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Big data analytics role in shaping the work of accounting function and accounting professionals

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Abstract

Purpose – This paper aims to examine how big data can be applied in accounting and identifies the competences future accountants at organizational level need to possess to remain competitive.

Design/methodology/approach – This study used the association of chartered certified accountants (ACCA's) framework and the technological, organization and environmental (TOE) theoretical framework to identify the skills and capabilities urgently needed by accounting professionals at the organizational level in the context of big data analytics. The authors conducted comprehensive content analysis of academic literature issues from professional accounting bodies, and reports of accounting practitioners to gain insights of competencies that accounting professionals at organizational level need to possess to be prominent in the big data era.

Findings – The findings show that in the big data era accounting professionals should acquire the seven competences to be competitive. The competencies are (1) skills in data analytic techniques and the use of statistical models; (2) knowledge of the business; (3) skills to control the risk from the emerging technologies; (4) skills and knowledge in accounting profession; (5) skills to understand the insights from big data analytics; (6) skills to test the quality, veracity and integrity of data; and (7) skills to communicate with others. The study also found that these competences do not exist alone. These competences are closely related to each other and complement each other, which means that accounting professionals cannot expect to stand out in the future competition by mastering only one or two of these seven competences.

Research limitations/implications – The application of big data analytics is still in its infancy and its effects have yet to be confirmed so that there is no reliable case to collect and analyse. One limitation is the absence of practical case in this paper. The findings will help accounting professionals to understand the future of work.

Practical implications – The findings will help accounting professionals to acquire new skills and knowledge in related areas and remain competitive in the post big data era.

Social implications – This study highlights skills necessary for accountants to thrive in a big data era, emphasizing the shift from traditional accounting functions to roles that integrate advanced data capabilities and strategic insight.

Originality/value – This is one of the few papers that seek to explore the competencies required by accounting professional at organizational level in the big data era using the ACCA's research of accountant's professional quotients and TOE theoretical framework. This paper seeks to contribute to the literature on accounting

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professionals' competencies at organizational level in the big data era. Big data analytics in accounting is influencing the evolution of accounting professionals' competencies and is a key interest in accounting change literature. The nature of accounting work will undergo fundamental changes due to big data. Yet we know little about this due to big data being in its infancy stage in the accounting literature.

Keywords Big data, Accountants, Skills and capabilities, Accounting professionals, Technological, organization and environment theory

Paper type Research paper

1. Introduction

In recent years, the rise of big data has led to an obvious shift in business environments across industries (La Torre *et al.*, 2018). A growing number of literature has provided evidence that blockchain, Internet of Things, smart contracts and artificial intelligence solutions have different functionality and can effectively solve various financial reporting and audit-related problems (Arnaboldi *et al.*, 2017; Brown-Liburd *et al.*, 2015; Oesterreich and Teuteberg, 2019; Roszkowska, 2021). Financial leaders are actively applying new technologies to their accounting department, to convert it from a cost centre to a value centre (Noah, 2019). But, as per Arnaboldi *et al.* (2017), the accounting practitioners regard big data as a burden rather than as an opportunity. They have become accustomed to the traditional deductive thinking, in which accounting variables and accounting models all fit together perfectly. The lack of clarity about these technologies will create further resistance, as evident in case of enterprise resource planning (ERP) system, where most accountants only regard the ERP system as a calculator with more powerful functions (Granlund and Malmi, 2002).

In the era of big data, accounting and auditing have undergone profound transformations, shifting from traditional compliance roles to dynamic, insight-driven functions. For auditors, big data enables comprehensive transaction analysis and enhanced fraud detection by identifying anomalies across vast datasets, thus elevating audit quality and accuracy (Brown-Liburd *et al.*, 2015). Meanwhile, accountants leverage data analytics to provide strategic insights that support organizational decision-making, allowing them to act as critical business advisors. This shift positions big data not only as a technological advance but as a catalyst reshaping the core of accounting practices and the competencies required of professionals in the field (ICAEW, 2019).

A survey conducted by the Chartered Global Management Accountant (2013) shows that approximately 87% of over 2,000 Chief Financial Officers are certain that programming-based big data analytics will transform the way business is done in the next 10 years. On the other hand, accountants are resisting to change due to the uncertainties related to the new work methods of working with automation and emerging technologies, and the potentially increased workloads (Hawker, 2018). The Institute of Management Accountants surveyed 161 senior finance professionals in July 2017; 42% of the respondents' expressed concerns that their jobs might be replaced by emerging technologies. Accountants who are working in general accounting functions, such as amortization and depreciation, billing, bank reconciliations and cash application, are the most worried respondents, and more than half of accounting professionals who work in education field are worrying that online education will replace their jobs in the very near future (Krumwiede, 2018).

Frey and Osborne (2017) estimated the probability of automation of 702 professions. Their research shows that, except for those in senior positions, accounting professionals will be gradually replaced by automation in the next 20 years. They suggested that high-skill and high-wage occupations are the least susceptible to automation. For those entry-level

accounting and auditing tasks that do not need communication with others, such as the collection of accounts receivable, account checking and bank statement reconciliation, have already become automated (Richins *et al.*, 2017).

The application of big data analytics is a brand-new opportunity for modern accountants to enrich their skills and knowledge, and to improve the quality of their work (Lodhia *et al.*, 2025). Aum *et al.* (2018) indicated that during the process of automation more jobs will be created for accountants, but only under the premise that accountants must be professionally trained to acquire new skills and knowledge in related areas. The forward-looking accounting professionals must explore how can the work of accountants continue to add value to organizations (Bhimani and Willcocks, 2014). Most accounting professionals and scholars agree that skills and capabilities related to data science and statistics are important, but it is unclear that how much knowledge is needed for accountants to effectively collaborate with data scientists (ICAEW, 2019). Sledgianowski *et al.* (2017) search of instructional resources related to big data and business analytics reveals a dearth of resources to support integration in the accounting curriculum. It may be that accounting educators are including big data and business analytics technological and information system competencies in their curriculum, but the content is not being shared in a public forum with other educators.

In this study we have conducted a comprehensive review of academic literature, issues from professional accounting bodies and reports of accounting practitioners to understand how the application of programming-based big data analytics in the accounting business affects accountants. The primary aim of this paper is to address the question: *What competencies and skills should accountants acquire at organizational level to remain competitive and add value in a big data-driven environment?* To achieve this, the study examines how big data can be applied in accounting and identifies what competences future accountants at organizational level need to possess to remain competitive.

The findings show that in the big data era, accounting professionals should acquire the seven competences to be competitive. The competencies are:

(1) skills in data analytic techniques and the use of statistical models;

(2) knowledge of the business;

(3) skills to control the risk from the emerging technologies;

(4) skills and knowledge in accounting profession;

(5) skills to understand the insights from big data analytics;

(6) skills to test the quality, veracity and integrity of data; and

(7) skills to communicate with others.

The study also found that these competences do not exist alone. These competences are closely related to each other and complement each other, which means that accounting professionals cannot expect to stand out in the future competition by mastering only one or two of these seven competences.

The study contributes to the literature by underpinning that the nature of accounting work will undergo fundamental changes due to big data. Yet we know little about this due to big data being in its infancy stage in the accounting literature. The way how accountants work will change from making decisions by human alone to making decisions in collaboration with the machines in big data age is a new skill that accountants need to develop. Big data analytics in accounting is influencing the evolution of accounting professionals' competencies and is a key interest in accounting change literature.

The remainder of this paper is structured as follows. In Section 2, we review the literature on the relationship between big data analytics and accounting. Section 3 describes accounting functions affected by big data analytics. In Section 4, we describe the theoretical framework for the study. Section 5 describes our methodology for collecting and analysing data. In Section 6, we present the findings of the paper. In Section 7, we discuss the findings followed by the future research in Section 8. Finally, in Section 9 we derive some conclusion.

2. Literature review

Big data encompasses information assets characterized by the five Vs: Volume, Velocity, Variety, Veracity and Value. *Volume* refers to the vast quantities of data generated; *Velocity* indicates the speed at which data is produced and processed; *Variety* represents the different types of data formats; *Veracity* relates to the accuracy and reliability of data; and *Value* underscores the actionable insights derived from data processing (Geerts and O'Leary, 2022). In an accounting context, big data's impact is evident in transaction validation processes. For instance, consider an organization that processes thousands of sales transactions daily. Using big data analytics, accountants can validate each transaction in real (velocity) while aggregating various data types, including invoices and customer feedback (variety). Ensuring data accuracy (veracity) is essential, as inaccuracies can lead to financial misstatements. Big data's volume enables accountants to analyse patterns across numerous transactions to detect anomalies, thus creating value by enhancing audit quality and operational efficiency. For example, a big data-driven ERP system could monitor all transactions for compliance, flagging those that deviate from typical patterns for further review, thereby supporting a "single source of truth" for financial data. The most recent definition developed by Fox (2018) focuses on explaining how to use the programming techniques to collect, organize and analyse big data, and it states that big data is where parallel computing tools are needed to handle data. The data collected can be structured or unstructured and comprise information sourced from social media platforms, applications from mobile devices, pictures, videos and wireless machine sensors (Warren *et al.*, 2015). Arnaboldi *et al.* (2017) suggested that functions that are more closely related to externalities, such as after-sales service and marketing, have a more open mind to the idea of big data from social platforms; functions that focus on internalities, such as accounting departments, have a conservative attitude towards internet-based technologies. The accounting data collected inside organizations are mostly structured data. Accountants are acquainted with analysing the structured data, for example, data from financial statements or sales data (Richins *et al.*, 2017). The accountants are preoccupied in transforming these structured data into the necessary format required for tax declaration submission, such as the 10-K format in securities and exchange commission (SEC's) system (IMA, 2020). In big data age, the more valuable business information are the unstructured data from social media platforms, data from mobile devices and the public data on the web. The implementation of big data analytics could effectively reduce the organization's reliance on assumptions and guesswork, and enables organization to enhance its capabilities to make decisions about customers, suppliers, employees, strategies and risks (ICAEW, 2019). A survey of organizations that have implemented programming-based big data analytics technique conducted by NewVantage Partners (2018) shows that 73% of the respondents agreed that they benefited from the implementation of big data analytics, and the biggest three benefits are improvements in decision-making, better customer service and reduced cost. Therefore, accountants are now expected to have knowledge of big data analytics and other automation technologies. They should be capable of conducting the problem-driven analysis and the exploratory analysis of both structured and unstructured data (Richins *et al.*, 2017),

Accounting scholars have researched the relationship between big data analytics and accounting through various lenses. Many scholars have focused on researching the opportunities and threats brought by big data analytics to the whole accounting profession, and what techniques might be outdated and replaced (Earley, 2015; Huerta and Jensen, 2017; Richins *et al.*, 2017; Warren *et al.*, 2015). Other scholars has focused on studying the impacts of big data analytics on managerial accounting (Appelbaum *et al.*, 2017; Quattrone, 2016; Rikhardsson and Yigitbasioglu, 2018) and the impacts on audit judgement and decision-making (Brown-Liburd *et al.*, 2015; Cao *et al.*, 2015). Some scholars have studied the activities of accounting professionals when forced to work with big data analytics (Goh *et al.*, 2019; Hampton and Stratopoulos, 2015), while others are more interested in studying the development of big data analytics in the whole accounting business and predicting the future of the industry (Lowe *et al.*, 2017; Rose *et al.*, 2017). The accounting scholar have not given sufficient attention to how big data analytics affects the everyday work of accounting professionals (Moll and Yigitbasioglu, 2019). In this research we will explore how big data analytics affects accounting professional and what competences should future accountants possess to remain competitive.

3. Accounting functions affected by big data analytics

The improvements in accounting functions by applying big data analytics focuses on the better insights, the greater efficiency and the improved coordination of risk and compliance activities. This in turn will reduce cost, improve efficiency and develop human resources. In this section we have focused on three major subareas of accounting, that is, financial accounting, management accounting and auditing, due to that most accounting practitioners work in these three fields.

3.1 Management accounting

Management accountants collected and readjusted financial and nonfinancial data to generate management reports, such as cost reports, performance reports (balanced scorecard) and budget reports, to support managers and employees in organizations to manage cost, to measure and reward performance, to plan and budget, to allocate resources, to monitor and evaluate, and eventually, to make decision (Brands and Holtzblatt, 2015). Unlike the traditional methodologies of cost management, big data analytics can assist management accountants in collecting and analysing all cost related data, financial and non-financial, textual and non-textual and preparing management reports in a continuous manner in realtime. It can help management accountants extract from both internal and external data sources, and be able to explain what has happened (descriptive analytics), what will happen (predictive analytics) and what is the optimized solution (prescriptive analytics) (Appelbaum *et al.*, 2017). This will improve the overall efficiency of management accounting.

Big data analytics will reduce cost for organization through a real-time updated big data warehouse by collecting and sorting out all relevant data, inside and outside the organization, financial and non-financial, textual and non-textual, from social medias and news (Cokins, 2013). In addition, big data analytics could enable management accountants create a budget model with data of 10 years of periods with less time and more accuracy. In addition, with big data, a continuous manner of budget monitoring and budget adjustment can also be achieved (Smith, 2016).

Human resource performance will also develop as the performance management supported by big data analytics is capable to operate a more dynamic balanced scorecard system which could provide a real-time performance measurement (Smith, 2016).

3.2 Financial accounting

For financial accounting, big data will reduce cost by improving the ability of financial accountants to evaluate and track intangible assets in real time, especially those off-balance sheet assets, such as customer lists, human resources, commitments and seller lists (Warren *et al.*, 2015). Big data analytics (unstructured textual data analysis) measures the market position by automatically retrieving the frequency of being referred as the competition/competitor in the 10-K reports of those organizations in the same industry (Li *et al.*, 2013). The text mining function of big data analytics can extract the frequency of an organization's customers and suppliers being referred as buyers and suppliers in 10-K forms to provide insights of bargaining power, and then organizations could adjust its purchasing and sales strategies. Applying big data analytics to extract information from social media platforms can enable organization not only get information relevant with customers satisfaction, but also review the organization's market competitive position from the perspective of the customers (Hampton and Stratopoulos, 2015). This will improve the overall organizational efficiency.

According to ICAEW (2019), big data analytics will improve corporate social responsibility (CSR) reporting. In the big data world, it will be extremely difficult for organizations to try to hide their activities that violate CSR under the rug. All CSR-related activities, good or bad, will be fully recorded on the Internet in a diverse and discrete manner. Using big data analytics to prepare CSR reports enables more abundant data resources inside and outside the organizations to be discovered and analysed. The application of big data analytics makes the carrier, the path of transmission and the audience of CSR information more diversified. After multidimensional big data analytics, CSR-related information will be disseminated to a wider range of audiences through the internal control system and external communication system in the form of CSR reports and non-reporting data.

3.3 Auditing

Auditors have long been accustomed to using computer-assisted technologies to analyse structured data in a problem-driven approach, and to identify relevant information and discard noises (Golia, 2013). In the past, auditors analysed structured datasets under the problem-driven approach to assess whether financial statements are materially misstated (Cao *et al.*, 2015). However, for those unstructured and non-financial data, the auditors currently have no adequate skills and capabilities to explore and mine (Dowling and Leech, 2007). According to Earley (2015), there will be four major improvements of applying big data analytics to auditing:

(1) auditors can test 100% of client's transactions;

(2) by providing insights into client's processes, audit quality can be improved;

(3) fraud will be easier to locate and detect because more unstructured data can be analysed; and

(4) the capabilities of analysing external data enable auditors to provide customers services with more dimensions and supports for solving problems.

This will improve efficiency and reduce cost for auditing.

Moffitt and Vasarhelyi (2013) suggested that big data analytics could assist auditors perform the work of data mining so that auditors could be able to analyse external data, including data from social medias, news and articles, more effectively and efficiently when they access their client's business risk, fraud risk, internal controls and going concern. If programming-based big data analytics is regarded as a legal audit procedure by the auditing

standards, then audit sampling techniques will be replaced by big data analytics which allows auditors to analyse all transactions and related data for years of period at one time (Gray and Debreceny, 2014). Instead performing tests of details, data analytics could review the entire populations to detect unusual patterns and anomalies (Richins *et al.*, 2017). Brown-Liburd *et al.* ((2015) suggested that for tasks requiring more subjective judgments, such as fraud risk assessment and suspicious transactions detecting, programming-based big data analytics could contribute due to its capacity to analyse high volume of data in real time.

In addition to improving the efficiency and reliability of assurance business, big data analytics has been also applied by auditors in other fields. In recent years, his majesty's revenue and customs (HMRC), the UK tax authority, to combat tax fraud, has started to use big data analytics to collect and analyse data from the Internet, social media platforms, land registration records, international tax authorities and banks as evidence to identify anomalies. It is impossible for HMRC to collect and analyse these huge volumes of data with existing human resources if there is no support from big data analytics (ICAEW, 2019). The SEC has been using big data analytics models to collect and analyse about one billion records every day from each of the 13 national stock exchanges to monitor the market, and identify fraudulent financial statements and audit failures (Cao *et al.*, 2015).

4. Technological, organization and environmental and the ACCA framework

The study uses the technological, organization and environmental (TOE) theoretical framework to understand any nuanced practical realities of big data's impact. The TOE framework is an organizational level descriptive theory which explains why and how organizations adopt innovative technologies such as big data (Baker, 2012; De Pietro *et al.*, 1990; Tornatzky and Fleischer, 1990). The TOE framework asserts that three contexts impact in decisions to adopt big data namely, technological, organizational and external environmental contexts (De Pietro *et al.*, 1990; Awa *et al.*, 2016). Baker (2012, p. 241) notes "as long as new technologies develop and novel contexts for adoption can be identified" the TOE framework provides a useful framework for analysis.

Tornatzky and Fleischer (1990) stated that the technological context includes useful technologies that are available internally and externally to a firm. A firm's decision to apply an innovative technology is dependent on the technological context of the industry in which the firm operates in. The adoption of new technology also depends how well the innovative technology matches the prevailing firm's infrastructure that sets the scope of change that the firm can undertake (Oladejo *et al.*, 2024). Innovative technologies external to the organization needs to be considered as they show firms how can they leverage the firm to progress (Baker, 2012).

Awa *et al.* (2016) noted that technology describes adoption in terms of the pool of technologies internal and external to the firm as well as their perceived usefulness. The use of sophisticated technology, such as big data guarantees the firms to pursue their goals in the most efficient and effective manner. Environmental factors that shape operational effectiveness, strategic positioning relate to marketplace forces, competitive pressures, government rules and regulation. Awa *et al.*'s (2016) study found that the adoption of ERP by small and medium-sized enterprises is more driven by technological factors than by organizational and environmental factors.

In relation to organization factors, management support and organization readiness were identified as factors influencing big data adoption in the firms (Lufti *et al.*, 2022). Decision-makers in firms are senior management team, and their endorsement is important for innovation adoption. In summary, top management support may facilitate technology/service learning and dissemination throughout the firm and plays an important role in the stages of

adoption. Furthermore, research dedicated to technology adoption has consistently substantiated the importance of the association between organizational readiness and big data adoption.

Automation can create new challenges that accountants need to understand and manage. Advisors are good at seeing big picture and spotting the problem. This is something technology could not replace in the short term. The transformative technology (e.g. big data analytics) will require training, testing and assurance where accountants as advisors can play a critical role in the future if they develop the right skills.

ACCA framework of research

Janvrin and Weidenmier (2017) argued that while the datasets are now larger than ever before and better data analytics software is available, the primary goal of accounting has always been the same – to create and provide information to internal and external decision-makers. Future accountants will need the comprehensive set of knowledge, skills, judgement and attributes to remain competitive. In this study, we have used the association of chartered certified accountants (ACCA) framework as opposed to ones of other bodies such as certified practising accountants (CPA), chartered accountants Australia and New Zealand, and chartered institute of management accountants because the ACCA framework provides the professional behaviour and qualities required by an accountant to meet the future needs and demands of his or her profession. This framework measures the capabilities and competencies of accounting professionals from seven different dimensions, and assess accountants with which combination of capabilities can best meet the requirements of organizations in big data age (Chua, 2016). The seven dimensions are: technical skills and ethics, intelligence, creative, digital, emotional intelligence, vision and experience. This study will use these seven dimensions of ACCA framework as the research framework alongside the TOE framework. The authors pre-read through all the chosen articles and reports (see Section 5.1), and the seven skills and capabilities were derived from these articles and then transformed based on the framework of ACCA's research of accountant's professional quotients (PQ). The seven skills and capabilities identified in this study are as follows (Table 1).

5. Research methodology

In this study, we have used the ACCA's research of accountant's PQ and TOE as research framework to identify the skills and capabilities urgently needed by accounting professionals at the organizational level in the context of big data analytics from seven dimensions (Chua, 2016). The study analyses the articles of accounting scholars, issues from professional accounting bodies and reports of accounting practitioners to gain insights of competencies that accounting professionals need to possess to be prominent in the big data era. The meaning of the framework, the scope of the articles, issues and reports collection and the approach and procedures to analyse these chosen articles, issues and reports are described in the following subsections.

5.1 Articles, issues and reports collection

To ensure a rigorous and transparent data selection process, we began by identifying our initial data set using the 2019 Australian Business Deans Council (ABDC) journal quality list for Accounting (Code 1501). This list was elected for its academic credibility and alignment with other recognized indices such as the Academic Journal Guide and SCIMAGO. From the list, we conducted systematic key word searches, using targeted terms including "big data in accounting", "data analytics and accounting", "competencies in big

Table 1. ACCA framework and skills and capabilities

ACCA's framework	Framework interpretation	Skills and capabilities identified
Technical skills and ethics	As accounting professional, the skills and capabilities to perform the duties of being a financial accountant, a management accountant or an auditor who can not only understand the insights of financial figures but also capture the essence of business	Skills and knowledge in accounting profession
Intelligence	The skills and capabilities to provide assurance of the quality of data, and the abilities to train the models	Skills to test the quality, veracity and integrity of data
Creative	The skills and capabilities to assess and evaluate the information extracted from big data analytics, based on which appropriate judgements can be made to provide supports for organizational decision-making process	Skills to understand the insights from big data analytics
Digital	The skills and capacities to stay cautious and alert to the risks brought by the application of new technologies, and to be able to manage the risks and governance the implementation of big data analytics	Skills to control the risk from the emerging technologies
Emotional intelligence	The skills and capabilities to identify the emotions of others and manage the relationship with the others, especially with data scientists and programming experts. The capabilities to speak foreign language and data language belongs to this category	Skills to communicate with others
Vision	The skills and capabilities to use the existing and emerging digital technologies to capture future trend; the preliminary knowledge of digital science; the awareness of digital governance	Skills in data analytic techniques and the use of statistical models
Experience	The knowledge of the business, customers, suppliers, competitive forces of the industry and the value chain, etc. The skills and capabilities to use the experiences in the business to detect false correlation in big data analytics	Knowledge of the business

Source(s): Authors' own work

Table 2. Data selection process

Key words and sources	Systematic key word searches		
Keywords	Big data, analytics, accounting profession, accountants, future, digital, the work of accountants, decision support, digitalization, the transformation of accounting information system, competences, skills, knowledge, capability…		
Sources	ABDC journal quality list	Webpage of professional accounting association	Webpage of the big four
Number of papers	28	6	7

Source(s): Authors' own work

data" and "future of accounting" (see Table 2 for full list). This process yields an initial pool of potentially relevant articles and reports that addressed the intersection of big data and the accounting profession. The time frame for the literature and document review was from 2015 to 2024. This framework applied to both academic and professional documentation. For the

Big Four publications, we conducted targeted searches of the official websites of Deloitte, PwC, KPMG and EY using the same keywords, supplemented by manual scanning of their insights and thought leadership archives to capture recent, high-relevance reports on big data in accounting; selection emphasized documents that provided concrete, practice-oriented insights aligned with the study's competency framework.

5.1.1 Inclusion and exclusion criteria. We applied disciplinary, topical and document-type filters to refine the data set. Specifically, we focused on literature related to financial accounting, management accounting and auditing ensuring alignment with the core domains of accounting practice. Only sources that explicitly addressed big data's implication for accounting roles and competencies at the organizational level were retained.

We excluded book chapters as they often offer broader overviews rather than empirical evidence or targeted professional insights. However, exceptions were made on when chapter presented unique or underrepresented perspectives directly relevant to our research questions.

We prioritized peer-reviewed empirical studies and industry reports that provided specific, actionable insights. Sources were excluded if they lacked clear methodological grounding or did not identify specific competencies relevant to accounting professional.

5.1.2 Screening process. Our screening involved multistage approach:

- internal screening of titles, abstracts and introduction to determine basic relevance;
- full-text review of shortlisted documents to assess methodological robustness, relevance to the study's objectives and depth of discussion on big data competencies; and
- final filtering based on alignment with our conceptual framework and emphasis on practical implications for the accounting profession.

From this process, 41 key sources were identified and included in the final analysis. These comprised:

- 28 peer reviewed articles (68.3%) from ABDC-listed journals;
- six professional reports (14.6%) from professional accounting associations (e.g. ACCA and CPA); and
- seven industry publications (17.1%) from the Big Four firms.

The final data set included contribution across sub-disciplines: These sources covered a range of topics, general accounting (22 articles, 53.7%), auditing (7 articles, 17.1%), financial accounting (5 articles, 12.2%), management accounting (5 articles, 12.2%) and ethics/governance (2 articles, 4.9%).

5.2 Research approach and process

We have conducted content analysis of the articles and reports mentioned in Table 3. The sampling phase started with choosing the representative textual documentations which must contain contents in both accounting (or accounting information system) and big data disciplines. Because the number of articles or reports covering both the disciplines is limited, we selected our study objects from the most representative academic papers of accounting scholars, industrial reports of reputable accounting association and the technical reports of the Big Four.

Figure 1 below shows the proceedings of qualitative content analysis from the initial theory/framework to the final analysis and interpretation.

Kohlbcher (2006) referred to analysis of material (summary, explication and structuring) using qualitative content analysis. This entails summary which involves reducing the

Table 3. Content analysis of articles

Type of documentation	Authors	Sub-field
Scholar paper	Moll and Yigitbasioglu (2019)	Financial accounting
Scholar paper	Warren *et al.* (2015)	Financial accounting
Scholar paper	Appelbaum *et al.* (2017)	Management accounting
Scholar paper	Brown-Liburd *et al.* (2015)	Auditing
Scholar paper	Richins *et al.* (2017)	General accounting
Scholar paper	Hampton and Stratopoulos (2015)	Financial accounting
Scholar paper	Goh *et al.* (2019)	General accounting
Scholar paper	Borthick and Pennington (2017)	Auditing
Scholar paper	Earley (2015)	Auditing
Scholar paper	Arnaboldi *et al.* (2017)	General accounting
Scholar paper	Möller *et al.* (2020)	Management accounting
Scholar paper	Rikhardsson and Yigitbasioglu (2018)	Management accounting
Scholar paper	Lowe *et al.* (2017)	Auditing
Scholar paper	Quattrone (2016)	Management accounting
Scholar paper	Rose *et al.* (2017)	Auditing
Scholar paper	Huerta and Jensen (2017)	General accounting
Scholar paper	Gunz and Thorne (2020)	Ethics
Scholar paper	Al-Htaybat *et al.* (2019)	Governance
Scholar paper	Cao *et al.* (2015)	Auditing
Scholar paper	Al-Htaybat and von Alberti-Alhtaybat (2017)	General accounting
Scholar paper	Han *et al.* (2023)	General accounting
Scholar paper	La Torre *et al.* (2018)	Financial accounting
Scholar paper	Garanina *et al.* (2022)	General accounting
Scholar paper	Varma *et al.* (2021)	General accounting
Scholar paper	Spanò *et al.* (2022)	General accounting
Scholar paper	Sun *et al.* (2024)	Auditing
Scholar paper	Yusuf and Dagunduro (2024)	General accounting
Scholar paper	Theodorakopoulos *et al.* (2024)	General accounting
Accounting association report	Chua (2016); Association of Chartered Certified Accountants	General accounting
Accounting association report	ICAEW (2019)	General accounting
Accounting association report	ICAEW (2018)	General accounting
Accounting association report	CPA Canada (2019)	General accounting
Accounting association report	IMA (2020)	Financial accounting
Accounting association report	CIMA (2016)	Management accounting
Publication of Big Four	PWC (2018)	General accounting
Publication of Big Four	PWC (2015)	General accounting
Publication of Big Four	Deloitte (2020b)	General accounting
Publication of Big Four	Deloitte (2020a)	General accounting
Publication of Big Four	KPMG (2019)	General accounting
Publication of Big Four	KPMG (2023)	General accounting
Publication of Big Four	EY (2024)	General accounting

Source(s): Authors' own work

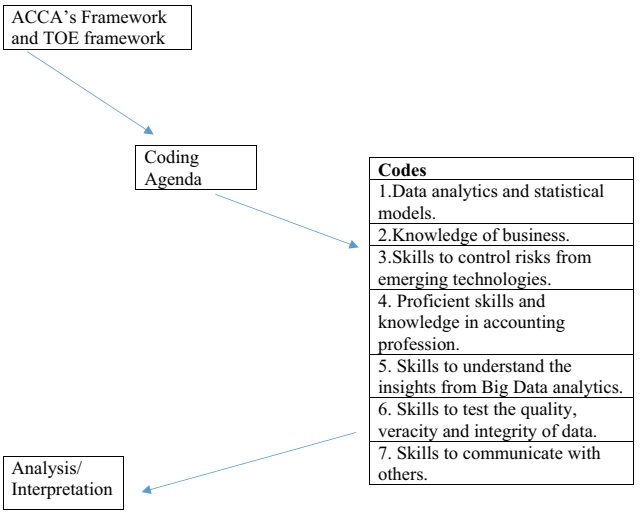

Figure 1. Proceedings of qualitative content analysis
Source: Courtesy of Kohlbcher (2006) with slight modifications

material to essential content and making it manageable. Explication refers to clarifying unclear parts of the material by interpreting the context. Structuring, on the other hand, is about organizing material based on specific themes.

This study uses thematic content analysis, a qualitative research approach that systematically identifies and categorizes recurring themes in text-based data (Braun and Clarke, 2006; Sharma *et al.*, 2010, 2014; Krippendorff, 1980; Miles *et al.*, 2014; McCraken *et al.*, 2018). We use a structured, deductive coding approach, where data is categorized according to the ACCA framework dimensions.

The unit of analysis in this study is defined as the complete sentence or paragraph within the selected documents that explicitly discusses accounting competencies relevant to big data analytics at organizational level. Each time such a sentence or paragraph appeared in the selected articles and reports; it was recorded under one of the seven competency categories. This approach ensures that the analysis focuses on accountants' competencies at organizational level. The organization level is the main subject of the study.

Captured textual statements were coded into predefined categories based on their relevance to the identified competencies. If a statement covered multiple competencies, it was coded under the most dominant theme. This method enhances reliability and ensures the findings are grounded in both academic and professional accounting discourse. Based on the general understanding of content and insights from the ACCA's and TOE framework, seven major themes – data analytic skills and statistical models, knowledge of business, skills to control risk from emerging technologies, proficient skills and knowledge in accounting profession, skills to understand the insights from big data analytics, skills to test the quality, veracity and integrity of data and skills to communicate with others – were created. The seven codes were developed based on the ACCA's framework of research of accountants' PQ. This framework served as the conceptual foundation for identifying the competencies essential in the evolving landscape of the accounting profession. Subsequently, each code was mapped to corresponding dimensions the TOE framework which provided an additional

analytical lens for contextualizing these competencies. The TOE framework influences the refinement of the codes by highlighting the interplay between technological capabilities, organizational readiness and environmental pressures in shaping the development and relevance of accountants' professional skills. The final coding scheme reflects both the competency-based perspectives of ACCA and the structural dimension of the TOE framework, enabling a more holistic understanding of the skills required for accounting professional in big data environment. See below for examples of thematic content analysis.

The selecting phase started with selecting and highlighting the most presentative statements (sentences, paragraphs, or a portion of a page, occasional words or phrases are not included) from the chosen documentations (Elo and Kyngäs, 2008), and the selected statements should be under the scope covered by the above-mentioned seven dimensions. In this phase, the statements should signify the essence of what this study wishes to record and analyse. The selected statements should link to the scope and purpose of this study, be exhaustive, mutually exclusive, independent and developed from a single classification (Saunders *et al.*, 2009). We started with reading all the selected articles and reports, and manually captured and highlighted sentences or paragraphs that describe the skills and capabilities accountants should acquire under the context of the application of online- and programming-based big data analytics. The chosen skills and capabilities were under the scope of the seven dimensions framework. The captured textual statements were processed and analysed under opening coding, and then collapsed and classified into those seven skills and capabilities based on their similarities (Burnard, 1991). For instance:

> […] our research into Big Data and the profession has also emphasized the importance of business and commercial skills, and the opportunity for accountants to play a bridging role […] as a result, while data and statistical skills are important, they are only part of the picture[…] (ICAEW, 2019).

From this paragraph of textual statement, the competence of *knowledge of business* can be captured, and it will count one time in the *knowledge of business category.*

> […] these authors suggest that, to remain relevant, accountants will need to develop expertise in interpreting and utilizing data analytics […] one needs to consider the "full-circuited knowledge system in place", which includes both the manager's tacit knowledge and the information system […] (Moll and Yigitbasioglu, 2019).

From this paragraph of textual statement, both competences of *skills and knowledge in accounting profession* and *skills in data analytic techniques and the use of statistical models* can be captured, and it will count one time for each of *skills and knowledge in accounting profession* and *skills in data analytic techniques and the use of statistical models.*

During the process of reviewing the chosen articles and reports, each time there is a complete sentence or a complete paragraph describing one of the seven skills and capabilities, the author added a record under this category in the spreadsheet of work (Appendix Table A1).

6. Findings

In the big data era there has been a rapid expansion of forensic accounting and business analytics, which has increased the need for data mining skills, as well as forensic IT investigative skills (Pan and Seow, 2016). The human accountant in the big data environment will analyse any anomalies that occur, focusing more on the transactions that require nuanced in-depth analysis, forensic investigation and fraud examination (Appelbaum and Nehmer, 2017). This study reviewed 41 papers and reports to answer the research question of what competencies and skills should accountants acquire to remain competitive and add value in a big data-driven environment? The

study showed that under the circumstances of the application of big data analytics, accounting professionals should acquire the following competences to be competitive and relative:

- skills in data analytic techniques and the use of statistical models;
- knowledge of the business;
- skills to control the risk from the emerging technologies;
- skills and knowledge in accounting profession;
- skills to understand the insights from big data analytics;
- skills to test the quality, veracity and integrity of data; and
- skills to communicate with others.

The role of big data in societies give rise to deal with changes within the accounting profession and the role of accountants. The accounting sector has experienced disturbances due to new technologies such as big data (Richins *et al.*, 2017). These changes have emerged from the external environment.

6.1 Skills in data analytics techniques and the use of statistical models

Being proficient in programming techniques is unnecessary because no one expects an accountant to program or code. However, in the annual technical reports, ICAEW (2019) stated that "[…] understanding the basic principles of programming is necessary, because in the Big Data era, the communication with data scientists and programming experts will become one of the most important responsibility of accountants[…]". According to the survey conducted by ACCA, the majority of over 2,000 professional accountants believe that there is a key gap of skills between their domain of knowledge, and digital science (Chua, 2016). Accountants are now required to possess data analytics capabilities – not necessarily coding skills, but a deeper understanding of statistical models, data mining and programming principles (ICAEW, 2019; Yusuf and Dagunduro, 2024). The environment pressures from professional organizations (e.g. ACCA and ICAEW) and also regulatory agencies shape accountants to enhance their proficiency in technology adoption such as big data (Awa *et al.*, 2016). The professional accounting bodies and the Big Four have been investing heavily in big data technologies and have expectations that the accountants are well acquainted with the big data (see Yusuf and Dagunduro, 2024). The professional accounting organizations shape accountants to embrace technology like big data through curriculum updates, continuing professional development programs, research initiatives and advocacy for the adoption of technology within the profession (International Federation of Accountants, 2019). From an organizational context, the ability of an organization to support continuous learning and professional development has become a key differentiator in enabling accountants to adapt to the new data-rich environment.

According to La Torre *et al.* (2018), big data represents a new intellectual capital asset, necessitating a renewed interest in IC accounting to understand its value determinants such as data quality, security and privacy. They argue that "Big Data's value lies in an organization's ability to transform enormous volumes and types of data into knowledge that is useful for business decisions" (La Torre *et al.*, 2018). This underscores the importance for accountants to adapt to using problem-driven methods to analyse larger datasets and build capabilities in analysing unstructured data. Therefore, the technological shift demands that accounting professionals become fluent in problem driven approaches and comfortable interpreting both structured and unstructured data.

Accounting professionals, especially auditors, are already familiar with the domain of data analysis. The essence of auditing is to collect and analyse structured evidence from the

audit target, assess its financial status, detect fraudulence and then issue an audit opinion on whether financial statements comply with applicable financial standards. However, the capabilities of accountants and auditors have significantly expanded in recent years:

> The advent of Big Data analytics has enabled accountants and auditors to extract insights from vast troves of data that were previously unimaginable. By harnessing sophisticated algorithms and machine learning techniques, professionals can now identify patterns, trends and anomalies in financial data with unparalleled speed and precision (Sun *et al.*, 2024).

By receiving additional training in unstructured data analysis techniques, accountants can effectively apply problem-driven methods that simultaneously analyse structured and unstructured datasets. Varma *et al.* (2021) emphasized that accountants should become comfortable with data analysis, particularly when unstructured data significantly influence decision-making processes.

Moreover, Sun *et al.* (2024) highlighted that:

> […] unlike traditional auditing methods constrained by the limitations of data scale and processing speed […] auditors now have the capacity to conduct comprehensive analyses across all available data. This shift towards an all-data audit approach significantly enhances the breadth and precision of audits, bringing to light subtle risks and problems that previously evaded detection.

Also, they argued that:

> […] in today's environment, auditors must adapt to the influx of diverse data sources, including social media information, online transaction records and Internet of Things data. These sources offer fresh perspectives and entry points for audit investigations (Sun *et al.*, 2024).

With their deep business domain knowledge, accountants are ideally positioned to monitor and control big data analytics functions within organizations. Accountants should gradually adapt to utilizing these comprehensive analytical approaches to manage larger, more diverse datasets.

Garanina *et al.* (2022) underscored the importance of acquiring these skills, highlighting that "[…] accounting necessitates new competencies in data analytics and an understanding of the implications of this technology on accounting practices". This illustrates technological context that includes useful technologies that are available internally and externally to accountants in firms (Tornatzky and Fleischer, 1990). In this case the big data are the useful technologies available to the accountants to tease out the structured and unstructured data and to derive important insights from the datasets. In alignment with this, PwC (2015) noted that:

> […] we believe demand will continue to exceed the supply of candidates who have an analytical mindset, technical skills and a foundation for leadership. So, while skills in data analytics will be desired, we believe broader business acumen, global awareness, relationship skills and leadership abilities will be just as coveted.

This further reinforces the profession's growing expectation that accountants integrate strong data analytics skills with broader professional capabilities to remain competitive in a big data-driven business environment.

6.2 Knowledge of the business

The valuable business acumen of accountants enables organization to achieve its long-term goals. The principle of data analysis states that the data analysis should be performed by someone who understands organization's business model well enough to make decisions about whether the given models are still feasible when the veracity and integrity of the underlying data cannot be trusted (Jones, 1991). Data scientists with exploratory analysis

skills can identify the hidden patterns and correlations in the databases, but compared to accounting professionals, due to their lack of understanding of the organization's business, their ability to recognize false correlations and spurious patterns is limited. Richins *et al.* (2017) indicated that:

> […] for accountants, their ability to understand business language and familiarity with the industrial operating model enables them to identify and interpret relevant data, to eliminate false patterns and to transform the results of Big Data analytics into implementable strategies […].

Moreover, data scientists may identify patterns, but accountants' business acumen enables them to recognize false correlations and make better strategic decisions (Theodorakopoulos *et al.*, 2024). The integration of big data insights into business decision-making requires a strong understanding of organizational goals and industry dynamics (Sun *et al.*, 2024). As PwC observes, "while skills in data analytics will be desired, we believe broader business acumen, global awareness, relationship skills and leadership abilities will be just as coveted. This broad base will equip students to not only solve challenges, but also to frame these issues in a broader context, so they can ask the right questions, the ones that lead to root causes and solutions" (PwC, 2015).

A report by Hays (2004) on Walmart shows the importance of understanding the business when applying big data analytics. Walmart applied big data analytics to discover a perfectly correlated pattern between the hurricane warnings and the sales of flashlights and strawberry flavour Pop-Tarts (a biscuit brand). Walmart planned sales based on this discovery, it has deployed strawberry flavour Pop-Tarts from other cities and even from other neighbouring states. However, Walmart found that before the hurricane, any brand or flavour of biscuits were sold out, regardless of whether it was strawberry flavour Pop-Tarts. The business logic behind this is so simple that there is almost no need to give any consideration, which is, the human instinct to survive in the face of disasters forces them buy large quantities of food that can be easily found and stored. The reason that big data analytics discovered that pattern was only in the hurricane season, the stock of strawberry flavour Pop-Tarts is more abundant than other brands. Walmart paid a quite amount of logistics cost and labour cost for the misuse of the result of big data analytics to make sales decision. If Walmart's managements could better understand the nature of the business, similar losses would not have occurred. From the above example, the big data analytics seem to be driven by technological factors than by organizational and environmental factors. This case illustrates dangers of over reliance on pattern recognition without business acumen from a technological context. The accounting sector is an example of an organizational field that has experienced disturbances due to new technologies (Richins *et al.*, 2017). From a technological context, big data tools are reshaping accountants' technical skillsets. However, it is essential for accountants to have analytical knowledge of the business rather than merely relying on big data for strategic decision-making:

> Big Data technology harnesses its formidable data processing and analysis prowess to distil valuable insights from vast datasets, furnishing more robust and holistic support for the formulation of accounting standards and systems. By mining and analysing external data such as market trends and industry benchmarks, we can more accurately assess pivotal indicators like asset valuation and enterprise risk profiles (Sun *et al.*, 2024).

The analytical knowledge is promoted by the accounting profession through its ongoing professional development programs and seminars. From an organizational context, the accounting profession encourages upskilling through ongoing professional development programs and ethics training.

6.3 Skills: control the risks from the emerging technologies, understand insights from big data analytics and communication

The use of internet-based technologies, including big data, will not only provide opportunities but also intensify the vulnerabilities and risks (Moll and Yigitbasioglu, 2019). Applying data analytics to accounting tasks can generate concerns about organizations maintaining data confidentiality and integrity, the effects of data analytics on data biases and whether data analytics will increase auditors' legal liability (Schneider *et al.*, 2015). Emerging technologies, such as big data analytics or automation, are extremely powerful, but using data in this way brings well-established risks, such as cyber-attack and data leakage (ICAEW, 2019). Research indicates that the ability to manage financial and technology-related risks is becoming a core competency for accountants, ensuring compliance with industry standards (Theodorakopoulos *et al.*, 2024). According to CPA Canada (2019), in 2017, 90% of the respondent firms suffered at least one cyber-attack, half of whose sensitive data have been stolen, and it costs a total 370 M Canadian dollars to recover the stolen data and restore the systems. In addition to manage and control the conventional risks rooting in internet- and computer-based technologies, such as cyber-attack risks and confidentiality disclosure risks, organizations must also consider the governance of risks of big data warehouse and big data analytics models. From a technological perspective, new risks such as cyber-attack and algorithmic bias have emerged.

Yusuf and Dagunduro (2024) noted that:

> Big Data analytics provides tools for identifying financial risks and bridging uncertainty through real-time data access, allowing for fact-based decisions, rather than relying on assumptions and guesswork about customers, employees and vendors.

This highlights the importance of accountants developing robust competencies in risk management to harness these opportunities responsibly:

> Through regular training and education initiatives, employees can acquire the skills to identify and address various information security risks, adhere to information security policies in their daily tasks and collaboratively fortify the enterprise's information security defences (Sun *et al.*, 2024).

Therefore, accountants could play an irreplaceable role in the management and control of risks relating the application of big data analytics, and they could also deeply participate in the governance of data and big data models. The management of e-money and virtual assets, and the governance of their risks are also the main responsibilities of accountants. The management of e-money and virtual assets are more driven by technological factors than by organizational and environmental factors.

Another hidden but more crucial risk is the violation of ethics when using big data analytics and other emerging technologies. Sun *et al.* (2024) highlighted that "moreover, the Big Data milieu has birthed a plethora of emergent issues, data ownership, usage rights, privacy protection, that remain inadequately addressed within the confines of traditional accounting norms". Corporates obtains privacy-related data and often use the data opaquely so that they can prevent their violations from being detected and punished (O'neil, 2016). When it comes to ethics, accounting professionals have always received the most stringent training and controls (ICAEW, 2019). In university, all accounting courses contain a considerable section on ethics; in the pre-employment training of organizations, the requirements of ethics are far more rigorous than other aspects; in accounting qualification examinations, ethics is the most tested domain (Ali and Güngörmüs, 2013).Therefore, with appropriate training, accounting professionals would be qualified to do the job of controlling the ethical risks of big data analytics which also has the support of the senior management.

This is an organization factor within the TOE framework. Organizational competence in risk neutral judgement and ethical reasoning is just as important as data infrastructure, which is often under emphasized in TOE studies.

Accountants need to master not only traditional accounting skills but also data-driven analysis and machine learning techniques. These institutionalized norms create a shift towards multidisciplinary competencies, where proficiency in accounting, data analytics, risk management and IT systems are now seen as equally important. The professional accountants need to develop multidisciplinary competencies due to the uncertainty in the external environment due to big data analytics.

Comparing with the skills in data analytics techniques introduced in Section 4, the competences of understanding the insights from big data analytics is also closely linked to the knowledge of business and the knowledge of accounting. Brown-Liburd *et al.* (2015) suggested that:

> […] in the context of Big Data analytics, accountants no longer need to spend time using software […] but instead, they need to focus on monitoring, assessing and evaluating the information extracted and obtained through Big Data analytics, and then make appropriate judgements to provide support for organizational decision-making[…].

The ability to derive meaningful insights from large datasets is critical for improving strategic decision-making, and accountants' understanding of business dynamics allows them to use big data in impactful ways (Theodorakopoulos *et al.*, 2024):

> Big Data may change their [financial accountants'] ability to understand the company assets, features and conditions and, therefore, support fair value accounting. For instance, multimedia records (i.e. videos) of each asset may provide a more accurate record of the asset (Moll and Yigitbasioglu, 2019).

If accountants cannot make appropriate estimation and judgments based on the results of big data analytics, then this new technology is meaningless for organizations. Therefore, for accounting professionals, the skills, and capabilities to understand what big data analytics tells, is crucial.

The comprehending of the information extracted from big data analytics means not only to use the insights to create value for organization, but also to be able to stay prudent and neutral to question the results. When organization has implemented new technologies, such as big data analytics, accountants, the guardian of the organization's last line of defence against risks, need to be more alert and vigilant, and must maintain a risk-neutral attitude. To control the risks from applying the new technologies and to create value, organizations need someone inside who can question and challenge the insights and suggestions provided by the new technologies. Professional accountants who have been trained with the skills and knowledge in risk control can play a critical role in this regard. Accountants should also stay alert to those who use big data analytics in a black-box fashion (Moll and Yigitbasioglu, 2019).

The increasing integration of big data tools in audit, taxation and financial reporting is forcing accountants to adopt by acquiring new technical competencies, including proficiency in data analytics software, statistical methods and data visualization. Theodorakopoulos *et al.* (2024) emphasized that:

> […] data visualization software is an essential tool for accounting professionals who need to make sense of large amounts of financial data. These software tools allow users to turn complex financial information into visual representations that are easy to understand and interpret. This makes it easier for accountants to identify patterns, trends and insights that may be hidden in the data.

This is in line with technological context of TOE which includes useful technologies that are available both internally and externally for accountants in firms to use (Torantzky and Fleischer, 1990). A firm's decision to apply an innovative technology is dependent on the technological context of the industry in which the firm operates. The technological pressures are rapidly reshaping the required skillset of accountants. The accountants need to upgrade their technological skills including risk analysis to be conversant with newer technologies.

Accountants are expected to collaborate with data scientists and IT professionals to ensure financial reporting accuracy and strategic alignment. The integration of big data and analytics enhances communication with stakeholders by providing real-time financial insights (Theodorakopoulos *et al.*, 2024). The skills to communicate with another human, that is, the social intelligent, will never be replaced by any program or automation (PWC, 2015). According to the ACCA (2016) survey, when 2,000 professional accountants were inquired what skills could never be replaced by automation, more than 57% of respondents chose the option of capability to communicate with others (including foreign language skills) (Chua, 2016). The verbal communication with the client's accountants, managements and even the board of directors is an indispensable part as audit evidence; accountants must build good relations with important stakeholders such as banks, auditors, tax departments and securities firms; accountants need to communicate with front-line manufacturing personnel on cost management and with departments throughout the organization on budget preparation and budget monitoring:

> […] Accountants could focus on improving their skills in accounting subdivisions that require human interaction the most, such as […] merger and acquisition accounting, and the capabilities to interact and communicate with others smoothly will never be replaced by machines and technologies[…] (Galarza, 2017).

Traditionally, communication skills and persuasive capabilities were already an important indicator to measure the competences of an accounting professional. It is well known that capabilities of listening and speaking foreign languages cannot be replaced by automations, simply because oral communication contains emotions and sentiments unique to human. With the rises of developing countries such as China, India and Brazil, the trend of multi-polarization of the world is inevitable. Therefore, the capability to communicate proficiently in one or more foreign languages of these "new power" will greatly increase the value of accounting professionals (PWC, 2018).

In the big data era, accountants must master the skills and techniques to communicate with data scientists, system experts and programming experts. Just the same as human languages, data and computer programs also have their own unique language system. To communicate more efficiently with data scientists and program experts, basic knowledge of data language is worth being mastered by accountants. In addition to direct communication with these experts, accounting professionals can also serve as a bridge between them and other functions of the organization. As Deloitte (2020b) observes:

> In the digital finance organization, finance professionals will be fluent in the languages of business, technology, and data science, acting as translators who bridge the gap between analytics teams and decision-makers.

The accounting profession is promoting the communication skills which illustrates environmental context of TOE. External support from the accounting profession is essential in terms of improving communication skills of accountants, data scientists and the clients. We expand the environment dimension by showing that cross-cultural communication and global ethics influence accounting practice.

Environmental factors lead to a shift in accountants' skill sets, moving from traditional tasks to more complex data analysis and decision-making roles. This may also entail good communication skills with clients. The technological factor emerging from digital technology warrants a greater communication between the accountants and other specialized groups such as data scientists. This will help them understand information better and make appropriate financial decisions for the firm.

6.4 Proficient skills and knowledge in accounting profession

The integration of big data into accounting requires accountants to enhance their skill sets beyond traditional financial reporting. Yusuf and Dagunduro (2024) emphasized that:

> […] the integration of Big Data into accounting systems has also redefined the role of accountants. No longer limited to traditional bookkeeping and financial reporting tasks, accountants are now expected to leverage data analytics to provide strategic insights, predict future trends, and improve operational efficiency.

Accounting professionals should not only be proficient in financial accounting but also in digital technologies that enhance decision-making (Sun *et al.*, 2024). Accountants who are more familiar with financial information and an organization's structure have a strategic advantage in interpreting big data analytics results (Yusuf and Dagunduro, 2024). From a technological context, the integration of big data into accounting practice has reshaped the technological skill requirement for accountants. Let us start with an example. A company used big data analytics to extract sales information, such as the fluctuation of the sales price of competitors' products, on social media platforms. The extracted data showed that its major competitors in the same industry are increasing revenue at the expense of decreasing gross profit. After the company's accountants interpreted the analysed results, they found that these major competitors follow the product differentiation strategy and therefore have higher profit margins. For these competitors, it is completely reasonable to sacrifice gross profit margin to increase sales. However, as far as the company is concerned, its net profit is relatively low due to its cost-leading strategy. If the company follow the strategy of reducing selling price, the gross profit margin might drop to a lower level so that the company may not be able to continue its operations. The accountant combines his/her professional knowledge with the company's strategy and gives the company a suggestion that instead of lowering the selling prices of its products, it should increase research and development expenditures. This is an example of environmental factors that shape operational effectiveness through strategic positioning related to market forces and competitive pressures (Awa *et al.*, 2016).

Warren *et al.* (2015) highlighted that "the forms of Big Data (i.e. video, images, audio and text) complement traditional financial information and can provide improved transparency and usefulness for decision-making". This underscores the need for accountants to embrace new data types and integrate them effectively into financial reporting and decision-making processes.

The ACCA report states that:

> […] it is inevitable that the work of preparing financial statements will be replaced by automation, but truly understanding financial statements and appreciating the insights behind those figures will never be done by machines[…](Chua, 2016).

La Torre *et al.* (2018) argued that data visualization and user interaction are crucial for leveraging big data's value. They stated, "To unlock Big Data's value, measuring knowledge from data analytics requires an approach that privileges narratives over numbers" (La Torre *et al.*, 2018). This highlights the need for accountants to not only understand the technical

aspects of big data but also to effectively communicate and interpret these insights within a business context. Varma *et al.* (2021) emphasized that big data must support decision-making activities and be integrated into accounting information systems to enable continuous monitoring and control.

Theodorakopoulos *et al.* (2024) emphasized the transformative impact on auditing by stating that:

> […] traditional auditing methods involve manually reviewing a small sample of financial transactions to identify errors or discrepancies. However, with the help of Big Data analytics tools, auditors can now analyse entire datasets in real-time, making it easier to identify potential issues and irregularities.

If the organizations want to unlock the full potential of big data analytics in a business context, it is not enough to rely solely on computer scientists and data scientists. Accountants can use their deep understanding of business operation to identify insights related to organization's key competitive factors from the information extracted from big data analytics, and then to design appropriate financial metrics to measure and deliver these factors throughout the organization effectively (Richins *et al.*, 2017). Accountants who are more familiar with financial information and the organization's system and structure have a strategic advantage over other experts in reading the results from big data analytics (Kaplan, 2006). From an organization context, strategic positioning of accountants within decision-making is growing:

> Finance leaders are expanding their teams' capabilities to go beyond traditional reporting, developing advanced analytical skills, business acumen and technology fluency to deliver deeper insights and influence strategic decision-making (KPMG, 2023).

Although the future of big data analytics looks particularly bright and shining, accountants must not get lost in way of only perusing skills or knowledge in digital technologies. The advice given by (PWC, 2015) is that an accountant must be really proficient in the core skills, including financial accounting, managerial accounting, taxation and financial reporting systems, to use these core skills as a base to expand to more knowledge domain. Comparing with being a data scientist or model expert, accounting professional who can proficiently apply data techniques seems more realistic and cost feasible. This is an example of a change that is more driven by technological factors than by organizational and environmental factors.

The external pressures, particularly from accounting professions such as ACCA and Big Four are rapidly reshaping the required skill set for accountants. The expectations from the accounting profession and Big Four are for future accountants to develop digital competencies in their work alongside their traditional core skills of financial accounting, managerial accounting, taxation, auditing and financial reporting systems (Chua, 2016).

6.5 Skills to test the quality, veracity and integrity of data

Jones (1991) puts forward an important principle of analysing data, that is, the accuracy of the underlying data determines the accuracy of the analysis results:

> Data has always been the main limitation of accounting information systems, as the breach and leakage can result in extensive loss in both profit and reputation, especially for those that require estimations or apply prediction models, such as depreciation, risk assessment and budgeting (Yusuf and Dagunduro, 2024).

"[…] Ensuring the quality of data is particularly important for the accounting profession, because data quality assurance is at the core of financial reporting, internal control and management reporting […]" (Rikhardsson and Yigitbasioglu, 2018).

In the past few decades, accountants have often encountered challenges in running the management information system efficiently due to inaccurate, inconsistent, duplicated or outdated data. The operating logic of big data's analytics is to automatically collect and analyse "raw" data, and the use of "raw" data in reports means that data quality issues are becoming important, especially for those who are responsible for managing the quality of reports (Rikhardsson and Yigitbasioglu, 2018). In the big data age, collecting data from new data sources, such as social media platforms, will exacerbate the problems of data quality because data from these new data sources are more often to be inaccurate, inconsistent, duplicated or outdated (ICAEW, 2019). A research by Nagle *et al.* (2017) shows that only 3% of organizations' data qualify as standard data; on average, there is at least one crucial error for almost half of new created data. At this rate, millions of bad data will be created and stored every day (CPA Canada, 2019). Data quality, data veracity and data integrity are critical for implementing big data analytics, but as the data volume increases significantly, the complexity of training data increases (Chae *et al.*, 2014). The market analysis and predictions generated with data with poor quality will have significant adverse effects on the organization. These adverse effects may directly affect the profit of the organization, or indirectly affect the organization's market position, organizational operational efficiency and organizational culture (Haug and Stentoft Arlbjørn, 2011):

> The sheer volume and complexity of the data can make it difficult to analyse, and there are concerns about data privacy and security. As financial data becomes more valuable, the risk of cyber-attacks and data breaches also increases, making it essential for businesses to implement robust data security measures (Theodorakopoulos *et al.*, 2024).

Sun *et al.* (2024) highlighted that:

> […] employing data encryption technology emerges as a pivotal strategy […] Furthermore, access control technology emerges as a linchpin in ensuring data integrity. By delineating distinct access privileges for disparate users and rigorously constraining the handling and interaction with sensitive data, it serves as a bulwark against internal malfeasance and external encroachments.

Consistent with this, EY (2024) emphasized that:

> […] establishing rigorous data quality frameworks, including validation, cleansing and enrichment processes, is essential to ensure that the data feeding analytics systems is accurate, complete and trustworthy. Without these measures, insights generated can be misleading, potentially leading to poor business decisions and compliance risks.

The knowledge structure and moral constraints of accountants mean that they are a natural treasure of the organization who can help to run the big data analytics effectively. The prudence and scepticism of accountants allow accounting professionals to shoulder the responsibility of big data guardianship throughout the organization. The main responsibility of auditors has long been to provide assurance services, and therefore it is not difficult for auditors to testify the accuracy of the data. With fundamental training in data science, auditors can provide assurances for the authenticity of data. To filter and label interferential data and outliers to conduct model training to enhance the capabilities of big data analytics, the demand for auditors with basic knowledge of data science might upsurge.

The technological context of big data are leading to proficiency shifts where accountants are expected to operate not just as financial professionals, but as data analysts and technology users (Guthrie and Parker, 2016). These pressures push accountants to develop proficiency in

new technologies, including big data tool, data analysis and machine learning techniques, which was not traditionally part of the accounting profession (Schiavi *et al.*, 2024). This is part of extended role faced by the accounting profession as a result of big data technology in the external environment. In terms of organizational context, top management support is also essential where the upper-level management provides encouragement in implementing big data by providing, investing and planning a variety of courses for the company accountants (Hashim *et al.*, 2022). The next section brings the narrative together and discusses the findings.

7. Discussion

Our study highlights skills necessary for accountants to thrive in a big data-driven era, emphasizing the shift from traditional accounting functions to roles that integrate advanced data capabilities and strategic insights. As big data analytics reshapes organizational decision-making, accountants need more than foundational accounting skills. They must be equipped to interpret and apply complex data insights, transitioning from routine compliance roles to contributors of strategic value. This shift requires competencies in data analytics, business acumen, risk management and ethical judgement. Big data is an example of a change in external environment (Hinings *et al.*, 2018).

Table 4 below provides TOE factors that influence big data.

From the above table, we can see that all the factors which entail TOE were at play in the study. The TOE framework helps clarify that accountants' future competencies depend on their multidimensional readiness where TOE components converge. The technological enablers (e.g. analytical tools), organizational capabilities (e.g. training and support) and environmental pressures (e.g. professional expectations) are interdependent. Our study shows the technological context were greater at play then the organization and environment context. From a technological context, data analytics, a crucial skill in this new landscape, empowers accountants to identify patterns in vast datasets, facilitating more informed business decisions (ICAEW, 2019). However, their role extends beyond interpreting data;

Table 4. TOE Approach

TOE	Sub-dimension	Findings
Technology context	Relative advantage	Any opportunities, advantage, prospects for the organization in the current landscape that benefits from big data implementation
	Security and privacy	Emphasises the aspect of security and privacy of company data when adopting big data
Organization context	Skills	The ability of organization to have specific expertise employees to handle big data activities
	Top management support	Upper-level management in the organization structure gives encouragement in implementing big data by providing, investing and planning strategic directions for the company
Environment context	Competitive pressure	This indicates the situation of the surrounding entities of the organization such as suppliers and competitors who already get benefit from the big data activities
	Professional accounting body	Professional accounting organizations encourage good communication skill between accountants, data scientists and clients

Source(s): Authors' own work

accountants must discern the insights from analytics and translate them into actionable recommendations. This demands both technical know-how and an in-depth understanding of organizational goals and industry trends, enabling them to contextualize data-driven insights within a broader business framework (Richins *et al.*, 2017). Our findings emphasize that accountants who can bridge data analysis with business strategy contribute uniquely to organizational value creation, positioning themselves as indispensable in strategy formulation.

Risk management and data governance also emerge as critical areas, as accountants increasingly oversee ethical and regulatory issues linked to big data usage (Moll and Yigitbasioglu, 2019). Given the sensitivity of financial data and privacy concerns, accountants are naturally positioned to champion data governance protocols, leveraging their experience in compliance. Certifications like certified information systems auditor or certified in risk and information systems control can further solidify their capacity to navigate data risks effectively, thereby enhancing organizational trust in data-driven operations. Certifications enable accountants to gain legitimacy. Our novel findings from technological context shows accountants as business-data translators and can help identify misuse of big data generated patterns (e.g. the Walmart case in the findings section).

From the organizational context, communication and collaboration are equally vital in this environment. Accountants must act as intermediaries between technical teams and business leaders, translating complex data outputs into strategic insights that align with organizational goals (Brown-Liburd *et al.*, 2015). This requires not only technical language proficiency but also the ability to present insights in accessible terms to non-technical stakeholders, enhancing cross-departmental collaboration and decision-making efficacy. The upper-level management in the organization supports Big Data by providing investing and planning strategic directions for the company (Yusuf and Dagunduro, 2024). Our findings emphasize on ethics here which encompasses integration of ethics training into analytical skill-building.

From an environmental context, our finding distinguishes from prior literature by bringing in role of global professional bodies in shaping competencies of accountants. We also see a rise of cross-border communication and language skills amongst accountants. Ultimately, our study underscores that the future-proof accountant is one who continuously adapts, engaging in ongoing professional development to build competencies in data analysis, strategic insight and ethical governance. Those who embrace these evolving roles will find new relevance and value in the big data era, while those resistant to change may face obsolescence as routine tasks become increasingly automated (Frey and Osborne, 2017). Our findings provide a framework for the accounting profession to foster a resilient, future-ready workforce by developing these critical competencies.

We are making contributions to the study by identifying new skill sets for accountants in big data era. These skills entail skills in data analytics, techniques and the use of statistical models, skills to control risks from emerging technologies, skills to understand insights from big data analysis and skills to test the quality, veracity and integrity of data. We used a hybrid of TOE and ACCA's framework to inform our study on the competencies needed by accountants in the big data age. The key contributions are TOE is not only used to explain inertia and stability, but they can be used to explain change as well. The change here entailed the competencies future accountants need to have in the big data stage.

8. Future research

8.1 Education and continuing education

From the environment context in the big data era, new challenges have been brought to the entire accounting profession, including accounting schools and accounting professors. With the continuous development of big data analytics in accounting profession, the appeal that

accounting students should learn about big data analytics before being employed has become urgent. How to effectively integrate a certain level of knowledge of the emerging technologies into the continuing education courses of accounting practitioners is also an urgent challenge. Accounting schools and accounting scholars should strive to integrate topics related to emerging technologies into accounting courses so that students would acquire a certain level of knowledge before being hampered by these emerging technologies in the workplace (Goh *et al.*, 2019). PWC (2015) suggested that to make students competitive in the future auditing and taxation, accounting schools should open more data analysis courses so that their students can learn how to become data scientists. Therefore, it is important to explore how to integrate the knowledge of the emerging technology into accounting courses so that it is more understandable for accounting students and accounting professionals. Such studies on how to reform the accounting curriculum are urgently needed by the accounting profession, but at the moment, the relevant research is rare.

8.2 Data ownership and confidentiality

The ownership and availability of data are considered as the biggest challenges of using big data analytics, and this raise concerns linked to the invasion of privacy. The urgent demand for data will make the secondary market of consumer data more profitable than the original transaction that generated the data. This disruptive demand for data can lead to unethical business activities (Martin, 2015). The misuse of private data has caused concerns and triggered the need for business regulation. For the sustainable development of big data analytics, strict data policies and supervision systems are necessary (Huerta and Jensen, 2017). A key area of further research will be to explore how to assist legislators to regulate the use of big data by accountants, auditors and consulting firms.

9. Conclusion

This paper examines how big data can be applied in accounting and identifies the competencies future accountants at organizational level need to possess to remain competitive. For accounting professionals, a comprehensive understanding of accounting-related knowledge is the foundation of everything (Noah, 2019). Only by proficiently mastering the knowledge and techniques in accounting can the accounting professionals extend their capabilities and expand their domain to the other seven competences. The capabilities and skills to interpret the outputs produced by big data analytics is important for accounting profession. More often, answers cannot be directly obtained through the assistance of big data. Knowing what big data analytics is capable of is crucial. It is challenging to solve an undiscovered problem, so accountants must have a good understanding of the business and could locate and define business problems to use big data analytics to make support for organization's decision-making. To be able to use the language of data to communicate with data scientists and programming experts, and to convert the messages to be understandable for other functions of the organization should be assumed by accounting professionals. Accounting professionals might not need to know how to program an algorithm, but they must have a basic understanding of the source of data, the logics of the programming and the inherent biases of using big data analytics. More importantly, accountants must be very proficient in discovering the most suitable decisions can be made based on the outputs of big data analytics. In the big data era, big data will be regarded as a core asset that can create great value for the organizations. The capabilities to govern this asset and to manage the risks related to this asset should be the area accounting professionals need to improve.

The nature of the accounting work will undergo fundamental changes (Appelbaum *et al.*, 2017). The way how accountants work will change from making decisions by humans alone in the past to making decisions in collaboration with machines in the big data age. The

unique traits belonging to humans, such as communication, creativity, persuasiveness and innovation, become more valuable. Compared with data scientists or system experts, accountant's expertise, especially in strategic planning, risk control, process governance and business analysis, enable them to understand the insights of big data analytics to provide timely solutions to the operational problems and to provide continuous support for the decision-making. Accountants are considered as the best candidates who can support the work of data scientists in the exploratory analysis of both structured and unstructured data. In the big data age, the responsibilities of accountants are growing rather than diminishing. The digital transformation in accounting profession is inevitable: accounting professionals, who proactively embrace changes and gain new knowledge, will be able to provide value-added insights in all spheres of the business ecosystem, always stay at the forefront of emerging technologies, and become the most needed by organizations; those who are reluctant to embrace changes will be left behind, and find out that their skills and knowledge are redundant. TOE factors are at play with the accounting profession pushing for new competencies that accountants need to embrace in the big data age. Technological factors of security and privacy, organizational factors of top management support and environmental factors of competitive pressure and professional accounting body were obvious from the findings in our study. We contribute to the study by using a hybrid of TOE and ACCA's framework. TOE framework is one of those approaches that recognize the importance of the context in which big data are embedded and helps to identify new competencies of future accountants to remain competitive. Big data is an institution, a new environment under which accountants have to function in. Through the TOE framework, we uncover organizational and environmental factors shaping big data integration in accounting. In contrast to technology centric narrative, our findings show that business acumen and cross-disciplinary communication rooted in accounting practices are critical enablers of value creation. We refine TOE by emphasizing that successful big data adoption requires more than technical readiness – it demands organizational wisdom and external support structures that are uniquely provided by the accounting professionals.

This is one of the few papers that seek to explore the competencies required by accounting professionals at the organizational level in the big data era using the ACCA's research of accountants' PQ and TOE framework. We seek to contribute to the literature on accounting professionals' competencies in the big data era. Our findings will help accounting professionals to understand the future of work. They will be able to acquire new skills and knowledge in related areas and remain competitive in the big data era.

The paper is limited to selection of literature from 2015 to 2024. Future research could expand on the literature search. It may be also possible to have future research integrating the knowledge of the emerging technology into accounting curriculum so that it is appreciated by accounting students and accounting professionals. Such studies on how to reform the accounting curriculum are urgently needed by the accounting profession.

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Further reading

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Appendix

Table A1. Analysis of content analysis of articles

Authors	Type of documentation	Sub-field	Skills and knowledge in accounting profession	Skills to test the quality, veracity, and integrity of data	Skills to understand the insights from big data analytics	Skills to control the risk from the emerging technologies	Skills to communicate with others	Skills in data analytic techniques and the use of statistical models	Knowledge of the business
Moll and Yigitbasioglu (2019)	Scholar paper	FA	5	1	3	1	1	3	0
Warren *et al.* (2015)	Scholar paper	FA	1	0	2	0	0	1	1
Appelbaum *et al.* (2017)	Scholar paper	MA	3	1	0	2	0	0	1
Brown-Liburd *et al.* (2015)	Scholar paper	AD	2	3	2	1	1	2	3
Richins *et al.* (2017)	Scholar paper	GA	8	2	2	1	2	7	4
Hampton and Stratopoulos (2015)	Scholar paper	FA	4	0	0	3	0	1	1
Goh *et al.* (2019)	Scholar paper	GA	0	3	1	2	0	2	2
Borthick and Pennington (2017)	Scholar paper	AD	0	1	1	0	0	1	0
Earley (2015)	Scholar paper	AD	2	1	2	0	0	2	2
Arnaboldi *et al.* (2017)	Scholar paper	GA	0	2	1	1	1	1	0
Möller *et al.* (2020)	Scholar paper	MA	1	0	1	0	0	2	0
Rikhardsson and Yigitbasioglu (2018)	Scholar paper	MA	0	2	1	2	1	1	5
Lowe *et al.* (2017)	Scholar paper	AD	0	0	0	0	1	1	0
Quattrone (2016)	Scholar paper	MA	0	0	1	0	1	0	1
Rose *et al.* (2017)	Scholar paper	AD	0	1	0	0	0	0	3
Huerta and Jensen (2017)	Scholar paper	GA	1	2	1	5	1	3	4
Gunz and Thorne (2020)	Scholar paper	Ethics	0	0	0	5	0	0	0
Al-Htaybat *et al.* (2019)	Scholar paper	Governance	0	0	0	1	0	1	0

(*continued*)

Table A1. Continued

Authors	Type of documentation	Sub-field	Skills and knowledge in accounting profession	Skills to test the quality, veracity, and integrity of data	Skills to understand the insights from big data analytics	Skills to control the risk from the emerging technologies	Skills to communicate with others	Skills in data analytic techniques and the use of statistical models	Knowledge of the business
Cao *et al.* (2015)	Scholar paper	AD	0	0	0	1	0	1	0
Al-Htaybat and von Alberti-Alhtaybat (2017)	Scholar paper	GA	1	0	2	1	1	2	1
Han *et al.* (2023)	Scholar paper	GA	1	2	1	2	1	1	1
La Torre *et al.* (2018)	Scholar paper	FA	2	2	2	1	2	2	2
Varma *et al.* (2021)	Scholar paper	GA	2	0	0	1	0	0	1
Spanò *et al.* (2022)	Scholar paper	GA	1	0	1	2	1	0	0
Garanina *et al.* (2022)	Scholar paper	GA	0	2	2	2	0	2	0
Sun *et al.* (2024)	Scholar paper	AD	1	1	1	1	0	0	0
Yusuf and Dagunduro (2024)	Scholar paper	GA	1	1	1	0	0	1	0
Theodorakopoulos *et al.* (2024)	Scholar paper	GA	0	0	1	0	0	1	0
PWC (2018)	Publication of big four	GA	0	1	0	2	2	0	0
PWC (2015)	Publication of big four	GA	2	2	2	2	1	5	3
Deloitte (2020a)	Publication of big four	GA	0	4	3	1	4	2	0
Deloitte (2020b)	Publication of big four	GA	0	0	0	1	0	1	0
KPMG (2019)	Publication of big four	GA	2	1	5	4	3	2	6
KPMG (2023)	Publication of big four	GA	1	1	1	0	0	0	0
EY (2024)	Publication of big four	GA	0	1	2	1	0	0	0
ACCA (2016)	Accounting association report	GA	5	2	3	2	5	2	3

(*continued*)

Table A1. Continued

Authors	Type of documentation	Sub-field	Skills and knowledge in accounting profession	Skills to test the quality, veracity, and integrity of data	Skills to understand the insights from big data analytics	Skills to control the risk from the emerging technologies	Skills to communicate with others	Skills in data analytic techniques and the use of statistical models	Knowledge of the business
ICAEW (2019)	Accounting association report	GA	2	2	3	2	1	3	2
ICAEW (2018)	Accounting association report	GA	1	2	1	0	1	4	2
CACPA (2019)	Accounting association report	GA	3	3	4	4	1	2	1
IMA (2020)	Accounting association report	FA	0	2	0	0	0	1	1
CIMA (2016)	Accounting association report	MA	0	0	0	0	4	3	1
Sum of counts			50	45	50	53	36	61	51

Source(s): Authors' own work