

Key competencies for entrepreneurs in the age of artificial intelligence (AI)

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Abstract

The four entrepreneurial competencies identified in this study as essential to success in the artificial intelligence (AI) age were identified through an integrative review of the literature. The traditional entrepreneurial competency of opportunity identification fails to explain opportunity identification in an era where AI is ubiquitous. The four competencies developed into the framework are 1. algorithmic literacy and a data strategy for responsible AI governance, 2. hyper-adaptability, which enables iterative execution due to real-time insights from AI and the ability to pivot quickly, 3. human-centered creativity and empathy, which take advantage of human characteristics, such as vision, and the ability to understand and feel emotions, that AI cannot replicate, and 4. ethical and regulatory foresight, which allows entrepreneurs to anticipate the repercussions of AI deployment. The framework creates a transition from traditional efficiency-based business models to models of augmentation between humans and AI. This has significant implications for education, investment, and resiliency, demonstrated through multiple case studies, including Zest AI, Shopify, and Microsoft's Tay.

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1. Introduction and Conceptual Framework

1.1 The Entrepreneurial Landscape in the 21st Century

Entrepreneurship has been recognized as an engine for economic development, innovation, and social change for many years. Traditionally, entrepreneurs are defined as individuals who perceive opportunities, marshal resources, and take risks to create value through new enterprises (Schumpeter, 1934; Shane & Venkataraman, 2000). Historically, the core roles of entrepreneurs have been with managing resources, taking risks, and orchestrating innovation within uncertain environments (Drucker, 1985; Stevenson & Jarillo, 2007).

Business activity began to dramatically shift in the early 21st century as digital transformation gathered momentum. Emerging internet technologies, mobile technology, and cloud computing fundamentally changed how entrepreneurs were able to access markets, resources, and information (Nambisan, 2017; Autio et al., 2018). Digitalization created new business models, such as platforms and the gig economy, fundamentally transforming industry boundaries, while lowering entry barriers (Sussan & Acs, 2017).

Prior to widespread adoption of artificial intelligence, digital transformation was already shaping entrepreneurial skills and competencies, requiring more agility and increasing digital literacy, as well as access to data-driven synthesis to leverage opportunities (Brynjolfsson & McAfee, 2014; OECD, 2019). However, the rise of artificial intelligence introduced an even greater sense of urgency, creating new opportunities and challenges for entrepreneurs. Future exploration of entrepreneurial competency and challenges must include context in the era of AI.

1.2 The Disruptive Impact of Artificial Intelligence

Artificial intelligence (AI) refers to a variety of technologies that allow machines to perform tasks that would normally require human thinking, usually requiring perception, reasoning, and decisions (Russell and Norvig, 2021). In the business context, AI is often operationalized through machine learning (ML), which makes decisions based on its learning from the data and improves over time; deep learning, a subset of ML, uses neural networks for pattern recognition in complex situations; and generative AI, which profits by creating new content or solutions from data-based patterns learned (Goodfellow et al., 2016; Dwivedi et al., 2023).

AI use in business is changing the nature of the value created. In the past, the competitive advantage was often related to efficiency, and, in many cases, creating efficiency of standardized, routine work (Brynjolfsson & McAfee, 2014). AI-based working methods often allow organizations to achieve levels of efficiency that were once unattainable for operations with little human intervention (Bughin et al., 2018; McKinsey Global Institute, 2021). The entrepreneurial value creation has shifted away from a model of efficiency to exploring new products, services or strategies that utilize the unique qualities of AI's capacity (Cockburn et al., 2018; Raisch & Krakowski, 2021).

As a result of this shift, entrepreneurs now need to rely upon even newer skill sets, such as learning how to interpret insights from AI, considerations of ethics and regulations, and stimulating new levels of creativity when interacting with AI enhanced workplaces (World

Economic Forum, 2023). In this way, the disruption of AI is more than just technological, it has altered the skill sets and needed mindsets for successful entrepreneurship in the digital age.

1.3 Research Gaps and Article Objectives

Not only is the adoption of artificial intelligence (AI) advancing rapidly across a variety of industries, but there is also an important gap in the literature regarding a comprehensive and theoretically coherent model of entrepreneurial competencies for the AI era. Building on the important concepts introduced in earlier works--such as opportunity recognition, resource mobilization, and risk management (Shane & Venkataraman, 2000; Man et al., 2002)--have demonstrated that the digital transformation--especially the rise of AI--calls these competencies into question and expands the framework of those competency-based skills (Nambisan, 2017; von Krogh, 2018). The existing body of research has approached either the technological implications of AI on business OR the evolving nature of work, but often does not merge the previously mentioned perspectives to develop an integrated competency framework for entrepreneurs (Dwivedi et al., 2023).

While there are empirical studies considering skills such as data literacy, ethical decision-making, and digital agility (World Economic Forum, 2023; OECD, 2021), there is little agreement about which competencies are actively or arguably critical, and how these competencies interact in a context of an entrepreneurial workforce under the influence of AI (Raisch & Krakowski, 2021; Giones & Brem, 2017). This fragmentation neither pushes theoretical thinking nor assists entrepreneurs to better navigate an increasingly AI-driven environment.

This article attempts to address the research gap by systematically identifying, defining, and theoretically affirming a set of core competencies necessary for entrepreneurial success in the age of AI. Drawing from classical entrepreneurship theory, competency frameworks, and the most recent studies on AI's business-related influence, this will provide a much-needed theoretical anchor for future research and practice.

1.4 Methodology

This study implemented a systematic, integrative literature review methodological approach to examine and integrate the core competencies of entrepreneurs in the artificial intelligence (AI) age. This process began with a comprehensive review of academic databases, including peer-reviewed assessments, authoritative texts, and institutional reports to build a wide-ranging and authoritative review. Sources were engaged through explicit selection criteria. For the understanding of AI-related competencies, the past five years' research (2020–2025) was privileged for inclusion, whilst still incorporating historical precursors in entrepreneurship and organizational theory for theoretical spatialization.

The review resulted in an analysis based on thematic categories. Thematic categories consist of classical competency frameworks, an evolution of roles of entrepreneurship, and the disruptive nature of AI on business practices. In particular, identifying gaps in the literature on reading AI-based skills with traditional entrepreneurial competencies was essential. Once sources had been reviewed, an analysis process included a comparative and integrative synthesis encompassing salient findings across sources to create a conceptual framework.

The essay emphasized a transparent, replicable, and academically-rigorous methodology throughout the essay. The methodology aimed to ensure the proposed set of core competencies had theoretical validation and practical relevance that accounted for the dynamic of technology innovation and entrepreneurial success in today's business context. This epistemological framework is made to contribute to future research and influence educational and practical managerial practices in AI world.

2. Literature Review: Traditional vs. AI-Augmented Competencies

2.1 Review of Traditional Entrepreneurial Competencies

Entrepreneurial competencies have, for many years, been seen as important determinants of venture success and provide a basis for understanding how individuals see opportunities, marshal resources and innovate. Classic models have established well-founded models to understand such competencies. McClelland (1961) established a psychological framework which characterized entrepreneurs as one who have a high need for achievement or, one that is more likely to engage in risk-taking, goal-directed behavior. Shane and Venkataraman (2000) expanded the psychological model associating opportunity recognition with the cognitive processes that enable entrepreneurs to notice market and process gaps and exploit them.

More traditional research has led to a categorization of entrepreneurial competencies, initially noted by Man et al (2002) and Mitchelmore and Rowley (2010) within cognitive, behavioural and technical domains. Cognitive competencies include those cognitive skills which reflect the ability to recognize opportunity, problem-solve, and think strategically (Baron, 2006; Shane & Venkataraman, 2000) which provide entrepreneurs the ability to process complex information, see trends in the market, and make decisions in uncertain times. Behavioural competencies include personal attributes and personal skills such as leadership, resilience, networking and communication skills (Bird, 1995; Man et al., 2002), that provide entrepreneurs to manage a team, engage stakeholders with, or adapt to uncertainty.

Technical competencies, which initially were underrepresented in the research, are becoming more important now as ventures are tapping in to not only niche knowledge but also technology is becoming specific or specialized (Mitchelmore & Rowley, 2010; Morris et al., 2013). Such technical competencies include specific knowledge of industry, possessing financial literacy, or skill needed in operations to not only create the venture but also propel its growth.

Foundational research, such as Schumpeter's (1934) work, suggests the importance of innovation, while more contemporary work, such as dynamic capabilities perspective that articulates sensing, seizing, and transforming opportunities in fast-changing market, (Teece, 2007) adds to the development of understanding and framework of entrepreneurial competencies. Together, these provide a reasonably comprehensive understanding of entrepreneurial competencies's complexity and acts as a foundation for consideration of how opportunities are evolving in the context of artificial intelligence.

2.2 The Automation Threshold: What AI Replaces and Enhances

The swift advancement of artificial intelligence (AI) has fundamentally changed the terrain of entrepreneurial capabilities by reconceptualizing the delineation between tasks that can be automated and those that require pure human capacity. Literature shows that AI is particularly effective at performing routine, repetitive, and data-heavy tasks, including primary data analysis, predictive modelling, and process optimization (Brynjolfsson & McAfee, 2017; Jarrahi, 2018). For example, today's machine learning algorithms can process vast amounts of data in order to find patterns and make predictions at a faster rate and with greater accuracy than humans (Daugherty & Wilson, 2018; Bughin et al., 2018). In the same vein, AI-assisted research/models have begun to perform an increased variety of financial modelling, customer segmentation, as well as supply chain and operation optimization, with less need for human data entry and manual processes (Chui et al., 2021; Manyika et al., 2017).

Nonetheless, the automation boundary is neither fixed nor static, and evolves with the sophistication of AI technologies. More specifically, while tasks involving structured data and specific rules are particularly susceptible to automation, tasks that require creativity, constructing teamwork, complex problem-solving, emotional intelligence, and moral/ethical decision-making, remain principally in the domain of human activity (World Economic Forum, 2023; OECD, 2021). The automation boundary gap has led to the notion of "AI-enhanced effect," understanding AI as not necessarily replacing human labour, but rather augmenting human capacity (Jarrahi, 2018; Davenport & Mittal, 2022). AI has a powerful way of augmenting entrepreneurial decision making in real-time, increasing strategic foresight, and aiding risk evaluations (Daugherty & Wilson, 2018; Shrestha et al., 2019).

Furthermore, in addition to augmented entrepreneurial decision making, AI integrations create new forms of collaboration between machines and humans that emphasize hybrid competencies based on the combination of technical literacies coupled with interpersonal, creative, and engaged skills (Raisch & Krakowski, 2021; Wilson & Daugherty, 2018). Entrepreneurs who can use AI to complement their own knowledge, practices, and behaviours, will increase their ability to innovate, adjust, and create value, particularly in an increasing dynamic and complex market (Bughin et al., 2018; Chui et al., 2021). In sum, the automation threshold presents challenges and opportunities, determining a way to reframing our sense of core competencies in an age of AI.

2.3 Defining "Core Competency" in the Context of Technological Disruption

The meaning of "core competencies" has changed significantly due to the effects of rapid technological change, especially AI technology. Core competencies have traditionally been defined as a measurable set of knowledge, skills, abilities, and other characteristics (KSAOs) that allow individuals or organizations to perform a given task or achieve performance excellence (Boyatzis, 1982; Prahalad & Hamel, 1990). In entrepreneurship, core competencies represent the quintessential capabilities of entrepreneurs to identify opportunities, manage resources, and establish a competitive advantage (Man et al., 2002; Mitchelmore and Rowley, 2010).

With the increased proliferation of AI in business process and systems, the definition of a core competency needs to be reexamined and/or updated. Recent literature suggests that entrepreneurs need to develop technical skills, but they also need to develop adaptive and

strategic ability to excel in and during technological disruption (Teece, 2018, Shrestha et al., 2019). This entails the ability to continually learn, unlearn and relearn to navigate it in the evolving digital world (World Economic Forum, 2023).

A key differentiation has emerged to be between AI-Literacy and AI-competency. AI-Literacy means having a basic or fundamental understanding of AI concepts, AI tools, and the implications of AI use -think of it as similar to the digital literacy concept used in previous introductions of technology advances (Long and Magerko, 2020; Kong et al., 2021). On the other hand, AI-competency is about being able to strategically leverage AI-Literacy to solve complex problems, generate an innovation or are able to make evidence informed decisions (Jarrahi, 2018; Davenport and Mittal, 2022). In other words, the next level competency requires a combination of skills that include human reasoning, ethical reasoning, critical thinking, and leveraging AI as part of their overall business strategy (Raisch and Krakowski, 2021; OECD, 2021).

In this case, core competencies for entrepreneurs during a period of technological disruption can best be then understood as a set of dynamic, integrative KSAOs that encompass both AI-literacy, but also the ability to strategically leverage AI Literacy, so that entrepreneurs can utilize technology advances for sustained value creation.

2.4 Synthesis and Identification of the Need for a New Framework

The literature reviewed confirms that traditional entrepreneurial competencies (e.g., opportunity identification, resource mobilization, and strategic decision-making) hold great importance (Shane, 2003; Man et al., 2002). However, the fast-paced development and integration of AI into a business context is clearly reshaping the competency landscape (Jarrahi, 2018; World Economic Forum, 2023). Existing frameworks, informed by classical theory and dynamic capabilities, may not adequately address the challenges and opportunities provided by the AI-related disruption (Teece, 2018; Mitchelmore & Rowley, 2010). Recent research suggests that there is a disconnect between established skills and the emerging skills required when attempting to educate, strategize, and practice AI-literacy, and data ethics alone (Davenport & Mittal, 2022; Raisch & Krakowski, 2021).

This synthesis suggests that current models, based on traditional entrepreneurial theory, may not sufficiently prepare entrepreneurs for the complexities of the AI era. Therefore, the potential need for a new, integrative framework that incorporates existing, traditional entrepreneurial competencies, and real-time, hybrid competencies needed to navigate complex AI contexts is clear. This will be key in bridging competencies in entrepreneurship education, practice, and research with current advances and developments in technology.

3. The Proposed Core Competency Framework

3.1 Competency 1: Algorithmic Literacy and Data Strategy

In this artificial intelligence (AI) era, algorithmic literacy and data strategy comprise a core competency for entrepreneurs. Algorithmic literacy represents the capability to understand, interrogate, and critically evaluate AI models and algorithms in terms of functionality, constraints, and biases (Long & Magerko, 2020; Kong et al., 2021). This capability includes awareness of how algorithms "think" about data, identify types of bias, and evaluate the implications for model decision-making on business impacts (Jarrahi, 2018). On the other

hand, data strategy captures the capabilities to collect, curate, analyze, and govern data responsibly through data quality, data security, and compliance to evolving regulations from frameworks like EU AI Act (European Commission, 2021; OECD, 2021).

Entrepreneurs need to frame complex business problems in ways that can be solved by AI, and this too depends on understanding the capabilities and limitations of existing technologies (Davenport & Mittal, 2022; Shrestha, et al., 2019). Algorithmic literacy and the understanding of AI models enable them to select the correct AI application, interpret outputs, and assess the implications for automation and augmentation (Raisch & Krakowski, 2021). Interrogating the ethics surrounding the sourcing of data through widely adopted AI applications is a critical feature under the umbrella of algorithmic literacy, as accountability has shifted onto the entrepreneur to understand where the data came from and how it was used amidst a framework of global data protection and governance related to AI (World Economic Forum, 2023; European Commission, 2021). Aspects of a data strategy rely on the competency of being able to relate data initiatives to business objectives, driving innovation on responsibly sourced data while maintaining stakeholder confidence to produce business outcomes.

Recently, research indicates that algorithmic literacy and data strategy are not just technical competencies to be implemented but also strategic assets that can differentiate successful AI-enabled ventures in the market (Davenport & Mittal, 2022; Jarrahi, 2018). By understanding and mastering algorithmic literacy and data strategy as competencies allow the entrepreneur to leverage AI capabilities and navigate the potential ethical, legal, and operational challenges, while enhancing sustainable value propositions that foster a competitive advantage.

3.2 Competency 2: Hyper-Adaptability and Iterative Execution

Hyper-adaptability and iterative execution are critical skills for entrepreneurs navigating the fast-evolving terrain of artificial intelligence. Hyper-adaptability defines the propensity to quickly interpret and act upon high-volume, real-time data insights that guide firms to change direction based on new opportunities and threats (Raisch & Krakowski, 2021; Jarrahi, 2018). This ability both resides in the mental flexibility of the individual and the agility of the organization—all necessitating ongoing configuration of business models and processes (Teece, 2018; World Economic Forum, 2023).

The practical utility of hyper-adaptability derives from the management of accelerated Build-Measure-Learn cycles, which Eric Ries promotes in his book *The Lean Startup* (Ries, 2011). In this era of AI, Build-Measure-Learn cycles have further accelerated as entrepreneurs collect data at scale and utilize real-time analytics and machine learning feedback to quickly iterate ideas, products, services, and business strategy (Davenport & Mittal, 2022; Shrestha et al., 2019). This iterative execution produces rapid experimentation, learning from failures, and scaled successful innovations. In a further dimension, it will also involve balancing off the velocity of change across the organization, since few studies imply that AI often reshapes jobs, roles, processes, and culture that will change frequently (Kong et al., 2021; OECD, 2021).

Recent studies indicate that organizations demonstrating a high ability to adapt will outperform their peers in volatile or uncertain environments, especially when supported as a result of AI (World Economic Forum, 2023; McKinsey & Company, 2022). One critical task for entrepreneurs is developing a culture of continuous learning, feedback, and agile decision-

making, making it so that teams can pivot without delay, based on new data and insights about the realities of the market (Jarrahi, 2018; Teece, 2018). In the end, intuition and hyper-adaptability are not just relevant for survival but again demonstrate ongoing sustained competitive advantage in the fast-evolving world of AI-enabled entrepreneurship.

3.3 Competency 3: Human-Centric Creativity and Empathy

Human-centric creativity and empathy refer to the entrepreneur's ability to create uniquely human value through vision, motivation, and emotional intelligence—qualities that are difficult for AI to replicate (Huang et al., 2019; Raisch & Krakowski, 2021). This competency includes the capacity to envision new solutions, motivate others, and intuitively understand the complex social and emotional environment in which business decisions transpire (Amabile & Pratt, 2016). As AI replaces routine work, the value in entrepreneurship is found in human insight, intuition, and establishing meaningful connections with others (World Economic Forum, 2023).

In practice, human-centric creativity and empathy are essential for uncovering unarticulated customer needs—ones that may not show up in data alone, but come to the surface through deep listening and observation (von Hippel, 2005; Amabile & Pratt, 2016). Entrepreneurs need to not only motivate and manage human teams, but do so in a world where AI and automation are a constant, and create an environment that provides a sense of purpose and psychological safety for his/her team to innovate (Huang et al., 2019). Furthermore, emotional intelligence is crucial to complex negotiations that require an understanding of stakeholders' perspectives as well as managing interpersonal dynamics between parties that can determine the course of negotiations (Raisch & Krakowski, 2021; OECD, 2021).

Recent research suggests that AI captures patterns and optimizes better than humans, but cannot yet offer empathy, moral decision making or creative vision—all areas where human entrepreneurs can distinguish themselves (Daugherty & Wilson, 2018; Jarrahi, 2018). Accordingly, building human-centered creativity and empathy is not merely an offensive strategy against automation, but rather the will to proactively create value, within the context of AI (World Economic Forum, 2023; McKinsey & Company, 2022).

3.4 Competency 4: Ethical and Regulatory Foresight

Ethical and regulatory foresight refers to the entrepreneur's capacity to think ahead about the ethical, legal, and societal consequences of new AI-driven solutions. This capacity entails thinking one step ahead of changing regulations, considering broader societal implications of technology deployment, and elevating ethical norms into the overall business thinking (Floridi & Cowls, 2022; European Commission, 2021). As AI technologies become increasingly injected into everyday life, entrepreneurs will not only need to comply with current regulatory laws, but will also need to foresee future policy changes and societal expectations (Jobin et al., 2019; OECD, 2021).

In practice, ethical and regulatory foresight manifests in frameworks like Privacy by Design and Ethics by Design, whereby ethical principles and data protection are baked into the AI product development lifecycle (Cavoukian, 2011; European Commission, 2021). Entrepreneurs should also create robust governance frameworks to guard against issues of transparency, accountability, and fairness, especially in areas of AI implementation with

significant consequences (Morley et al., 2020; World Economic Forum, 2023). Proactive risk mitigation may include conducting impact assessments, engaging stakeholders, and putting processes in place to effect remedies and oversight (Jobin et al., 2019; OECD, 2021).

Recent attention and regulation, including the recently proposed framework of the EU AI Act, demonstrates the heightened necessity of compliance and ethical leaders in AI entrepreneurship (European Commission, 2021). These ethical leaders have the potential to build consumer trust, avoidance of expensive litigation, and appropriately justify their business plan of action for responsible innovation (Floridi & Cowls, 2022; McKinsey & Company, 2022). As indicated, ethical foresight is not just about compliance, it is strategically advantageous for the long-term success of the AI-driven ventures and to the acceptance by society in owning and using their business model.

3.5 Summary of the Framework

The framework developed identifies four necessary competencies in the time of AI for entrepreneurs: digital and data literacy; adaptability to learning agility; creativity and empathy human-centered focus; and ethical and regulatory foresight. These competencies support four important value leverages for entrepreneurs in the context of AI and human and ethical leadership (World Economic Forum, 2023; Jarrahi, 2018; Huang et al., 2019; Floridi & Cowls, 2022).

Table: Core Competencies and Value Drivers

Competency	Primary Value Driver
Digital and Data Literacy	Informed decision-making, leveraging AI tools
Adaptive Learning Agility	Rapid skill acquisition, resilience to change
Human-Centric Creativity and Empathy	Unique value creation, team motivation, negotiation
Ethical and Regulatory Foresight	Trust, compliance, risk mitigation

4. Discussion and Managerial Implications

4.1 Strategic Advantages of the Core Competencies

The convergence of core competencies—digital and data literacy, adaptive learning agility, human-centric creativity and empathy, and ethical and regulatory foresight—imparts substantial strategic advantages to entrepreneurs operating in an AI-driven business ecosystem. First, these competencies facilitate faster market-entry by enabling the entrepreneur to identify, assess and act on emerging opportunities enabled by AI technologies (Jarrahi, 2018; World Economic Forum, 2023) faster. Digital and data literacy allows the founders to be able to apply advanced analytics for on-time decision-making, while adaptive learning agility allows the start-up founder to continuously upskill and be responsive to changes in technologies (McKinsey & Company, 2022).

Second, as the global regulatory requirements for AI become more stringent, ethical and regulatory foresight reduces regulatory risk and enhances organizational resilience. Startups that embed privacy, transparency and ethically driven regulatory foresight into their business models are less likely to experience costly regulatory compliance processes and reputational failure when the regulation becomes more stringent (Floridi & Cowls, 2022; European

Commission, 2021). Ethical and regulatory foresight may be particularly valued in industries with higher regulation such as healthcare and finance.

Third, these competencies have relevance to startup valuation or attractiveness to investors. Venture capitalists are likely to evaluate ventures based on their organizational governance frameworks, the ethical use of AI and its commitment to responsible innovation (World Economic Forum, 2023; McKinsey & Company, 2022). Startups practicing in a manner that promotes these competencies will more likely be perceived as lower risk; demonstrating their sustainable development and long-term viability (Jarrahi, 2018).

In summary, not only will these competencies foster operational excellence and innovation, they will also support ventures to differentiate themselves, gain investment capital, and navigate the emerging AI regulatory requirement. Their strategic value lies in building trust with stakeholders, agility to adapt and re-skill in a changing environment and long-term competitiveness.

4.2 Implications for Entrepreneurial Education and Training

The swift adoption of artificial intelligence (AI) in the business ecosystem is prompting a significant paradigm shift in the field of entrepreneurial education and training. Business schools and incubators will need to move away from conventional curricular areas such as descriptive statistics and concepts of basic digital tools, with increasing focus on predictive modeling, data ethics, and strategic thinking with AI (World Economic Forum, 2023; McKinsey & Company, 2022). This will require AI literacy, algorithmic accountability, and ethical reasoning to be embedded into curriculum offerings in entrepreneurial programs (Floridi & Cowsls, 2022).

Entrepreneurial education should prioritize how students can use AI to create strategic advantages, as opposed to simply being able to use technical tools. This shift involves fostering agile learning capabilities, critical thinking skills, and the ability to interpret data and make actionable decisions using AI (Jarrahi, 2018). Incubators and accelerators are building modules around responsible AI use, regulatory compliance, and the impacts of society when a business utilizes automation and/or other advanced technologies (European Commission, 2021; OECD, 2023).

Furthermore, using experiential learning concepts, to the extent the business relies on learning around technology (artificial intelligence) that is school led, or independent use of advanced technologies in business ideas, can bridge learning from theory to practice. This provides future entrepreneurs with a skillset to innovate responsibly and competitively (World Economic Forum, 2023). To advance learning, the focus is moving away from teaching abstract digital skills to developing conceptual knowledge and engendering a holistic and strategic mind-set, where educators and students view AI and machine leading and building human value and/or valued based business in sustainable growth.

To summarize, entrepreneurial education must have an honest appraisal to produce leaders who are not only proficient in AI technologies, but are also capable of use, when appropriate, while being cognizant of strategic, ethical and adaptive based decision-making paradigms, with our current and increasing complex business environment.

4.3 Challenges in Developing AI-Age Competencies

Although AI-age competencies hold clear strategic value, entrepreneurs face challenges to both developing and using these capabilities. A key challenge lies in accessing talent with deep AI and data science skills. There is a worldwide shortage of individuals skilled in machine learning, data analytics, and AI ethics, which has created a buyer's market for skilled professionals and startups are often outcompeted by larger firms for scarce talent (World Economic Forum, 2023; OECD, 2023). Furthermore, the costs associated with acquiring and maintaining AI capabilities and advanced infrastructure often discourage early-stage ventures and scale-ups from risk-seeking, experimentation, and innovating at a pace that keeps up with AI advancements (McKinsey & Company, 2022).

A significant challenge also rests in organizational legacy mindsets. Many established businesses and some entrepreneurial teams are rooted in traditional decision-making models, and thus struggle to shift their cultures to adopt the strategies that leverage all forms of AI (Jarrahi, 2018). Changing these underlying mindsets involves both technical upskilling and leadership changes to shift organizational mindsets that prioritize ongoing learning, experimentation, and ethical considerations (Floridi & Cows, 2022).

Additionally, navigating recent regulatory developments related to AI adds complexity to accessing AI-age capabilities. Entrepreneurs need to stay updated with new regulations concerning the use of AI technologies, such as the European Union's AI Act, while at the same time applying relevant data privacy and ethical practices. Compliance will require research, resources, and/or access to legal and other specialists (European Commission, 2021).

In summary, the most significant challenges to developing AI-age capabilities include shortages of talent, organizational mindsets, early-stage financing towards many of the needed technologies, and regulatory uncertainty. To address these challenges will require concerted efforts from education, regulatory, and organizational processes to generate and mimic a future where the current and future as AI dominates.

4.4 Synthesis of Findings

The framework in our study provides a comprehensive overview of emerging core competencies needed by entrepreneurs in the era of artificial intelligence. By situating established theories of entrepreneurship and competency development with contemporary research on AI-enabled business transformation, the framework illustrates the need for entrepreneurs to develop not only technical competency in AI tools, but also strategic, ethical, and adaptive competencies. The framework emphasizes continuous learning, data-driven decision-making, and responsible innovation, as core competencies necessary for entrepreneurial success in an era of rapid change in the digital landscape. In addition, the framework addresses obstacles of attracting talent, limited resources, and organizational inertia and presents actionable insights into how educational institutions, policy-makers, and practitioners can address these challenges. Ultimately, this synthesis advances understanding of how entrepreneurial competencies need to evolve to leverage the potential benefits, and then address new challenges, created by artificial intelligence and position entrepreneurs to achieve sustainable growth and advantage in the modern business environment.

5. Empirical Examples and Case Studies

5.1 Case Study 1: Algorithmic Literacy in Action

Algorithmic literacy, defined as the capacity to understand, assess, and regulate algorithmic systems, has emerged as a key competency for entrepreneurs functioning in the AI age, especially in context of domain-specific algorithmic decision-making that raises ethical and regulatory accountability. Zest AI—the FinTech organization providing credit underwriting solutions leveraging machine learning—identified in the earlier period of its existence that algorithmic bias in credit scoring not only maintains social inequities but also subjected the organization to regulatory and reputational burdens (Zest AI, 2023).

To mitigate such consequences, Zest AI invested significantly in establishing expertise internally on matters algorithmic fairness, transparency, and bias. Specifically, Zest AI established best practices for its data management practices, including establishing training datasets that are diverse and representative of end-users, auditing for disparate impact on a regular basis, and employing explainable AI methods to ensure credit decisions could be understood and rationalized to the customer and regulator (for further detail, Mathew et al., 2016; European Commission, 2021). Algorithmic literacy altered Zest AI's ability to uncover and alter the sources of bias in its models, like when using historical datasheets reflecting racially discriminatory lending practices, and adapt to regulations like the EU's General Data Protection Regulation (GDPR) and the proposed AI Act (European Commission, 2021).

Zest AI's efforts with algorithmic literacy not only helped the organization avoid unnecessary regulatory expenses but also positioned it as an ethical AI delivering solutions in FinTech. Zest AI's focus on fostering algorithmic transparency and fairness was acknowledged by industry analysts and consumer rights proponents, which fostered trust amongst its clients and consumers (World Economic Forum, 2023). The Zest AI example demonstrates how algorithmic literacy provides entrepreneurs with the ability to navigate complex ethical and technical environments, transforming anticipated risks into competitive advantages, while establishing stable and sustainable businesses in the age of artificial intelligence.

5.2 Case Study 2: Hyper-Adaptability in Action

The capacity for hyper-adaptability--defined as the ability to sense, interpret, and act on changing market realities, that is, to pivot--has emerged as a hallmark entrepreneurial competency in the artificial intelligence era. For example, Shopify, a leading e-commerce platform, exhibited remarkable hyper-adaptability during the COVID-19 pandemic in 2020. Global retail was disrupted due to lockdowns around the world, but Shopify used AI-data analytics and conducted A/B testing to measure how consumer behaviors were changing, as these behaviors were continuously pivoting, in order to rapidly change product and service offerings (Shopify, 2021).

Shopify integrated AI-powered tools that tracked new consumption trends in real time, including a sharp rise in demand for online grocery products and at-home fitness products, to quickly improve their platform to satisfy merchants' needs. Additionally, Shopify's machine-learning algorithms provided the capability to augment storefronts with product recommendations based on other customer's purchasing behavior, provide preemptive fraud

detection, and personalize re-targeting marketing campaigns to merchants' customers, all while merchants tried to navigate severe uncertainty (Davenport & Mittal, 2022). Shopify's advanced AI capabilities also allowed for rapid real-time experimentation on the design of innovative new features to their platform, such as curbside pickup and local delivery, and unlimited possibilities for how to style storefronts, efficiently launched and scaled successful innovations while minimizing risk (Shopify, 2021).

This capacity to hyper-adapt allowed Shopify and its merchants to not only survive the immediate shock of the pandemic but also to gain strong footing in the rapidly scaling digital economy following the pandemic. The very dynamics presented by AI-enabled hyper-adaptability are what allow entrepreneurs to identify market data and leverage those insights in volatile, uncertain environments to make data-driven decisions to pivot their business model and capture opportunity (World Economic Forum, 2023). As the pace of change will continue to increase through AI implementation, it will be imperative that hyper-adaptability will remain a key entrepreneur competency for success.

5.3 Case Study 3: The Failure of Human-Centricity

Technical optimization and AI induced efficiency may be a celebrated trait of entrepreneurship across diverse venture types. However, a fundamental priority of human-centricity in user interaction is a significant variable in the failure of businesses. A case in point here is Tay, a Microsoft AI chatbot produced for Twitter that was released in 2016. Tay was developed to allow users to communicate and learn through user interaction by leveraging advanced natural language processing algorithms. The project team, however, focused on the rapid development of an AI product with advanced algorithms, while excluding robust user empathy, ethical guardrails, and qualitative analysis of online communities (Neff & Nagy, 2016).

Moments after Tay launched, it began to produce inappropriate and offensive content. Tay's language reflected the biases and toxicity it was exposed to while learning in its development environment. In the designers and developers failure to anticipate, plan, and account for the qualitative human nature of user interaction (such as human empathy, cultural sensitivity, and ethical boundaries) this resulted in a public relations crisis and the prompt retraction of Tay (West et al., 2019). With the Tay incident, we see how a mistaken emphasis on technical optimization can result in the retraction of the product, and reveal major implications from a human-centric design perspective and ongoing engagement with stakeholders throughout the developmental and deployment phases (Raisch & Krakowski, 2021).

The Tay incident points out the need for a balance of technical optimization, design and development, with an understanding of its user communities and their needs, values, and social context. As AI technologies and designs will continue to grow in prevalence, businesses now see the ability for continued human-centricity in design and delivery to be a core entrepreneurial characteristic (World Economic Forum, 2023). Failure to strike a balance between these facets of design (human-centricity and AI efficiency) puts companies not only at risk of product failure, but also damage to their public reputation and social trust.

6. Conclusion and Future Research Agenda

6.1 Summary of Key Findings

This study has examined evolving the prospects of entrepreneurs in the age of artificial intelligence, and articulated four key competencies critical for entrepreneurs to succeed within this changing landscape. First, algorithmic literacy was identified as a basic fundamental competency that allows entrepreneurs to understand, assess, and use tools driven by artificial intelligence and data-driven decision making. This competency is particularly important for confronting the technological complexities and ethical issues associated with acquisition and implementation of artificial intelligence technologies.

Second, hyper-adaptability is established as a key trait, representing the entrepreneur's capacity to react quickly and perform in response to technological disruption, the changing demands of the market, and new regulation. In a world where artificial intelligence increases the speed of change, to have the capacity to quickly pivot a business strategy and/or business model is critically important for lasting competitive response capacity.

Third, data stewardship and ethical responsibility are highlighted as essential, given the reliance on large-scale data and the increasing amount of focus on the social implications of artificial intelligence. Entrepreneurs must not only be responsible for complying with changing regulations, but also must be trustworthy by being transparent and fair, and both responsible and ethical in their use of data.

Finally, human-centricity represents a core competency by emphasizing empathy and user experience; and by creating useful value for customers and stakeholders. While artificial intelligence has the ability to optimize processes and generate insight, the skill of being human and addressing the needs of humans will continue to remain important for successful entrepreneurs in a technology driven world.

The primary theoretical contribution of the article is the development of a new, comprehensive framework that combines the four competencies mentioned above. The framework links core classical theories related to entrepreneurial competence with the unique attributes of the current era of artificial intelligence to create a whole model applicable to research and practice. Describing these competencies provides a roadmap for future research and for practitioner entrepreneurs who need developer competency to succeed during the current and constant technological change.

6.2 Limitations of the Current Study

This research provides a thorough framework to understand the core competencies needed of entrepreneurs in the era of AI, but the research encompasses many limitations. One limitation is that this research mostly focuses on high-tech startups and tech-based businesses, which may not be representative of the wider array of entrepreneurial activity spanning all industries and ways of entrepreneurship. This means that the emphasised competencies may be less relevant to entrepreneurs in traditional industries or in environments with limited access to emergent technology.

Another limitation is that the study is largely conducted within developed economies and regions with strong digital infrastructure. Thus, it may ignore distinct challenges and opportunities faced by entrepreneurs in emerging markets, or less-resourced settings. This focus on geography may restrict the generalizability of findings that may apply to global entrepreneurship ecosystems.

Due to the changing and still evolving nature AI technologies and advances in AI, there is a chance that some of the competencies established here will require adjustments and revisions, as newer trends emerge and new challenges arise.

Lastly, the conceptual framework discussed in this study has not been tested, and therefore has not been validated through academic research and/or real-world application for practitioners.

6.3 Future Research Directions

In the future, researchers should have the opportunity to validate the model of competencies suggested in the present study empirically using alternate approaches. Longitudinal studies that track entrepreneurs over time could determine whether the competencies identified ultimately contribute to venture performance and to venture adaptability in fast-moving, AI-infused markets. Researchers may also consider quantitative studies, such as large-scale surveys, or structural equation modeling to empirically evaluate the reliability and predictive capabilities of the competency model in different industry contexts and geographic regions. In addition, experimental designs could enable researchers to determine the impact of individual competencies on entrepreneurial outcomes in AI-intensive contexts.

Another exciting research direction is to study the convergence of AI and social entrepreneurship. Scholars may wish to evaluate how AI technologies enable or inhibit social and environmental pursuits and to identify any unique competencies for entrepreneurs operating in this arena. Comparative studies between commercial and social entrepreneurs may uncover unique traits in competency acquisition and application. Finally, future scholars should also study the ethical, cultural, and regulatory aspects of the entrepreneurial competency development process amid rapid technological change. Addressing areas mentioned would provide opportunities to refine the competency framework to better facilitate practice while simultaneously illuminating our understanding of entrepreneurship in an era of artificial intelligence.

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