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Management education in the age of information overload

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Abstract

Purpose – The purpose of this paper is to advocate for the integration of quantitative reasoning into management education and leadership development literature. The authors argue that the increasing complexity of managerial decision contexts, particularly in the age of information overload, demands that leaders possess the ability to critically analyze and interpret quantitative information.

Design/methodology/approach – This viewpoint paper uses narrative argument to explore the concept of quantitative reasoning and its relevance to management education. The authors draw on research from mathematics education, psychology and management to support their argument. They also use real-world examples, such as the COVID-19 pandemic, to illustrate the importance of quantitative reasoning in contemporary leadership.

Findings – This paper argues that quantitative reasoning is a critical skill for organizational leaders. It highlights the limitations of traditional management education in preparing leaders to effectively navigate data-rich environments. The authors contend that incorporating quantitative reasoning into leadership development programs can improve decision-making effectiveness.

Originality/value – This paper offers a novel perspective on leadership development by emphasizing the significance of quantitative reasoning, a concept borrowed from the field of mathematics education, to close a gap in current management education practices.

Keywords Management education, Leadership development, Decision-making, VUCA, Quantitative reasoning

Paper type Viewpoint

Errors in decision-making for organizational leaders often hold extreme consequences. Crises have provided poignant examples that leaders make decision errors when they are

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unable to integrate and make sense of information, such as during the Cuban missile crisis, Hurricane Katrina and the more recent COVID-19 pandemic (Finkelstein, Whitehead, & Campbell, 2009; Schippers & Rus, 2021). Such errors often expose shortcomings in how leaders understand, interpret and critique quantitative information in decision-making processes (Okoli, Arroteia, & Ogunsade, 2023). Today, organizational leaders face increasingly dynamic decision contexts, such that integrating and making sense of myriad sources of quantitative information is becoming an essential leadership skill (Karaali, 2023). Yet, management education programs are not adequately developing the quantitative capabilities leaders need to operate within current decision contexts (McClure & Sircar, 2010).

This paper introduces quantitative reasoning to the management education and leadership development literature and calls for its study by management scholars. Our call to action mirrors a previous call to action in management education – the increased focus on ethical reasoning in management education – precipitated by the fall of Enron in 2001 (cf., Gini, 2004). The collapse of the energy trading giant brought to light a gap in manager preparation, particularly as provided in collegiate schools of business, leading to calls for sweeping curriculum changes over the following years by scholars (Beggs & Dean, 2007) and through a white paper from the Association to Advance Collegiate Schools of Business (Phillips, 2004).

We offer here that the COVID-19 pandemic was the exogenous shock that has illuminated an enduring gap in manager preparation related to quantitative reasoning in decision-making. To close the gap, this viewpoint paper aims to convince management education scholars that quantitative reasoning, a concept borrowed from the field of mathematics education, is necessary for managers who need to make sound decisions, as well as to promote its study within the skills-based approach to leadership development.

Describing the gap in management education

We define quantitative reasoning as a higher-order competence in the use of quantitative information (i.e. data, math, statistics or logic) within the context of practical situations (Karaali, Villafane Hernandez, & Taylor, 2016). In plain language, it means critical thinking when numbers are involved. It is important to distinguish between quantitative reasoning and quantitative skills. In contemporary management education there is a strong emphasis on quantitative skills, which might be subdivided into basic numeracy skills and context-specific or applied quantitative skills.

Management educators generally agree that basic numeracy skills are essential and business schools ubiquitously include training of these skills in their curriculum through general mathematics, business mathematics and statistics courses. Examples might include algebra and statistics. In these courses, students learn basic mathematics principles and practice applying them by solving problems. Quantitative reasoning is not a measure of overall skill in the use of basic mathematics, but rather competence in understanding, interpreting and using quantitative information to make sound decisions.

Business schools also provide a wide variety of context-specific mathematical training, often referred to as applied mathematics. It is essential that managers possess context-specific quantitative skills, such that context is inseparable from skill in the application of mathematics to organizational management. As such, much of the applied mathematics taught in business schools is linked to context. For example, interpreting a bell curve is applicable across multiple disciplines, though the way students employ that skill depends on the discipline of the course. In a finance course, the bell curve is a fundamental concept when understanding risk, performance and investment analysis, whereas in a management or

marketing course, students may apply it to concepts like employment discrimination or salary distribution (Daniels, Appenzeller Knowles, Lindner, & Naasz, 2024).

In organizations, accountants, engineers and scientists all use distinct context-specific mathematical tools and their early-career success generally depends on their level of skill in applying these tools to solve problems (Fisher, 2019). Hence, expertise in applied mathematics is often a catalyst to leadership roles. For example, senior leaders in oil and gas companies are likely to have formative training and experience in the context-specific mathematical tools of engineering, whereas those in banking companies are likely to have expertise in the tools of finance. Quantitative reasoning is not expertise in context-specific mathematical skills, such as engineering, computer science or finance. Instead, as a higher-order competence, quantitative reasoning might enable organizational leaders to understand, interpret and integrate multidisciplinary quantitative information into their decision processes as they ascend into more generalized leadership roles.

Much of undergraduate and graduate management education focuses on building mathematics skills; teaching students to leverage tools and techniques to solve problems using numbers. McClure & Sircar (2010) previously noted that management education programs were failing to meet the needs of students, employers and society, but focused on updating the quantitative skills being taught in business schools to match contemporary business environments. Mathematics education scholars have suggested that solely focusing on skills-based approaches falls short of preparing students and that educators should increase focus on critical thinking and metacognition (Su, Ricci, & Mnatsakanian, 2016), both key leadership skills (Mumford, Todd, Higgs, & McIntosh, 2017). Here, we expand these arguments to suggest that focusing on quantitative skills falls short of the revolutionary change that has occurred in business environments, coined as the *Fourth Industrial Revolution* (Schwab, 2016).

We therefore argue that thinking critically about quantitative information is undervalued in management education, where the focus is instead on training students in market-ready skills in finance, accounting and statistics, among others. Indeed, many readers of this article can likely point to numerous examples of courses where students are given numbers-based problems and asked to find mathematical solutions. However, it is likely more difficult to find examples in your curriculum where students receive multiple sources of quantitative information and are asked to make a managerial decision. Organizational leaders now often face the challenge of staring down complex quantitative information when making decisions. Leaders must be equipped to synthesize data, ask appropriate questions, challenge assumptions and use conclusions drawn from data to support decision-making in dynamic environments. Evidence suggests that management education and leadership development programs are falling short in equipping them to do so.

Why this gap matters

"That's why you get paid the big bucks" is a phrase often directed at organizational leaders facing tough decisions. Certainly, decision-making is an essential function of leadership (Tichy & Bennis, 2007; Vroom & Yetton, 1973) and the decisions of organizational leaders create broad-reaching effects that transform individuals, organizations and society as a whole (Schneider, 2002). Accordingly, how leaders make decisions and methods for developing the decision-making capacity of leaders are of interest to scholars and teachers of management (Kahneman, 2011; Walumbwa, Maidique, & Atamanik, 2014). Managerial decision-making has been studied from diverse perspectives such as rationality (Miska, Hilbe, & Mayer, 2014), intuition (Samba, Williams, & Fuller, 2019), empathy (Holt & Marques, 2011), affect (George, 2000) and ethics (Craft, 2013). These scholarly descriptions move into practice

through management education and leadership development programs where the focus is on growing the capability of individual leaders and building organizational capacity to recognize and solve challenges (Day, 2000; Day, Fleenor, Atwater, Sturm, & McKee, 2014; Dixon, 1993; Mumford, Friedrich, Caughron, & Byrne, 2007). In the leadership development field, decision-making is considered an essential skill that must be developed in individual leaders (Schoemaker, Krupp, & Howland, 2013). Management educators, therefore, have designed programs to train current and future leaders in the skills and competencies required to make effective decisions by drawing from the literature on leader decision-making.

Of late, much attention has been paid to the contexts in which organizational leaders make decisions (Mumford et al., 2007; Wu, Shao, Newman, & Schwarz, 2021). Specifically, scholars have been interested in the increasingly dynamic nature of organizational environments resulting from the Fourth Industrial Revolution (Schwab, 2016). This increased dynamism is often characterized by the acronym VUCA: volatile, uncertain, complex and ambiguous (Mack & Khare, 2016). Organizational leaders frequently operate in VUCA decision contexts and must be prepared to make effective decisions under these challenging conditions (Caughron, Ristow, & Antes, 2019; Lawrence, 2013). A common organizational response to VUCA environments is the systematic collection and analysis of massive amounts of data, which has been enabled by advanced technologies, hyperconnectivity and artificial intelligence (Elkington, 2018; Walumbwa et al., 2014). The collection, processing and ready availability of data to organizational decision-makers has led some management scholars to describe the current era as the *information age* (Roetzel, 2019), whereas others have more playfully called it the *age of information overload* (Levitin, 2014).

To combat information overload and enable leader decision-making, organizations use a wide assortment of experts in the analysis of data, with job titles such as business analyst, data scientist, management analyst, operations researcher and statistician, who primarily serve to transform large quantities of data into digestible quantitative information in support of leader decision-making. The U.S. Bureau of Labor Statistics (2025) forecasts that four of the 10 fastest growing occupations (e.g. data scientists at 36% and operations research analysts at 23%) in the USA from 2023 to 2033 involve analyzing organizational data to enable leader decisions. As a result, organizations have rapidly adopted terms like *data-driven decision-making* to describe a systematic approach to leveraging big data and artificial intelligence as drivers of business operations and managerial decision-making processes (Brynjolfsson & McElheran, 2016). Without a doubt, there is a shift in the environment where organizational leaders make their decisions. Not surprisingly, organizational leaders have differing levels of comfort with the numerous sources of quantitative information they rely on to make decisions. Their comfortableness likely affects how they respond to data experts when presented with quantitative information.

We have observed two predominant responses by organizational leaders who are uncomfortable with or overwhelmed by the quantitative information presented in a dynamic decision-making context. First, the leader may disregard quantitative information (e.g. recommendation generated by an analyst, artificial intelligence decision aid or subject-matter expert) as a coping mechanism to reduce the demands of the decision situation (Carillo, 2017). Decades of research on bounded rationality suggests that these leaders will likely overemphasize the value of experience and intuition as justification for resistance to information they cannot fully integrate into their decision schema (Simon, 1991). Second, the leader may accept quantitative information without adequately questioning analytical assumptions, methodology or rigor. Effectively, this is an error in their unwillingness or inability to adequately process the information (Eubanks & Mumford, 2010). In this

credulous response, the leader undervalues their own experience and intuition, as well as other competing sources of information, and defers the decision to a recommendation based primarily on quantitative information (Mosier & Skitka, 1996). In both cases, the delicate balance of intuitive and analytical information is disturbed, resulting in suboptimal decision-making processes (Orlandi & Pierce, 2020).

Both options, disregarding without cause and blindly accepting without critical scrutiny, serve as a form of *saving face*. The uncomfortable, overwhelmed or unconfident leader refuses to admit that they did not understand the information presented, nor to pursue greater clarity by questioning the source of the quantitative information (e.g. a business analyst). Often, this occurs because the leader is ill-equipped to conceptualize meaningful questions and views the public display of their shortcomings as too risky to the image they are trying to project (Bolino, Kacmar, Turnley, & Gilstrap, 2008). This all-too-frequent response to quantitative information is more concerning because contemporary business environments increase demands on leader decision-making and the magnitude of effects that result from those decisions, including errors (Eubanks & Mumford, 2010; Lawrence, 2013).

We argue, therefore, that the skills and competencies previously linked to effective leader decision-making may be incomplete for designing effective management education programs in the information age. Given the extensive systematic integration of data analytics into organizational operations, we propose that emphasizing quantitative reasoning is a needed addition to contemporary management education and leadership development programs. The capacity to think critically about quantitative information or quantitative reasoning, would improve organizational leaders' comfort in asking meaningful questions, challenging assumptions and integrating unfamiliar quantitative information into their decision schemas. Increasing scholarly and practitioner attention to integrating quantitative reasoning throughout leadership development processes will enable leaders to incorporate quantitative information in their decision-making processes more effectively, leading to better decisions and improved results for organizations.

Anecdotal evidence on quantitative reasoning deficits

Mathematics education scholars have argued that individuals must engage in quantitative reasoning to make effective decisions as citizens, students and employees in a data-driven world (Harrison, 2021). Here, we extend that argument to suggest that quantitative reasoning plays an integral, yet underemphasized and undertrained, role in managerial decision-making processes, particularly when the context is rich with quantitative information as it typically is in contemporary VUCA environments. Evidence suggests that individuals assumed to be highly numerate (e.g. medical doctors) may not be (Taylor & Byrne-Davis, 2017), and this is likely true of leaders in industry, government and other social institutions. Considering the weight of their decisions, preparing organizational leaders to effectively reason with quantitative information in these situations is exceptionally important.

As an example, media and social media coverage of the COVID-19 pandemic was saturated with infographics, epidemiology statistics and medical research information, which brought to light significant gaps in the quantitative reasoning of both the public at large and leaders of major corporate, governmental, nonprofit and even scientific organizations (Ancker, 2020). While numerous articles were published to encourage citizens to make informed decisions, misinformation and disinformation were readily accepted as truth while scientific evidence was disregarded as misinformation (Best, 2020, 2021).

In workplaces, employees (e.g. HR analysts) rushed to build decision-supporting information papers and briefings to enable senior leaders to make decisions about policy changes in response to COVID-19 (e.g. remote work, face masks, vaccination mandates,

etc.) with significant impacts on business operations, risk management and financial costs. The ability to effectively respond to COVID-19 was dependent on effective decision-making and decision-making depended on a general understanding of mathematical or statistical concepts, such as probability theory (Lewis, 2021, p. 10) and exponential modeling (Karaali, 2020). The COVID-19 pandemic made clear that quantitative reasoning aids leaders in understanding and evaluating imperative information to reach conclusions and make effective decisions, while also indicating that we have not adequately prepared many organizational leaders to succeed in this capacity.

Our call to action

To be effective decision-makers, organizational leaders must be critical consumers of information, follow sophisticated arguments and understand supporting evidence. It seems intuitive that reasoning is an essential element of effective leader decision-making and scholars have explored the fundamental role of reasons in the decision processes of leaders (Westaby, Probst, & Lee, 2010). Furthermore, specific forms of reasoning have been examined for certain types of decisions, such as moral reasoning and ethical decision-making (Small & Lew, 2021). Studies in these areas have recommended that management education programs focus on building leader competence in reasoning to improve future decision-making effectiveness (Thiel, Bagdasarov, Harkrider, Johnson, & Mumford, 2012). As organizational leaders face growing complexity in their environments, the need to solve novel, ill-defined or *wicked* problems will increasingly require the application of quantitative information and the capacity to reason with it (Caughron et al., 2019; Lawrence, 2013; Mack & Khare, 2016).

We therefore extend previous thinking regarding the role of reasoning in leadership decision making to suggest that quantitative reasoning is required to improve leader decision-making capability and that leadership development and management education programs must focus thusly. Leaders need the confidence and competence to recognize the mathematical principles used to generate information and recommendations from data, to ask intelligent questions of experts and analysts, to clarify misunderstandings and voice their hesitations and to suggest alternative viewpoints.

Skills-based models of leadership development should begin to integrate quantitative reasoning with other problem-solving skills. Effective management education programs in the information age must produce leaders capable of quantitative reasoning and determine or recommend the most appropriate pathways for leaders to acquire, practice and hone this competence. That means leaders who possess comfort with data-rich situations and a *habit of mind* to make sense of, understand and apply quantitative information in decision-making processes. The study of quantitative reasoning, as borrowed from the field of mathematics education, offers a pathway for developing this habit of mind, and it is for this reason that we encourage management scholars to integrate quantitative reasoning into extant management education and leadership development models. To assist in this endeavor, we offer guidance on following a decision-making framework that many leaders use, particularly during crisis.

Quantitative reasoning inside a decision-making framework

Understanding the sheer volume of leadership approaches that exist, we focus explicitly on expanding a skills-based model (Mumford et al., 2017) that supports a problem-solving approach relying on sensemaking, as it integrates many of the skills identified (Mumford et al., 2007). We tie in our call for increased focus on quantitative reasoning by integrating a recent qualitative study that presented a conceptual model of key leadership competencies needed in today's environments (Schmidt, van Dierendonck, & Weber, 2023). Notably, we

mesh these theoretical and conceptual discussions together as the overlap is significant and indicative of the need for quantitative reasoning in leadership development programs.

First, the interested reader should immediately go to Mumford et al. (2007) to learn deeply how this cognitive examination of leaders in crisis illuminates the problem-solving process. We submit here that it is in such crisis situations where the proper use and interpretation of data is of utmost importance. Here, we will make several broad strokes around the model to help as we integrate quantitative reasoning.

Mumford et al. (2007) sensemaking during crisis model explicates a process that represents steps including, but not limited to:

- environmental scanning;
- deviance with current mental models of how the organization and environment should be interacting under normal circumstances;
- identification and assessment of changes (i.e. problem identification);
- information gathering vis-à-vis case-based knowledge, including integration here of both causes of the "problem" and goals of a solution (i.e. experiential knowledge); and
- use and analysis of cases based on problem causes, resources and availability, restrictions to solutions, contingency options and plans, overall goals, emotions of stakeholders involved, individual and other situational stakeholders and their potential impact and systems that influence or may be influenced by the crisis.

We pause here to insert quantitative reasoning as a specific competency that must be employed during problem-solving, from Schmidt et al. (2023). Specifically, Schmidt et al. posit the need for analytical skills, comprised of interpretation skill and pattern recognition, data self-efficacy, comprised of basic statistical skills, technical infrastructure management skills, skills with big data (analysis and visualization), skills with experimental design and skills in key performance metric (KPI) development. First, interpretation and pattern recognition are essential for steps outlined above, specifically Steps 1, 2, 3 and 5. Leaders must understand data patterns and have the ability to identify aberrations – large or small – to recognize and define problems. Second, the data self-efficacy competency must be present for leaders during these steps as well. Specifically, they must begin to use this competency and underlying skills (e.g. statistical skills, software skills, KPI development) as they determine *which* experiential knowledge to activate and analyze based on the available data related to the problem.

Continuing the process steps from Mumford et al. (2007), leaders follow case analysis with formulation of their prescriptive mental model (i.e. the vision for moving forward), forecasting, evaluation of forecasting with internal and external reflections and analysis, plan and backup plan formulation, implementation and influence. Of course, these steps once again show serious need for the understanding and application of data – specifically in Step 7, forecasting, and Step 8, evaluation of forecasting models.

Understanding this is a brief treatment, the key principle is the need for integrating quantitative information into a decision-making framework that relies on case-based or experiential leadership knowledge. Organizational leaders do not make decisions in a vacuum. They also are rarely the person who performs complex quantitative analyses, generates quantitative information or reports or provides quantitative evaluation or recommendations from a context-specific lens. Instead, leaders must integrate multifaceted sources of information – including quantitative, qualitative and intuitive – to make decisions

in dynamic situations with incomplete information or suboptimal decision conditions (Kahneman, 2011).

Quantitative reasoning in the management classroom

As you might expect, the authors of this viewpoint paper have been loosely experimenting with methodologies for teaching quantitative reasoning in management classrooms, including with undergraduate and graduate business students as well as with professionals in leadership development programs. These are some general lessons learned, which we hope might enable future scholars to more rigorously examine the efficacy of approaches to, and outcomes of, teaching quantitative reasoning in the management classroom. Next, we will share those lessons and then provide two examples we have used.

We have identified at least four critical elements of an impactful quantitative reasoning activity. First, the student must be in the role of decision-maker; activities where students simply solve math-based problems are inadequate. The student must be required to make a choice. Second, the student should be presented with multiple sources of quantitative information that require them to evaluate the sources of information. Here, it is important that the different sources of information are interrelated; for example, contradict one another, are of varying value to the decision, or are from more/less reputable sources. Third, there is no obvious right answer. While problems in basic and applied mathematics often have a single correct answer, problems requiring leadership decisions rarely do. Finally, the activity should be iterative in nature; that is, the student should have multiple rounds to receive feedback, hone their decision process, and answer again, until they are able to demonstrate effective reasoning in the face of quantitative information.

Recently, we adapted a course in which students were expected to apply several mathematical skills learned in previous courses, such as break-even analysis and cost modeling. For some students, these activities were challenging, whereas for others, they were redundant with previous courses. To shift the learning objective from quantitative skills to quantitative reasoning, we consolidated several of the applied mathematics tools into a single activity. In that activity, students assumed the role of CFO and were required to decide whether they would approve the purchase of a new fleet of delivery trucks powered by either electric, natural gas, diesel or gasoline. To enable their decision, they were provided with several recommendations from their fictitious staff, including a break-even analysis from the fleet manager (based on miles driven), delivery service cost modeling from the finance team and a decision brief recommending a course of action from the delivery manager (based on vehicle capability). The provided decision tools included intentional errors reflective of typos or basic miscalculations, as might be expected in real-world situations. Students were required to write a one-page memorandum stating their choice and justification (i.e. reasoning) for choosing. Grading was pass/fail and students could reattempt the activity as needed to receive a passing score.

In another activity, students were required to determine whether claims made in corporate advertisements could be substantiated (Daniels & Appenzeller Knowles, 2022). Students used critical thinking skills, sought out other sources of data and generated questions to evaluate the merit of the claims. Prompting questions, such as “Who or what was in the sample?” encouraged students to consider what was being studied, or “Are the findings those of a single study/source or multiple studies/sources?” helped students investigate the reliability of a claim. The exercise placed the students in a practical situation where they needed to evaluate the credibility of an information source, then engaged them to ask intelligent questions and construct logical arguments about whether a consumer should believe a company’s claim. Although fairly simple, teaching students to ask these types of

questions and critically analyze numerical information provides the building blocks needed for applying quantitative reasoning to more complex problems in the future.

Conclusion

Mathematics education offers a consensus that quantitative reasoning represents a higher-order competence: the critical ability to analyze numeric information essential for constructing or understanding sophisticated arguments based on quantitative evidence. Advocates of incorporating quantitative reasoning into the broader university curriculum emphasize that citizens must be equipped to interpret quantitative information, detect misinformation, ask insightful questions of experts and engage confidently with authority (Steen, 2001).

In today's data-rich environments, organizational leaders increasingly rely on data-driven decision-making tools and integrating quantitative information into their decision frameworks is an essential capability. Within organizations, data scientists, risk analysts and finance professionals, among others, generate, analyze and communicate quantitative information tailored to specific objectives and uses. Quantitative reasoning calls for these experts to represent their mathematical and analytical insights in ways accessible to non-specialists, both verbally and in writing (Cardetti, Wagner, & Byram, 2019).

Conversely, organizational leaders need not master the technical aspects of each analysis required for their decisions, but rather must cultivate a mindset that enables them to ask clarifying questions, interpret data effectively, and, ultimately, incorporate quantitative insights into their decision-making processes. Here, we have tried to encourage management education scholars to consider the concept of quantitative reasoning as described in the field of mathematics education as an essential addition to the evolving landscape of leadership development programs.

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