real examples		
Chicago	MSCA 37001 Hadoop Workshop			
Stevens institute of technology	BIA 678 Big Data Seminar	Tools Hadoop, HBase will be used to explain the changing world of data		
Stevens institute of technology	BIA 686 Applied Analytics in a World of Big Data	Four areas of analytics (text, descriptive, predictive, and prescriptive) to tackle real problems		

Sources: The information about courses in this Table is provided through each university's website.

Panel B: Chinese University

College/University	Program Type	Forensic Accounting Program Major Courses
Hainan Vocational College of Political Science and Law	Three-year Diploma	Introduction to forensic accounting; financial accounting practice; introduction to theory of laws; rules of evidence; economic laws; cross-examination in forensic accounting; accounting in the digital environment
Bohai University	Bachelor of Management	Forensic accounting; forensic accounting case studies; civil procedure law of China; criminal laws; criminal procedure law of China; business valuation
East China University of Political Science and Law	Bachelor of Accounting	Economics; introduction to management; management information system; econometrics; financial accounting; auditing; financial management; taxation; financial statement analysis; accounting frauds- case studies; forensic accounting; economic laws; rules of evidence; computer forensics; securities law; banking laws; accounting laws; laws of commercial documents
Heibei Polytechnic College (Now part of Langfang Normal College)	Bachelor of Management	Civil procedure law of China; writing for forensic reports; business valuation; tax practice; capstone project
Hunan University of Finance and Economics	Bachelor of Law and Management	Criminal laws; civil laws; business laws; company laws; laws of accountants; introduction to forensic accounting; fraud examination; forensic and investigative accounting; tax laws; legal risk management
JiangXi University of Finance and Economics	Bachelor of Law	Theory of laws; criminal laws; civil laws; company laws; financial accounting; intermediate financial accounting; advanced financial accounting; financial management; auditing; fraud examination; investigation of economic crimes; forensic accounting; writing for forensic reports; accounting information system
Nanjing Audit University	Bachelor of Law	Theory of laws; constitutional laws; criminal laws; civil laws; criminal procedure law of China; civil procedure law of China; company laws; intellectual property laws; contract laws; financial accounting; principles of economics; accounting information system; forensic accounting; auditing; investigation of economic crimes; rules of evidence
Yunan University of Finance and Economics	Bachelor of Accounting	Intermediate financial accounting; intermediate financial management; auditing; accounting information system; advanced financial accounting; auditing: case studies; introduction to forensic accounting; forensic and investigative accounting; rule of evidence; taxation; criminal procedure law of China; civil procedure law of China; legal right; tax planning; financial statement analysis
Zhejiang University of	Bachelor of	Criminal laws; civil laws; administrative laws; criminal procedure law of China; civil procedure law

Finance and Economics	Management	of China; contract law; company law; insurance law; taxation; auditing; rules of evidence; investigation of economic crimes
China University of Political Science and Law	Master of Law	Civil procedure law of China; tort laws; constitutional law; criminal laws; administrative laws; civil procedure law of China; criminal procedure law of China; family laws; history of Chinese laws; company laws; contact laws; intellectual property laws; taxation; securities laws; international laws; advanced forensic accounting; investigation and evidence collection; bankruptcy laws; internal audit and internal control; tax planning; investigation for economic crimes; cyber security for e-business
Fudan University	Master of Professional Accounting	Advanced auditing; business ethics and code of ethics for accountants; advanced financial accounting; advanced financial management; advanced managerial accounting; management information system; international accounting standards; China taxation; internal control; tax planning; business laws; quantitative method (big data analytics); merger and acquisition; financial markets and financial derivatives
Nankai University	Master of Professional Accounting	Advanced auditing; business ethics and code of ethics for accountants; advanced financial accounting; advanced financial management; advanced managerial accounting; internal control; tax planning; legal and financial issues of merger and acquisition; management information system; Big Data analytics; risk management; quantitative method (data analysis)

Sources: A web-based survey of Mainland universities/colleges websites in 2017

Results presented in Panel A of Table III suggest from the studied nineteen universities, five offers both forensic accounting courses and Big Data/data analytics courses and eighteen universities offer at least one course in Big Data. Almost all forensic accounting and Big Data courses are offered at the graduate level. These forensic courses cover a variety of frauds from tax to financial, cyber, employees and misappropriation of assets and educate students about fraud prevention, deterrence, and detection. Big Data courses cover a variety of topics from understanding Big Data and its main pillars of volume, variety, velocity, and veracity to large-scale data analytics with time-series analysis and modeling techniques and Hadoop and MapReduce, data warehousing and data mining.

Panel B of Table III reports that from the twelve forensic accounting programs in China, one offers a three-year diploma program, eight bachelor degree programs and three master degree programs. Two master degree programs have a standalone Big Data and data analytics course in their forensic accounting programs. This material suggests that master programs seem to be better in incorporating Big Data/data analytics into forensic accounting programs. We obtained information about each forensic accounting program, such as the description of related courses and/or curriculum's objectives and goals by searching the university or college website to obtain information about the forensic accounting education. We use thematic analysis as a categorizing or classification strategy for qualitative data to analyze a broad reading of data into patterns and developing themes. Our findings show that diploma programs usually train students to prepare for the vocational and practical works, and they do not emphasize the latest technological trends, such as Big Data/data analytics. Compared with Bachelor degree programs, forensic accounting programs at master degree level have more resources into curriculum design to ensure the program quality and design.

Big Data Topics in a Standalone Course

Table IV summarizes the relevant Big Data topics for a standalone course as presented in prior studies (e.g., Grover S. Kearns, 2006; EY, 2014 and 2016; Wixom et al., 2014; Business Intelligence Congress, 2012; Babita Gupta, et al., 2015).

Table IV: Big Data Topics of a Standalone Course

Grover S. Kearns (2006)		BIC 3 survey (2012)		Wixom et al., (2014)		Babita Gupta, Michael Goul, and Barbara Dinter (2015)		EY (2014, 2016)	
Topics	Descriptions	Topics	N/A	Topics	Descriptions		N/A	Topics	Descriptions
Data structures	Relational and hierarchical databases, Schemas, Access controls	Data management		Data streaming	Data streaming management capabilities	Database management		Data visualization (dashboards)	

Data encryption	Encryption, Hash algorithms, Secret and public key systems, Digital signatures and certificates,	Data integration		Data movement	Data analysis with processing (MPP) architectures	Data visualization		Data mining	(ACL, IDEA): reasoning, sequence analysis, cluster analysis
Recovery of Digital Data (optional)	Hard disk file structure, Free space, File slack, RAM slack	Data warehousing		Data governance	Data governance, privacy, and security	Data security/privacy		Social and web monitoring tools	
Networks, Internet, and E-Commerce	Network topologies, WAN/LAN, Servers, EFT, EDI and X.12, HTML, XML, XBRL,	Data mining/ predictive analytics				Data/text mining (predictive analytics)		Forensic analytics software	Encase; IBM Counter Fraud; SAP Fraud Management Fraud and Security
Cyber Crime, Computers and the Auditors	Cybercrime and related laws, accounting and auditing standards	Data Integration/ ETL				Business Intelligence infrastructure: data warehouse		Data analytics	Statistical analysis, query design and data visualization
E-mail	Mail protocols (POP, IMAP, SMTP),	Reporting OLAP				Business Intelligence user tools		Cybercrime	
Forensic and Analytical Tools (optional)	The forensic workstation, Imaging software	Visualization				Business Intelligence applications			
Information Assurance and Authentication	Authentication of digital evidence: integrity and controls.	Advanced analytics				Business Intelligence management			
Legal Issues Affecting the IT Audit	Computer Fraud and Abuse Act, Electronic Communicatio ns Privacy Act	Expert system/ artificial intelligence				Business Intelligence and organizational issues			

Table IV indicates that data management is considered an essential Big Data topic (Grover, 2016; BIC 3 survey, 2012; and Gupta et al., 2015). Grover (2016) emphasizes data structures, such as relational and hierarchical databases. Understanding of data structures is the basis for arranging the dataset and managing the database. While data security and privacy are considered important (Wixom et al., 2014), Grover (2016) focuses on data encryption, information assurance, and authentication. Data visualization is also regarded as important (BIC 3 survey, 2012; Gupta et al., 2015 and EY 2014, 2016) because it provides a visual representation of information, leading to clear and effective communication.

Data/text mining is an important technique for discovering pattern and rules within a vast amount of data (BIC 3 survey 2012; Gupta et al., 2015; and EY 2014, 2016). Data analytics, which provides predictive analytics is also covered (BIC 3 survey 2012; Gupta et al., EY 2014, 2016). Both Grover (2016) and EY (2014, 2016) consider the technique for web monitoring to be important despite different terminologies, such as social and web monitoring tools by EY (2014, 2016) and transaction logs, log file analyzers and intrusion detection by Grover (2016). Reporting tools such as OLAP are considered useful (BIC 3 survey, 2012 and Gupta et al., 2015). While some place emphasis on the knowledge in Big Data systems, Gupta et al., (2015) use the term BI system management and BIC 3 survey (2012) uses the term expert

system/artificial intelligence. Forensic analytical tools and the issues relating to cybercrime are considered important in several studies (EY 2014, 2016 and Grover, 2016).

Taken together, results of prior studies synthesized Table IV and review of forensic accounting and Big Data offerings at eleven universities in China and nineteen universities in the U.S. as presented in Table III, underscore the importance and relevance of the following integrated forensic and Big Data topics:

1. Data management
2. Data security and privacy
3. Data visualization
4. Data/text mining
5. Data analytics
6. Web monitoring
7. Reporting tools (e.g., OLAP)
8. Big Data systems (e.g., BI systems, expert systems)
9. Forensic analytical tools (e.g., Encase)
10. Cybercrime and attaches
11. Cybersecurity
12. Financial reporting, tax and cyber frauds
13. Use decision trees, mining, clustering and regression on Big Data sets
14. Big Data analytics and algorithms
15. Fraud deterrence, prevention, and detection

We also review prior research in addition to investigation of universities Big Data and forensic accounting course offerings presented in Table III. Prior studies (e.g., Tu Manhui et al., 2012; Gary C. Kessler and Michael E. Schirling, 2006; John C Molluzzo and James P Lawler, 2015) propose or identify several Big Data related courses as summarized in Table V.

Table V: Big Data Courses

Gary C. Kessler and Michael E. Schirling (2006)		Tu Manhui et al., (2012)		John C Molluzzo and James P Lawler (2015)	
Courses	Descriptions	Courses	Descriptions	Courses	Descriptions
Analysis of Digital Media	Aspects of digital media, understanding the advantages and limitations of using digitally produced data, and procedures to ensure proper handling and presentation	Digital Forensics Fundamentals	Digital forensic investigation procedures, private regulations and public law issues, evidence acquisition/preserving/analysis/report	Big Data Ethical Framework	BDA privacy, regulatory and security standards governing analytics professionals
Computer Forensic I	Criminal justice and computer technology, types of computer and Internet crime, the investigation life cycle, evidence collection, legal issues, search and seizure cryptography and steganography, mobile devices, and future challenges	Advanced Computer Forensics	Advanced features of forensic tools, windows registry, memory analysis, advanced file system analysis (deleted and hidden data, metadata, temporary file), applied decryption	Big Data Foundation Technology	BDA high performance infrastructure platform and storage technologies and tools
Computer Forensic II	Concepts in digital/compute forensic analysis and Internet investigations, advanced legal concepts, subpoenas and search warrants, seizing digital media, imaging and authenticating drives, file system, and forensic hardware and software	Network/Internet Forensics	Internet and Network security, ethical hacking, network traffic analysis, log analysis, web attack, E-mail forensics, internet application forensics, social computing forensics		
Cybercrime	Economic and other crimes perpetrated over the Internet or other telecommunications, crimes ranging from auction	Mobile Digital Forensics (required for undergraduate but	Wireless security and attacks, wireless track and investigation, cell phone, IPhone, IPod, PDA, Blackberry, etc.		

	fraud, identity theft, and social engineering to child sexual exploitation, e-mail scams, and phishing	optional for graduate)			
White Collar Crime	White-collar crimes, from fraud and embezzlement to Medicaid/Medicare fraud, the use of the Internet and computers to commit these crimes, ways white-collar crimes are committed, the "essential elements" of many of these crimes, and the evidence necessary to prove these crimes	Courtroom Experience	Work with digital forensic practitioners from public/private sectors on a mock case, integrating knowledge and skills from forensics law, criminal justice, forensic psychology, and digital forensics fields, and present in a mock courtroom		
Senior Seminar In Digital Investigation	A capstone, senior-level course that provides students with an opportunity to prepare a thesis or perform some other comparable project. It is intended to bring together elements from the entire program and demonstrate original work	Digital Forensics Professional Project (optional for undergraduate but required for graduate)	Integrate existing knowledge and skills in digital forensics and conduct research to understand advanced cyber-crime methodologies and techniques and research on advanced digital forensics		

Table V shows that both Kessler et al., (2006) and Tu et al., (2012) develop curricula for computer forensics into two level courses, one being foundation and the other being advanced. The foundation courses commonly cover legal issues, individual components of an investigation life cycle, and computing techniques such as different computer operation systems and file systems, as well as some common computer forensic tools. In advanced computer forensics, while both highlighting authenticating drives and file systems, Kessler et al., (2006) place emphasis on a balance of legal aspect and computer technical proficiency and Tu et al., (2012) focus more on the technical aspect, such as data encryption and decryption. Molluzzo et al., place emphasis on the high-performance infrastructure platform, and storage technologies along with tools for Big Data analytics.

Kessler et al., (2006) and Tu et al., (2012) both propose a course on cybercrimes. However, Tu et al., (2012) propose two separate courses, namely network/internet forensics and mobile digital forensics. These courses highlight the crimes in the social network and investigation techniques. Kessler et al., (2006) and Tu et al., (2012) both propose that students should work on a project for consolidating their knowledge and techniques. This project course is considered important because students through the research can not only understand the contemporary methodologies on the forensic in the big-data era, but also the investigative and analytic skills. As shown in Table V, Fundamental Computer forensics, advanced computer forensics, Cybercrimes and Forensic project are the common Big Data courses. Results presented in Tables III and V suggest that integrated Big Data and forensic accounting courses are more appropriate to be offered at graduate level to ensure that students have prerequisite financial and managerial knowledge as well as basic computer skills before taking as specialized courses.

Discussion and Conclusion

Currently, there is an increasing demand to integrate Big data/data analytics into the forensic accounting programs. This article investigates the integration of Big Data/data analytics into forensic accounting programs by examining the forensic accounting and Big Data courses offered by twelve Chinese and nineteen U.S. universities. The results of our analyses of Chinese forensic accounting programs finds that forensic accounting programs at master degree level have better conformity than those at undergraduate level with the data-driven accounting curriculum. This research also reviews prior literature on Big Data topics and courses. We find that Big Data topics for a standalone course could include: (1) technical knowledge (data structures, networks/internet and e-commerce, data encryption, e-mail protocols, big data technologies—Hadoop, Map Reduce, SQL query); (2) investigation knowledge (cybercrimes, digital evidence seizure, recovery of digital data, legal issues affecting IT investigation); and (3) data analytics (data mining, social and web monitoring, data analytics, predictive analytics, data visualization, text analytics). We also find that Big Data courses including computer forensics, network

forensics, cybercrime, and courtroom experience, could be incorporated into the forensic accounting curriculum. These Big Data topics and courses could update the forensic accounting education to prepare students for their career challenges.

There may be several caveats with this paper. First, this research does not differentiate Big Data topics at undergraduate, graduate, and MBA levels. Babita Gupta, Michael Goul, and Barbara Dinter (2015) argue that Big Data Analytics courses are different at undergraduate, graduate and MBA levels. The undergraduate course should "emphasize an understanding of BI tools;" the graduate course is for business intelligent (BI) specialists and should focus on developing "BI applications using state-of-the-art tools to solve business problems in enterprises;" the MBA course is for BI generalists and should emphasize "how BI implementations can benefit businesses tactically and strategically at the enterprise level" (Babita Gupta, Michael Goul, and Barbara Dinter, 2015, p 456).

Second, the lists of Big Data topics and courses are by no means all-inclusive and exhaustive. It is possible that these Big Data topics/courses do not represent all of the topics/courses that should be covered in the forensic accounting curriculum. Third, the sample of twelve universities in China and nineteen in the U.S. is relatively small. Thus, the results of the study should be interpreted with cautions. It is possible that universities not included in our sample cover forensic accounting and Big Data education in other accounting and business courses. This paper presents several directions for future research. First, the data was gathered through a search of Internet information that is constantly changing, and it is a snapshot at a moment. A future study could examine if the quality and content of forensic accounting programs in China and the U.S. are changing in recent years. Future research could investigate the topics to be covered at undergraduate and graduate levels and develop teaching cases and resources to prepare students to acquire the Big Data/data analytics as well as forensic accounting knowledge. Finally, future study could survey both academics and practitioners to gather their opinions regarding the skill sets and important topics related to Big Data/data analytics and forensic accounting.

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