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The Journal Editorial Team would like to thank the reviewers for their time and effort. The comments that we received were very constructive and detailed. They have been very helpful in our effort to continue to produce a top-quality journal. Your participation and timely response are very important for providing a distinguished outlet for original articles. In this issue, articles are assigned digital object identification (DOI) numbers to make sure readers and researchers can reliably find your work and to help track the ways your work is cited by others.

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THE EVOLUTION INTO CUSTOMER 4.0: A SYSTEMATIC LITERATURE REVIEW

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Abstract

As markets evolved into a globalized system, customers changed their behavior. Organizations must adapt their customer relationship management in the context of evolving expectations. This research aims to provide a systematic literature review of the evolution of customer concepts, focusing on Customer 4.0, in the digital era. It also identifies the main characteristics of customer 4.0, and which gaps and opportunities exist in the current literature on this topic.

Keywords: *Customer 4.0; Voice of the Customer; Customer Satisfaction*

1. Introduction

In this fast-evolving society, the emergence of Customer 4.0 represents a paradigm shift in consumer behavior propelled by advancements in technology and a hyper-connected global marketplace. This paper presents a comprehensive exploration of Customer 4.0, employing a systematic review methodology to explore the existing literature to better understand how that concept evolved and the main characteristics of this new customer profile.

The history of the consumer era provides a context for the origin and evolution of customer 4.0. From the focus on products during the Customer 1.0 area to the values-driven approach of Customer 3.0, each era shows how customer preferences, market changes, and technological advancements have evolved. The advent of Customer 4.0 presents a new era characterized by unprecedented connectivity, digital fluency, and higher consumer expectations.

The fusion of digital technologies, social media, and IoT infrastructure amplifies the voice of consumers, ushering in an era where feedback is instantaneous, omnipresent, and profoundly impactful. Organizations can extract valuable insights from vast amounts of customer data by leveraging artificial intelligence (AI), machine learning, and data analytics. These insights enable them to develop agile, customer-centric strategies that cater to the sophisticated preferences of customer 4.0. Exploring the concept of Customer 4.0 reveals a story of change, creativity, and adjustment shaped by how consumers behave, how technology evolves, and how organizations respond. This study aims to clarify the emerging trends, hidden chances, and significant impacts driving this pivotal change in consumer behavior.

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2. Methods

A literature review was conducted following a systematic review. To be considered a systematic review, the research must follow an organized process with three steps, as explained by Materla et al. (2017). These three steps consisted of planning the review, where the research questions were developed, key terms and relevant databases were identified, and a timeline was established. The second step consisted of conducting the review by searching the databases, reviewing the resulting papers, and selecting the papers for the literature review after careful examination. The last step consisted of reviewing the results and reporting the findings.

Three research questions were determined for this study:

1. What are the main characteristics of Customer 4.0 as described in the current literature?
2. How did the concept of Customer 4.0, and what are the major important factors in its development?
3. What gaps exist in the current literature on customer 4.0, and what are the opportunities for future research?

The main objective of this study is to comprehensively analyze existing research related to Customer 4.0, to gain a thorough understanding of their characteristics, behaviors, and preferences. Given the novelty of this concept, only articles published between 2010 and 2023 are considered. The search considered four databases: ProQuest, Engineering Village, IEEE Xplore and Web of Science. This study considered only articles published in English. Three key terms were identified and used in this study: customer 4.0", "consumer 4.0, and "marketing 4.0".

Figure 1 shows the flow diagram generated for this search. In total, 133 articles were retrieved from the database search, and five other articles were considered based on other searches or references from the retrieved articles. After removing duplicates, a total of 93 articles were included. The studies were screened based on their titles and abstracts. If an article was considered consistent with the topic, it was selected for further analysis of the full-text content. Articles that were not related to the specific topic of this study were excluded. In total 35 abstracts were excluded because they were not relevant to this research. The remaining papers were assessed for eligibility based on the full article. A total of 28 articles were not pertinent to the topic after the full article review. After this analysis, 30 papers were considered for this literature review.

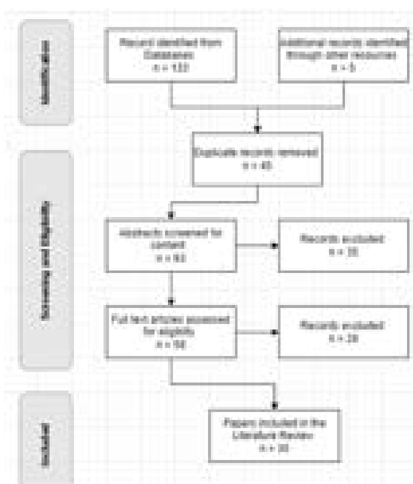

Figure 1. Research Flow Diagram

3. Literature Review

Customer 4.0, or Consumer 4.0, is a relatively new concept used in different sources, but does not have an established definition yet. Customer 4.0 is considered a conceptual extension derived from the industry 4.0 framework. As Madsen (2019) explains, many concepts have been inspired by Industry 4.0, such as Quality 4.0, Logistics 4.0, and Customer 4.0. The term "4.0" has evolved into a widely recognized view, where the concepts with the 4.0 suffix are linked to innovation (Polivka & Dvořáková, 2022). To better understand the concept and importance of customer 4.0 to organizations in this digital era, it is important to acknowledge the evolution of this concept.

The origin of customer 1.0 concept can be related to the first marketing era, which dates back to the 1950s. Since the product's primary purpose is to solve a need, there is no real attachment of the customer to a brand (Baciu, 2020). At that time, customers were limited in product and service diversity, buying and using what was available to them at the time of purchase, which contributed to detachment of the product from its brand. This is known as the product-oriented era, and there is no attachment to the customer. (Kotler et al., 2010). During this period, the customer primarily focused on the price and quality of the options (Wereda & Woźniak, 2019).

The consumer 1.0 pattern is related to the era of mass production, which flourished at this time when the focus was industrial machinery. The company's main purpose was to produce as much as possible at the lowest possible cost to serve the masses at the lowest price (Xi, 2021). The customer was given standard products with few or no customization options (Kotler et al., 2010). A remarkable phrase from Henry Ford is an excellent characterization of that time: "Any customer can have a car painted any color that he wants as long as it is black."

Customer engagement is minimal and mainly involves broadcast messages through traditional advertising channels. During this period, communication was conducted between organizations and customers, with marketing messages focused on the product (Tarabasz, 2013). Customer feedback was limited and was gathered through the traditional voice of the customer (VOC) channels, such as focus groups, questionnaires, phone calls, surveys, and mail.

As society evolved through the third industrial revolution, customer characteristics evolved to customer 2.0. Marketing influences customer opinions and buying decisions (Wereda & Woźniak, 2019). This period ranges from 1950 to 1990, when competition between companies increased and customers were given more options and differentiated between companies in terms of quality, price, and brand recognition. This time is known as the customer-oriented era (Baciu, 2020). The main aim of marketing strategies at that time was to achieve customer satisfaction and improve customer retention (Bheekharry, 2022).

The decision becomes more about products that optimally fulfill customers' needs at the best value. Companies also start to understand their customers better and invest in propaganda that will attract customers and differentiate their brands from competition. During this time, the ideas of "customer is always right" and "customer is king" take place and work for most businesses since customers' needs are seen as priorities (Khargharia et al., 2023).

At that point, VOC were gathered through traditional methods, such as surveys, questionnaires, and customer interviews. However, it is also the beginning when companies gather information from online forums, product reviews, and chats. The increased use of technology has allowed companies to gather passive VOC through different channels. Organizations can then start to invest in segmentation and personalization in their niche (Kotler et al., 2010).

As globalization and the Internet started to impact daily activities significantly, customer perception of the market changed, evolving to a customer 3.0 view. In the 3.0 era, the concepts from 1.0 and 2.0 are still present, but with globalization, the number of options available is wider than that of local shops. The same product can be obtained from different locations worldwide (Tarabasz, 2013; Baciu, 2020). Therefore, customer retention and loyalty are crucial aspects for survival in a competitive market.

It is also important to note that at this time, customers did not want to choose from the few options provided by the companies, but customized their products to their own needs and desires. Henry Ford's statement was no longer valid. Customers want to be part of the experience and co-create the product they would buy. It is also the first time that customers decide on their loyalty based on the product itself and the experience of buying or using a service (Blazquez-Resino et al., 2020).

Dash et al. (2021) emphasize that marketing integrates three concepts during the era of customer 3.0: brand identity, brand image, and brand integrity. Brand identity is defined as how the brand projects itself to the public. On the other hand, brand image refers to how customers perceive the brand. If these two concepts are aligned, it is a good indication that the company is marketing itself correctly and that customers understand their motivations and confirm their essence. Brand integrity can be considered the extent to which a brand is trusted and reliable. Winarko et al. (2022) highlight that all three concepts are important and positively influence customer satisfaction.

Marketing strategies to gather VOC during this time involved not only traditional methods and pre-existing strategies, but also ethnographic research, co-creation workshops, stakeholder interviews, ethical customer surveys, and storytelling with meaningful content explicitly tailored to different types of customers and consumers (Kotler et al., 2010).

The customer 3.0 era is value-driven, dating from 1990 to 2010 (Aloysius, 2020). The main change from the 2.0 era is that customers are looking not only for the product but also for the brand's purpose, mission, vision, and values and comparing them to theirs. The main differentiator between brands is what the company believes and how they prospect their mission to the world (Kotler et al., 2010).

In this era, consumers are viewed as buyers and humans with feelings and emotions. Marketing is tailored to show customers that the company cares about them, their community, and the world. They also want to create unique customer relationships (Wereda & Woźniak, 2019). Similarly, customers want a sense of belonging as they can see the company and its products as part of their existence (Baciu, 2020).

Currently, we live in a world of connectivity. Everything is connected through the Internet of Things (IoT) and multiple equipment. Cell phones have numerous capabilities and can be used to buy products, schedule services, and provide feedback on multiple channels for different products, services, and experiences (Khargharia et al., 2023). Therefore, marketing had to evolve to better understand this new type of customer, Customer 4.0.

Digitalization has shifted the focus of marketing research towards data analytics methods that leverage AI, chat sessions, and clicks to gain insights into online and offline customer behavior, as explained by Opresnik (2022).

Globalization has created a different world for organizations. Companies are now competing with multiple companies from different locations worldwide for the same user/consumer. Social media has intensified this competition, whereby smaller organizations can compete with larger multinational companies (Kotler et al., 2019). As highlighted by Martin-Guart and Cavia (2014), two main factors made this shift necessary by the end of the 20th century: the empowerment of customers, the technological changes that directly impacted the media, and how customers interact with brands.

Bheekharry (2022) highlights that when considering this shift, marketing had to adjust to a flow that went from vertical – the company creating products and pushing them down to the customers– to horizontal, where customers create and supply ideas to companies that can commercialize exactly what customers want. The push strategy, where the company advertises through different one-way channels such as television, has little to no impact on customer behavior (Opresnik, 2022). This strategy also created a significant change as companies moved away from large-volume products to low-volume niches, where the sense of exclusiveness attracted customers.

The profile of these customers has changed in past years from passive to more active and demanding. The Customer 4.0 era (2015- forward) brought a new challenge to organizations that needed to adjust to a much faster and more dynamic market (Czerwinski & Domanski, 2023). Customers now have not only more information about the products and the brand, but they can also access it so easily that, in a matter of minutes, they can become detractors or ambassadors of a brand, which would take a much longer time in the past (Martin-Guart & Cavia, 2014).

Wereda and Woźniak (2019) emphasize a key distinction between previous generations of customers: persuasive marketing tactics no longer supersede individual personalities and desires. This distinction means that customers will not change their beliefs based on traditional marketing strategies; they will buy only what they want and when they want, only when they exceed their expectations, add value, and satisfy their creativity (Bangarwa & Boora, 2021). This movement has intensified the need for companies to initiate value co-creation processes. This can be achieved through product development or the resolution of problems and complaints, as explained by Rubio et al. (2020) and Xi (2021) in their works.

One word commonly used to describe Customer 4.0 is netizen, a citizen of the Internet (Kotler et al., 2019). The word netizen is mainly defined by people who use the Internet as natives, using the Internet to share content from one person to another. Kotler et al. (2019) define netizens as “social connectors.” One of the main differentiators of customer 4.0 is that they are very demanding because they are highly knowledgeable and informed about what they want. They tend to weigh the effort involved in the value gained from the transaction/interaction. They aim to maximize the value extracted from their decisions by minimizing risks and maximizing benefits (Sharma, 2019).

A significant generational change has impacted customer profiles in recent years (Hwang & Kim, 2019). Gen-Z and Millennials became consumers, so the demand for a new marketing strategy became essential. These generations are typically highly educated and technologically savvier than Boomers and Gen-X (Dash et al., 2021). As explained in the work of Roncevic (2020), consumers usually consult the Internet even if they are physically at a store to verify if the price differs and gather information about the product through reviews. Other characteristics of customer 4.0 are their elevated awareness of new trends and technology, higher quality standards, ongoing education, focus on environmentally friendly products and sustainability efforts, and social consciousness, as defined by Skawińska et al. (2023).

The main word for any area of the 4.0 era was connectivity. The same is valid for Customer 4.0. Customers are connected to brands through the Internet, as never before. As Martínez-Ruiz et al. (2021) describe, consumer 4.0 combines physical and virtual channels to be omnipresent and creates a long-lasting relationship with the brands of their choice. At this point, sellers and buyers are connected by creating a common understanding rather than through official membership guidelines. This shared connection evolves with products, concepts, emotions, and aspirations (Gau, 2019).

As discussed earlier, the main concepts in Marketing 3.0 are brand identity, image, and integrity. Adding brand interaction was necessary to adapt to the new Marketing 4.0 era and to please the Customer 4.0 (Dash et al., 2021). Ghonim et al. (2022) corroborates that adding brand interaction elevates overall customer satisfaction in the hospitality sector. They also highlight that, among all concepts, brand image is the one that most influences customers alongside brand interaction. The main idea behind Marketing 4.0 is to use online and offline systems on behalf of the organizations to guide the customer through the path known as the 5A – Aware, Appeal, Ask, Act, and Advocate (Yasar & Polat, 2022).

Brand interaction is based on consumers' need to interact with brands continuously in real-time (Skawińska et al., 2023). As stated by Dash et al. (2021), the positive effect of the three elements of Marketing 3.0, is only efficient if the brand effectively interacts with customers. As Yasar and Polat (2022) emphasize, the customer during the 4.0 era is a key player in organizations' marketing strategies. Customers are brand advocates, and advocacy is critical to keeping and attracting new customers (Dash et al., 2023).

To meet the needs of Customers 4.0, which demands faster responses across multiple channels, companies have to adopt an omni-channel channel. As Mateus (2021) explained, this means streamlining online and offline interactions to enhance the customer experience and simplify the search process, making it more convenient for customers.

For decades, regular consumer opinions and feedback have been highly important and influential in obtaining new customers for any business. The word of mouth (WOM) concept has been upgraded to a new concept called electronic word of mouth (EWOM), which has no physical boundaries. Previously, the user's opinions could only reach a certain number of people in their circle. Currently, the reach is unlimited. People from different countries can see and know each other's opinions about a product, which is one of the reasons why brand advocacy is important in this market (Kotler et al., 2019).

One primary source of EWOM is virtual communities, where stakeholders share their experiences and exchange knowledge, skills, and competency. When brand advocates share their delight with a product or service in a virtual community, more attachment to the brand is obtained. With the data gathered from these communities, companies can adapt their strategies and understand what is working and what can be improved based on the organic feedback created in those communities (Rubio et al., 2020).

As explained by Hu et al. (2023), WOM or EWOM can be either positive or negative. When consumers express satisfaction, they encourage others to try products or services. On the other hand, when WOM is negative, it exposes flaws and deficiencies in products or services, which can cause other consumers not to buy the product or service and make the company acquire a bad reputation. Negative feedback should be taken as areas to be improved by the companies and acted upon to contain possible damage due to negative WOM.

WOM and EWOM are extremely important in acquiring new customers. It is also essential to highlight, as verified by Upamannyu et al. (2021), that customer loyalty significantly impacts WOM, especially when product prices are high. Their work exemplifies how corporate and brand images are related to customer loyalty and WOM. Digital customers are unwilling to spend money on products or companies with a bad reputation.

Furthermore, organizations must adapt their customer relationship management (CRM) methods. The necessary changes cannot undergo a long process to translate what is being communicated by the customer to their products (Martin-Guart & Cavia, 2014). As technology makes the world move faster, available data must be used and analyzed as quickly as possible because it might become outdated much faster than before.

Therefore, organizations need to adjust and understand how to please a new generation of customers. Marketing needs to find an equilibrium between the use of traditional and new digital marketing strategies (Dash et al., 2021; Roncevic, 2020). On the same topic, traditional methods for capturing and analyzing VOC are still applicable, but modern methods can be highly effective, primarily because of the high volume of changes. Through Marketing 4.0, VOC can be captured through channels such as social media listening, IoT device feedback, and customer interactions through available channels, including chat, call center, and e-mail (Kotler et al., 2019). With the new VOC methods, customers do not even realize that they are giving feedback or interacting with the brand because that interaction can happen with one click and organically (Raina & Lamkuche, 2023). AI can be a helpful tool for capturing and analyzing modern VOC techniques (Opresnik, 2022).

As explained by Khargharia et al. (2023), IoT devices generate massive amounts of data that can benefit from multiple ends. VOC gathering and analysis can be optimized using correct data science techniques, such as machine learning and artificial intelligence. The main advantage of using IoT devices is that data gathering does not depend on human interaction, unlike traditional methods.

The vast use of social media and IoT technologies allows companies to automate their marketing segmentation strategies using more efficient targeting. Thus, they can better understand customers' buying trends, forecast what they want and when they want, and engage more efficiently, creating more sales (Raina & Lamkuche, 2023).

4. Conclusions and Future Work

The systematic review presented in this paper offers a multifaceted exploration of customer 4.0, shedding light on its defining characteristics, evolutionary trajectory, and implications for the current market.

From the current literature, it is possible to identify some of the main characteristics of customer 4.0. They are digitally savvy consumers, significantly changing their behavior. Characterized by unprecedented connectivity, elevated expectations, and preference for personalized experiences, Customer 4.0 merges digital fluency with consumer empowerment convergence. The implications of these characteristics extend across different industries, compelling organizations to change strategies, enhance engagement, and cultivate authentic brand relationships.

The development of Customer 4.0 results from a mix of past trends, new technologies, and changing social norms. Each customer era stage marks a shift in consumer behavior. With the rise of customer 4.0, a significant leap forward is driven by widespread digital tools, easy access to information, and a highly interconnected global market. This significantly shifts marketing strategies, emphasizing customer focus, engagement across all channels, and collaboration in creating value. In this new environment, old marketing approaches give way to flexible, data-centered methods that value adaptability, authenticity, and power to consumers. By leveraging AI, machine learning, and data analysis, organizations gain valuable insights, make quick decisions, and build strong, lasting connections with their audiences.

Studying Customer 4.0 and its preferences opens doors to exploring various areas, from ethical implications to customer satisfaction. As Customer 4.0 engages with brands through digital platforms, issues of privacy, data security, and ethical marketing practices have become increasingly relevant. Future research could examine how ethical considerations influence consumer trust, loyalty, and brand perception in the context of Customer 4.0. Another aspect that could be explored are the detailed dimensions of consumer behavior, technology use, and market trends, revealing new patterns, opportunities, and practical insights to enhance customer satisfaction.

In conclusion, Customer 4.0 represents transformation, innovation, and adaptation. By understanding the characteristics, evolution, and implications of Customer 4.0, organizations can gain valuable insights and a deeper understanding of consumer behavior, technological innovation, and market dynamics. As companies gain insight into the preferences of this new generation of customers, they can enhance their products and services, leading to higher customer retention and satisfaction, which is crucial for surviving in today's highly competitive market.

5. Disclaimer Statements

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6. References

Aloysius C, A. (2020, June 11). Customer 5.0 and predictive analysis [Online forum post]. www.linkedin.com. Retrieved August 9, 2023, from https://www.linkedin.com/pulse/customer-50-predictive-analysis-aloysius-chan/

Baciu, L. (2020). Customers 4.0: Who They Are? What They Want? Why Companies Should Reinvent for Them? Lumeer. https://www.lumeer.io/customers-4-0-who-they-are/

Bangarwa, K., & Boora, K. (2021). Retailing 4.0: A Study in the Context of New Transformations of the Retail Market. Journal of Marketing Vistas, 11(2), 19–32. https://www.proquest.com/scholarly-journals/retailing-4-0-study-context-new-transformations/docview/2889704082/se-2?accountid=10003

Bheekharry, N. D. (2022). Moving on with Digital Innovation: The Always-Connected Customer. In Lecture notes in networks and systems (pp. 557–571). https://doi.org/10.1007/978-981-19-2225-1_49

Blazquez-Resino, J. J. B., Broncano, S. G., Ruiz-Palomino, P., & Estévez, P. J. (2020). Dealing with human resources in the age of consumer 4.0: Aiming to improve service delivery. Frontiers in Psychology, 10. https://doi.org/10.3389/fpsyg.2019.03058

Czerwiński, B., & Domański, J. (2023). Contemporary consumer trends. Foundations of Management, 15(1), 51–62. https://doi.org/10.2478/fman-2023-0004

Dash, G., Kiefer, K., & Paul, J. (2021). Marketing-to-Millennials: Marketing 4.0, customer satisfaction and purchase intention. Journal of Business Research, 122, 608–620. https://doi.org/10.1016/j.jbusres.2020.10.016

Dash, G., Rishi, B., Akmal, S., Paul, J., & Chakraborty, D. (2023). Digitization, marketing 4.0, and repurchase intention in E-Tail. Journal of Global Information Management, 31(1), 1–24. https://doi.org/10.4018/jgim.322303

Gau, W. (2019). A reflection on marketing 4.0 from the perspective of senior citizens' communities of practice. SAGE Open, 9(3), 215824401986785. https://doi.org/10.1177/2158244019867859

Ghonim, M. A., Elsawy, W. Z., Elsotouhy, M. M., & Khashan, M. A. (2022). The impact of Marketing 4.0 on customer satisfaction and engagement: The distinctive role of brand interaction in the Egyptian hotel industry. International Journal of Hospitality & Tourism Administration, 1–30. https://doi.org/10.1080/15256480.2022.2127435

Hu, L., Mi, C., & Liu, H. (2023). The influence factors of the characteristics of live broadcast e-commerce anchors on consumers' intention to recommend WOM: a S-O-R perspective. In Lecture Notes in Computer Science (pp. 455–464). https://doi.org/10.1007/978-3-031-48060-7_34

Hwang, J. J., & Kim, J. (2019). Food tourists' connectivity through the 5A journey and advocacy: comparison between generations Y and X. Asia Pacific Journal of Tourism Research, 25(1), 27–38. https://doi.org/10.1080/10941665.2019.1580756

Khargharia, H. S., Rehman, M. H. U., Banerjee, A., Montori, F., Forkan, A. R. M., & Jayaraman, P. P. (2023). Towards Marketing 4.0: Vision and Survey on the role of IoT and Data Science. Societies, 13(4), 100. https://doi.org/10.3390/soc13040100

Kotler, P., Kartajaya, H., & Setiawan, I. (2010). Marketing 3.0. https://doi.org/10.1002/9781118257883

Kotler, P., Kartajaya, H., & Setiawan, I. (2019). MARKETING 4.0: MOVING FROM TRADITIONAL TO DIGITAL. In WORLD SCIENTIFIC eBooks (pp. 99–123). https://doi.org/10.1142/9789813275478_0004

Martín-Guart, R., & Cavia, J. F. (2014). Advertising and media agencies in the face of the change in the media ecosystem. Cuadernos.info, 34, 13–25. https://doi.org/10.7764/cdi.34.572

Materla, T., Cudney, E. A., & Antony, J. (2017). The application of Kano model in the healthcare industry: a systematic literature review. Total Quality Management & Business Excellence, 30(5–6), 660–681. https://doi.org/10.1080/14783363.2017.1328980

Mateus, A. F. (2021). Omnichannel marketing and consumer behavior. In Smart innovation, systems and technologies (pp. 347–361). https://doi.org/10.1007/978-981-33-4183-8_28

Opresnik, M. O. (2022). The Internet-of-Things and AI and their use for marketers. In Lecture Notes in Computer Science (pp. 308–316). https://doi.org/10.1007/978-3-031-05064-0_23

Polivka, M., & Dvořáková, L. (2022). Marketing 4.0 – a Systematic Review. In Annals of DAAAM for . . . & proceedings of the . . . International DAAAM Symposium. (pp. 0411–0420). https://doi.org/10.2507/33rd.daaam.proceedings.058

Raina, A., & Lamkuche, H. S. (2023). The need for marketing automation: A review. AIP Conference Proceedings. https://doi.org/10.1063/5.0176843

Roncevic, A. (2020). Contrasts of Contemporary Marketing. Economic and Social Development: Book of Proceedings. https://www.proquest.com/conference-papers-proceedings/contrasts-contemporary-marketing/docview/2462679664/se-2?accountid=10003

Rubio, N., Villaseñor, N., & Yagüe, M. (2020). Value co-creation in Third-Party managed virtual communities and brand equity. Frontiers in Psychology, 11. https://doi.org/10.3389/fpsyg.2020.00927

Sharma, S. (2019). The role of perceived value and gender on customers' purchase intention of ride sharing services. International Journal of Asian Business and Information Management, 10(4), 31–46. https://doi.org/10.4018/ijabim.2019100103

Skawińska, E., Zalewski, R. I., & Wyrwa, J. (2023). Students' Food Consumption Behavior during COVID-19 Lockdown. Sustainability, 15(12), 9449. https://doi.org/10.3390/su15129449

Tarabasz, A. (2013). The Reevaluation of Communication in Customer Approach – towards Marketing 4.0. International Journal of Contemporary Management, 12(4), 124–134. https://dspace.uni.lodz.pl/handle/11089/11386

Upamannyu, N. K., Rajput, S., & Bhakar, S. (2021). Antecedents of Customer Loyalty and Word of Mouth: A study on Consumer Durables in Emerging Economies. FIIB Business Review, 12(4), 439–458. https://doi.org/10.1177/23197145211053398

Wereda, W., & Woźniak, J. (2019). Building Relationships with Customer 4.0 in the Era of Marketing 4.0: The Case Study of Innovative Enterprises in Poland. Social Sciences, 8(6), 177. https://doi.org/10.3390/socsci8060177

Winarko, T., Parapak, E. R., Virananda, S. A., Yulianti, R., & Istijanto, I. (2022). The effect of perceived value and marketing 4.0 on customer satisfaction and purchase intention in e-commerce context. International Journal of Electronic Commerce Studies, 13(3), 69. https://doi.org/10.7903/ijecs.2121

Xi, W. (2021). Changes in marketing strategy structure based on smartphones. E3S Web of Conferences, 251, 01019. https://doi.org/10.1051/e3sconf/202125101019

Yasar, O., & Polat, T. K. (2022). A Fuzzy-Based application for Marketing 4.0 brand perception in the COVID-19 process. Sustainability, 14(24), 16407. https://doi.org/10.3390/su142416407

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EVOLUTION OF TECHNOLOGICAL LEADERSHIP WITH THE INTRODUCTION OF INDUSTRY 4.0

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Abstract

The advent of Industry 4.0 has reshaped the landscape of technological leadership, marked by the integration of the Internet of Things into manufacturing environments. This study explores the evolution of leadership within the context of Industry 4.0, differentiating between managers and leaders. The journey from employee 1.0 to employee 4.0 is outlined, highlighting the transformation from obedient subordinates to self-managers, strategic business units, entrepreneurs, and, ultimately, individuals with free-flowing viewpoints in the workforce.

This study delves into the distinct requirements for effective leadership in each industrial phase. In Industry 1.0 and 2.0, leaders focused on mastering machinery and adapting to emerging technologies, while Industry 3.0 saw the rise of information technology and employees as entrepreneurs. The advent of Industry 4.0, characterized by the Internet of Things (IoT), demands leaders to be cross-hierarchical, team-oriented, and cooperative, placing a premium on personal competence.

A 2-dimensional matrix is introduced to summarize the essential attributes of technological leadership in Industry 4.0. The matrix, gauging "concern for people" and "concern for innovation and technology," distinguishes between "technological leaders" and "digital leaders." While technological leaders emphasize technology, digital leaders exhibit high concern for both technology and people. This study emphasizes the significance of digital leaders in fostering innovation through a cooperative and team-oriented approach, aligning with the collaborative dynamics of Industry 4.0.

Keywords: *Industry 4.0; Leadership 4.0; Digital Leadership; Technological Leadership*

1. Introduction

In today's dynamic business landscape in which technological advancements shape industries and redefine organizational paradigms, the concept of employee experience has emerged as a critical factor. Whether seasoned professionals or fresh talent entering the workforce, daily interactions with leaders significantly impact job satisfaction, motivation, and overall well-being.

Employee experience, once relegated to the periphery, now occupies center stage. Forward-thinking companies recognize that investing in employee well-being pays dividends: reduced turnover, heightened innovation, and a competitive edge. However, amidst this realization, a gap remains—a dearth of comprehensive research, particularly within the hospitality sector, where the literature trails behind the rapid pace of change.

Enter the disruptive force of COVID-19—the catalyst for what some call The Great Reshuffle or

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The Great Migration. Worldwide, employees reevaluate their work environments and seek roles that align with their aspirations. Compensation alone no longer suffices; the work experience itself—its richness, purpose, and alignment with personal values—has become paramount.

Leadership has also evolved. The advent of Industry 4.0, characterized by digital transformation, automation, and interconnected systems, has reshaped how leaders operate. No longer confined to traditional hierarchies, leadership now navigates a complex landscape of data-driven decision-making, agility, and adaptability.

In this context, the research brought forth delves into the heart of the matter: How has technological leadership transformed with the advent of Industry 4.0? By examining this evolution, this study aims to shed light on the critical interplay between leadership practices and employee experience. As organizations strive to attract and retain top talent, understanding the nuances of leadership in the digital age becomes imperative.

Part of the research into employee experience aims to uncover whether various factors are more relevant than others in impacting employee experience. Leadership is one such component that has evolved over the introduction of Industry 4.0. As leadership is an important component of employee experience, and industry 4.0 has ushered in a digital age, this study aims to highlight the evolution of technological leadership with the introduction of Industry 4.0.

2. Research Methodology

This review was planned, conducted, and reported in adherence to the preferred reporting items for systematic reviews and meta-analyses (PRISMA). These guidelines help researchers transparently display findings via the results of a systematic literature review, infusing transparency, quality, consistency and credibility into the process (Moher et al., 2009). This study aimed to answer the following research question:

RQ1: How important is leadership as a factor in employee 4.0 and industry 4.0 concepts?

RQ2: How has technological leadership evolved with the introduction of Industry 4.0?

To examine the literature on industry 4.0, employee 4.0 and leadership 4.0, papers from a wide array of industries were examined from peer-reviewed journals. Databases and searching platforms used include Inspec, Compendex, EBSCOhost (many DBs but primarily Business Source Premier), Google Scholar, and Web of Science.

Articles were subdivided into three sections, depending on the content, to address the research questions. The sections are classified as follows:

1. Articles regarding industry 4.0
2. Articles regarding employee 4.0 and employee experience
3. Articles regarding leadership 4.0

3. Literature Review

3.1. Industry 4.0

To understand the evolution of leadership 4.0, one must first understand what industry 4.0 is, or the Fourth Industrial Revolution. The introduction of steam and water in production led to the first industrial revolution, followed by mass production in the 1880s using electricity to spur the second industrial revolution. In the 1970s, the third industrial revolution was kicked off by using computers to fully automate factories. Many factories are close, but few to none can be considered fully automated. This brings us to the fourth industrial revolution, initially coined from "Industry 4.0" in the Hanover fair in 2011 (Haddara & Elragal (2015) as cited in (Schönreiter, 2017).

The vision of Industry 4.0 shows human and robot working side-by-side to streamline processes, significantly reducing planning complexity and save up to 20 percent due to significantly improved productivity (Menrath et al. (2015) as cited in (Schönreiter, 2017). To take this even further, a survey of top companies revealed the companies expect "greater flexibility, optimized processes, individualized products, fast realization of new products, cost savings and resource efficiency" (VDE: Industrie 4.0 as cited in (Schönreiter, 2017, p. 125). A similar vision of Industry 4.0 is one which global networks exist of smart machines automatically communicating and controlling one another (Kasapoglu, 2018).

Oberer and Alptekin (2018) discussed how Industry 4.0 is characterized by the manufacturing environment introduction of the Internet of Things, while the first three industrial revolutions were the result of mechanization, electricity, and information technology.

3.2. Employee 4.0

To contextualize the importance of leadership in industry 4.0, one must gain an understanding of the evolution of employees over time as well as the important factors that drive employee experience, and how leadership plays a critical role.

Haijian and Fangfang (2018) provide a comprehensive overview and ground-setting for the evolution of employee 1.0 to employee 4.0, describing the journey from subordinates with little initiative and who obey orders (1.0) to self-managers who become strategic business units (2.0) to entrepreneurs with roles of maker or partner (3.0) to finally free-flowing viewpoints of labor whereby these once-individual entrepreneurs can act as such within the company. In keeping with this journey from 1.0 to 4.0, the requirements of successful leadership in each period would differ drastically.

In Industry 1.0, technology was a term limited to advancements in machinery, so keeping pace with technology was learning to operate the new machinery in the latest and greatest fashion. Leaders would need to stay abreast of the latest manufacturing techniques. Regarding their employees, subordinates in this phase were largely subordinate and took direction, so the leader did not have to possess much technological leadership. Similar leadership is present for industry 2.0, characters by the employees being self-managers (Haijian & Fangfang, 2018) as well as the age brought in by electricity (Oberer & Alptekin, 2018). Technology existed more at this point, but not to the extent we know it today. Phones, record players, punch card, etc. were around, so leadership at this point would take on a more active role as employees were not just being led by the managers but starting to forge their own paths. Structured performance reviews (typically annually) would likely be the central themes in industry 2.0.

Industry 3.0 was ushered in with the introduction of information technology (Oberer & Alptekin, 2018) and employees seen as entrepreneurs (Haijian & Fangfang, 2018). Employees no longer saw themselves as subordinates, but as free-willed individuals trying to make the best of their personal situation. Leaders in this age were likely just trying to keep up with the pace of the technological change. The subordinates working with the technology likely knew more than the "boss", and as such would have a tough time taking direction from a manager still relying on pen, paper, and face-to-face meetings to infrequently discuss performance. The world wide web made information sharing much easier and simple across the globe, which would impact the manager whose role used to be information sharing to now more of a cheerleader role, helping maximize the employees and concern for their well-being and training of new technologies.

Industry 4.0 came about with employees seen as entrepreneurs both concerned with their own careers path but also optimizing their employer's success (Haijian & Fangfang, 2018), while the Internet of Things provided the backdrop for the new age (Oberer & Alptekin, 2018). In this dimension, innovation is the key factor, as the best technological leaders realize the need to be cross-hierarchical, team-oriented, and cooperative (Oberer & Alptekin, 2018). The personal competence of the leader is paramount in this phase of industrial revolution, more so than in previous ages where the competence of the leader was to give direction and prioritize.

Along with the understanding of the evolution of employees from industry 1.0 to 4.0 is an understanding of employee experience and the important factors driving experience.

Employee experience is categorized many ways depending on the research topic and aims. One study by Yildiz et al. (2020) classified many sub-criteria under four main criteria of communication, leadership, positive organizational culture, and human capital's development opportunity. See the figure below for an in-depth look at each of these criteria with relevant sub-criteria beneath from the authors. Through modeling exercises, the authors discovered that not all main criteria we equally important with respect to employee experience. The most significant was leadership (C2) at 36.9% weighting – almost three times as important as communication (C1) at 12.6%. Full weights for each criterion and sub-criteria can be seen in Figure 1 below.

The Weights of Main and Sub Criteria

Main Criteria	Weights of Main Criteria	Sub Criteria	Global Weights of Sub Criteria
Communication (C1)	0.126	Transparent and open communication (CO1)	0.012
		Collaborative work environment (CO2)	0.013
		Knowledge sharing (CO3)	0.039
		Continuous and constructive feedback (CO4)	0.061
Leadership (C2)	0.369	Transformational leadership (L1)	0.228
		Participative management (L2)	0.089
		Coaching (L3)	0.026
		Inspiration (L4)	0.026
Positive organizational culture (C3)	0.177	Common vision and commitment (P1)	0.092
		Fairness and trust (P2)	0.031
		Flexibility and work-life balance (P3)	0.016
		Recognition and reward based culture (P4)	0.038
Human capitals' development opportunity (C4)	0.328	Training opportunities (H1)	0.029
		Open to experimentation (H2)	0.015
		Empowerment (H3)	0.163
		Clear goals and expectations (H4)	0.121

Figure 1. Weights of Main and Sub Criteria (Yildiz et al., 2020, p. 1054)

As demonstrated by Yildiz et al. (2020), employee experience is far more than just paying employees appropriately. Through a series of criteria and sub criteria, the authors showed that leadership is a vital component to employee experience.

3.3. Leadership 4.0

As Yildiz et al. (2020) displayed, leadership is one of the most important determinants to employee experience. As the world evolves and quality 4.0 takes shape, what about the emergence and importance of leadership 4.0? What does this term even mean and how is it relevant today (and tomorrow)?

Leadership in the digital world revolves around the organizational mission and objectives and influencing peer groups; doing so requires leadership competencies like cognitive readiness, critical thinking, and emotional and social intelligence (Bawany, 2017). Along with forward-looking traits are essential backward-looking characteristics whereby leaders must be able to see into the past to determine the future (Boneau & Thompson, 2013).

Kasapoglu (2018) discusses leadership 4.0, an important topic in today's focus on the fourth industrial revolution. In the article, the upper echelon theory is discussed, pointing to upper leadership and their decisions influencing the success of the entire organization. Leaders influence about 15% of the variance found in business performance and another 35% of the business strategy choice. So overall the leader can account for about half of the performance variance across organizations (Tidd & Bessant as cited in (Kasapoglu, 2018)).This notion begs the question of how the leader can be better equipped to lead the organization, by which Matzlera & Hinterhuberb as cited in (Kasapoglu, 2018) call for the need of step-by-step tools and methods for managers to better understand the wants and needs of the customer, as well as enhancing communication throughout the process, which can be another point of failure.

4. Results

The introduction of Industry 4.0 has brought about significant changes in technological leadership, particularly in the service industry. Leadership has evolved with the advent of Industry 4.0 in the service sector and embraced the Leadership 4.0 concept in several ways as shown in Figure 2 and discussed below [see for example Pozzi, R., Rossi, T., & Secchi, R. (2023)., Črešnar, R., & Nedelko, Z. (2020), Xu, L. D., Xu, E. L., & Li, L. (2018), and Bach, C., & Sulíková, R. (2021)].

Digital Transformation. Industry 4.0 has accelerated the digitization of services, enabling organizations to offer innovative digital solutions to customers. Technological leaders in the service industry recognize the importance of leveraging digital technologies such as cloud computing, mobile applications, and online platforms to deliver seamless, personalized experiences to their customers.

Data Collection. With the proliferation of connected devices and sensors, service organizations have access to vast amounts of data about customer preferences, behavior, and interactions. Data quality is very important to continue the digital transformation. It includes four V's: Volume - have enough data, Velocity – real time data, Variety – the correct data points, and Veracity – consistency and accuracy. Technological leaders harness this data through advanced analytics and AI algorithms to gain actionable insights that drive decision-making processes. By utilizing data-driven approaches, leaders can optimize service delivery, anticipate customer needs, and enhance overall satisfaction.

Technologies. Industry 4.0 technologies, including robotics and automation, have revolutionized service operations. Technological leaders leverage robotics process automation (RPA) and autonomous systems to streamline repetitive tasks, improve efficiency, and reduce operational costs. By automating routine processes, leaders can free up human resources to focus on more complex and value-added activities, thereby increasing productivity and competitiveness.

Improved Customer Experience: Industry 4.0 enables service organizations to deliver enhanced customer experiences through personalized, on-demand services. Technological leaders leverage digital platforms and AI-driven algorithms to tailor services to individual customer preferences, anticipate their needs, and provide proactive support. By offering seamless, omnichannel experiences, leaders can foster customer loyalty and differentiate themselves in a competitive market.

Remote Service Tools: Industry 4.0 technologies facilitate remote service delivery, allowing organizations to reach customers anytime, anywhere. Technological leaders leverage tools such as video conferencing, remote diagnostics, and augmented reality to provide virtual support and troubleshooting services. By eliminating geographical barriers and offering remote assistance, leaders can improve service accessibility and convenience for customers while reducing the need for on-site visits.

Cybersecurity and Data Privacy: As service organizations increasingly rely on digital technologies and data-driven processes, cybersecurity and data privacy have become paramount concerns. Technological leaders prioritize cybersecurity measures to protect sensitive customer information and ensure compliance with data protection regulations. By implementing robust cybersecurity protocols and encryption technologies, leaders can build trust with customers and safeguard their digital assets.

Agility and Innovation: Industry 4.0 fosters a culture of agility and innovation within service organizations. Technological leaders embrace agile methodologies and encourage experimentation to rapidly prototype and launch new services. By fostering a culture of innovation, leaders can stay ahead of market trends, identify emerging opportunities, and continuously evolve their service offerings to meet changing customer demands.

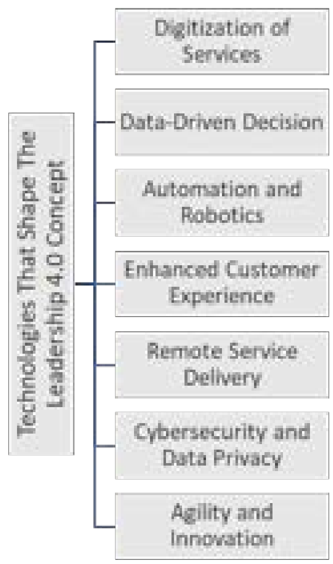

Figure 2. Technologies Affecting and Shaping Leadership 4.0

The academic community have since been busy evaluating the effects, effectiveness and impact of such technologies and how transformed the industry to embrace the leadership 4.0 concept.

5. A Technological Leadership 4.0 Framework

Oberer & Erkollar (2018) introduce the notion of Leadership 4.0, which is simply the concept of leaders in Industry 4.0. Even if a company isn't a tech company, in the era of Industry 4.0, digitization effects every company and every leader. Leaders must become Leaders 4.0 to succeed. The authors proceed to introduce the 4.0 Leadership matrix with the axes of concern for people and concern for innovation and technology. A framework is displayed below in Figure 3 followed by a discussion of the key points and how to best implement this framework in practice.

Figure 3. Leadership Matrix (Oberer & Alptekin, 2018, p.8)

The four quadrants:

- Freshman leader – low concern for both people and innovation/technology
  - This is a leader stuck in the old ways, with concern for traditional processes and little concern for people
- Social leader – high concern for people, low concern for innovation/technology
  - Leader that is regarded as good by the employees, but is not advancing the evolution or adoption of the latest technology.
- Technological leader – low concern for people, high concern for innovation/technology
  - Concerned with the latest advancements in innovation and technology with low concern for employees
- Digital leader – high concern for both people and innovation/technology
  - Able to understand the complex relationship between technology and people, focusing on the organizational model and alignment with human nature

An interesting point in the matrix developed is the distinguishing between a "technological leader" and a "digital leader". This paints an interesting contrast whereby a "technological leader" can be seen as one who emphasizes the latest and greatest in technology and pushes the teams to utilize the best that the world has to offer. Where this leader would falter, by extrapolation, is in the employee-center motivation for the individuals to innovate. This high concern for people is what moves the leader to a digital leader, having the upmost concern for not just the technology but also the people that make it happen. High tech companies need their employees to be focus on innovation and need leaders to foster that innovation through team-orientation and a cooperative approach. Digital leaders in industry 4.0 should be seen as being in the trenches with their team rather than sitting by and simply barking order or providing a simple annual performance appraisal, as was expected and satisfactory for earlier stages of the industry journey.

This Leadership 4.0 matrix is valuable to assessing where leaders are in the transformation to Industry 4.0 and should be regularly applied to understand who is leading the way and who is falling behind in organizations wishing to be at the forefront of the fourth industrial revolution.

6. Conclusion and Next Steps

This study has explored the critical role of leadership in the context of Industry 4.0 and Employee 4.0, addressing two primary research questions.

RQ1: How important is leadership as a factor in Employee 4.0 and Industry 4.0 concepts?

The findings underscore that leadership is a pivotal factor in the successful implementation and sustainability of Industry 4.0 initiatives. Effective leadership fosters a culture of innovation, adaptability, and continuous learning, which are essential for navigating the complexities of Industry 4.0. Leaders who are visionary and supportive can significantly enhance employee engagement, motivation, and productivity, thereby driving the overall success of technological transformations. The concept of Employee 4.0 emphasizes the need for leaders to be not only technologically adept but also capable of inspiring and guiding their teams through the digital transition.

RQ2: How has technological leadership evolved with the introduction of Industry 4.0?

Technological leadership has undergone a profound transformation with the advent of Industry 4.0. Traditional leadership models, which often focused on hierarchical structures and top-down decision-making, are being replaced by more dynamic and collaborative approaches. Leaders in the Industry 4.0 era are required to possess a deep understanding of emerging technologies and their potential impact on business processes. They must also be agile, adaptable, and open to continuous learning. The evolution of technological leadership is characterized by a shift towards a more inclusive and participatory style, where leaders empower their teams, encourage innovation, and facilitate cross-functional collaboration. This evolution is essential for organizations to remain competitive and responsive to the rapid technological advancements that define Industry 4.0.

In conclusion, the importance of leadership in the context of Industry 4.0 cannot be overstated. As organizations continue to embrace digital transformation, the role of leaders will be crucial in shaping the future of work and ensuring the successful integration of advanced technologies. The evolution of technological leadership reflects the changing demands of the modern industrial landscape, highlighting the need for leaders who are both technologically proficient and capable of fostering a culture of innovation and collaboration.

7. Disclaimer Statements

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8. References

Bach, C., & Sulíková, R. (2021). Leadership in the context of a NewWorld: digital leadership and industry 4.0. Managing global transitions, 19(3). https://doi.org/10.26493/1854-6935.19.209-226

Bawany, S. (2017). The Future of Leadership in The Fourth Industrial Revolution. Leadership Excellence Essentials, 2017(12), 18-19.

Boneau, J., & Thompson, G. (2013). Leadership 4.0: It's a brave new approach. Leadership Excellence Essentials, 2013(1), 6.

Črešnar, R., & Nedelko, Z. (2020). Understanding future leaders: How are personal values of generations Y and Z tailored to leadership in industry 4.0?. Sustainability, 12(11), 4417. https://doi.org/10.3390/su12114417

Haijian, L., & Fangfang, Z. (2018). Employee transition and future outlook: Evolution from employee 1.0 to employee 4.0. China Economist, 13(3), 78-87. Retrieved from http://dx.doi.org/10.19602/j.chinaeconomist.2018.05.07

Kasapoglu, A. (2018). Leadership and Organization for the Companies in the Process of Industry 4.0 Transformation. International Journal of Organizational Leadership, 7(2018), 300-308. Retrieved from https://ssrn.com/abstract=333761

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Annals of internal medicine, 151(4), 264-269. https://doi/full/10.7326/0003-4819-151-4-200908180-00135

Oberer, B., & Alptekin, E. (2018). Leadership 4.0: Digital Leaders in the Age of Industry 4.0. International Journal of Organizational Leadership, 2018. Retrieved from https://ssrn.com/abstract=3337644

Oberer, B., & Erkollar, A. (2018). Leadership 4.0: Digital Leaders in the Age of Industry 4.0. International Journal of Organizational Leadership, 2018, 1-9. Retrieved from https://ssrn.com/abstract=3337644

Pozzi, R., Rossi, T., & Secchi, R. (2023). Industry 4.0 technologies: critical success factors for implementation and improvements in manufacturing companies. Production Planning & Control, 34(2), 139-158. https://doi.org/10.1080/09537287.2021.1891481

Schönreiter, I. (2017). Significance of Quality 4.0 in Post Merger Process Harmonization. In: Piazolo F., Geist V., Brehm L., Schmidt R. (eds) Innovations in Enterprise Information Systems Management and Engineering. ERP Future 2016. Lecture Notes in Business Information Processing, 285, 123-134. https://doi:10.1007/978-3-319-58801-8_11

Xu, L. D., Xu, E. L., & Li, L. (2018). Industry 4.0: state of the art and future trends. International journal of production research, 56(8), 2941-2962. https://doi.org/10.1080/00207543.2018.1444806

Yildiz, D., Temur, G., Beskese, A., & Bozbura, F. (2020). Evaluation of positive employee experience using hesitant fuzzy hierarchy process. Journal of Intelligent & Fuzzy Systems, 38(1), 1043-1058. https://doi:10.3233/JIFS-179467

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COURSE GAMIFICATION: APPLYING THE KANO MODEL TO GATHER STUDENT PERCEPTIONS

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Abstract

Design for Six Sigma (DFSS) is a critical component of the Six Sigma methodology, focusing on product, process, and service design. DFSS is proactive, focusing on design rather than existing processes. Its wide application in various sectors, from manufacturing to service industries, has proven its effectiveness. Despite this, its adoption in education remains limited. This research explores the application of DFSS in education, particularly in redesigning a course through gamification to enhance student engagement. This study addresses this gap by illustrating how DFSS principles can enhance education, mainly through gamification. Gamification, incorporating game elements into learning, holds promise for engaging students and improving learning outcomes. Using the DMADV framework, the study defines project objectives, gathers the voice of the customer using the Kano model, analyzes survey data, designs gamification elements, and verifies their effectiveness through student feedback. Results indicate several attractive elements identified through the Kano model, such as smartphone integration and clear rules. Implementation challenges, particularly in a Jeopardy-style review session, are identified and addressed using DFSS tools such as failure mode and effects analysis. Subsequent surveys capture student feedback and suggest improvements, highlighting the iterative nature of DFSS. The study underscores the potential of DFSS in educational redesign, particularly through gamification, to enhance student engagement and learning outcomes. While focused on a specific course, the methodology's generalizability and applicability to diverse educational contexts warrant further exploration for broader implementation.

Keywords: *Gamification; Design for Six Sigma; Education*

1. Introduction

Design for Six Sigma (DFSS) is part of the Six Sigma continuous improvement methodology. While Six Sigma drives process improvements, DFSS focuses on product, process, and service design (Cudney & Agustiady, 2016). Six Sigma drives improvements in existing processes towards a goal of 3.4 defects per million opportunities (dpmo) or a sigma level (σ_{Level}) of six. Often, existing processes

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can only be improved to a certain extent, usually with a sigma level of approximately 4.5. Further improvements require redesigning the product, process, or service accomplished through DFSS. DFSS takes the voice of the customer (VOC) and translates these needs into the design or redesign of the product.

Six Sigma follows the five phases of continuous improvement: define, measure, analyze, improve, and control (DMAIC). Similarly, DFSS follows a five-phase methodology: Define – Measure – Analyze – Design – Verify (DMADV). Both Six Sigma and DFSS methodologies strive for variation reduction and on-target performance. However, since Six Sigma is applied to an existing process, it is considered reactive. DFSS focuses on the design of new products, processes, and services and, therefore, is considered a proactive approach.

DFSS has been widely used in manufacturing (Treichler et al., 2002; Koch et al., 2004; Antony et al., 2005), product development (Creveling et al., 2002; Gremyr & Fouquet, 2012), service (Antony, 2002; Cudney & Furterer, 2012), and healthcare (Taner et al., 2007; Mandahawi et al., 2010). While the research has grown in these areas, implementation in education has been slow to gain momentum. However, Six Sigma has shown a steady increase in the research relating to education (Cudney et al., 2014; LeMahieu et al., 2017). In terms of design applications within education, many researchers are applying the Lean Six Sigma methodology rather than DFSS to redesign education processes and services (Hess & Benjamin, 2015; Shokri & Nabhani, 2015; Yadav & Desai, 2015; Svensson et al., 2015; Sunder, 2016; Uluskan, 2016). A lack of research illustrates the broad possibilities of employing DFSS in course and curriculum design, teaching DFSS principles, and applying DFSS within institutions for continuous improvement, amongst many other areas. Therefore, this study aims to illustrate how DFSS can be utilized in education. In particular, this study explores how to redesign a course by adding gamification to improve student engagement.

Gamification is the process of implementing training or tasks with game elements. This concept is important as it forms the basis for the work done in this project. As a side note, all aspects of gamification associated with this project were created and instituted into an undergraduate quality engineering course. As such, the project attempted to create an environment conducive to learning and comprehension by implementing games and gaming elements. While gamification was the primary goal, the project followed the DFSS methodology, considering other essential elements.

2. Relevant Literature

In order to conduct the research, the relevant literature on the use of gamification and DFSS in education was reviewed.

2.1. Gamification in Higher Education

Despite being a recognized method for engaging students, gamification remains relatively underexplored in higher education. Some studies have explored gamification and how to incorporate gamification into higher education courses. Castillo-Parra (2022) found that gamification improved learning by focusing on the main motivations of human behavior, in particular, reinforcements and emotions. Gamification was incorporated during the COVID-19 pandemic when learning moved quickly to online methods focused on case and project-based online learning. The gamification model was found to be a feasible model for university academic processes. Molina-Carmona and Largo (2020) highlight different uses of gamification in education, either by training students in different subjects or abilities or by enhancing their involvement in the class subject. Gironella (2023) identified the importance of focusing on students' motivation and designing the course in higher education as student-centric. The students rated the gamified structural design and the integrated course mechanics highly motivating. They also rated that the gamification design contributed to their success and positive learning experience in the course. The study by Gené et al. (2019) uses gamification in MOOCs to increase students' engagement. Their study presents encouraging results regarding using gamification to improve students' satisfaction. Subhash and Cudney (2018) performed a systematic literature review on gamification in higher education. They found little research on incorporating gamification in the engineering profession through 2018. They found several advantages of gamification, such as higher student engagement, motivation, and attitude, leading to improved course performance.

2.2. DFSS in Education

In reviewing the published literature, it is clear that the application of DFSS in education is minimal. The papers varied from curriculum development and course instruction to designing buildings on campus. The articles are summarized in chronological order to aid in illustrating trends.

A study by Johnson et al. (2006) employed DFSS at the University of Miami to design a dormitory concept for upper-level students, including juniors, seniors, and MBA students. The purpose was to create a high-class learning community yet break even from a financial perspective. Several of the DFSS tools utilized in the study include market segmentation, Kano survey, quality function deployment, TRIZ, and the Pugh concept selection matrix. Through DFSS, the research team developed detailed designs for the dormitory and a checklist of requirements for the bids to build the dormitory. Further, metrics were established, and a dashboard was developed to monitor and control any inconveniences tenants may experience.

Cudney and Kanigolla (2014) evaluated the use of project-based learning in DFSS instruction through a survey administered after completing a semester project. Students in the graduate-level course were required to conduct a DFSS project to redesign a product. The survey results were analyzed using Fisher's exact test to assess the knowledge students perceived they received through the semester project. The results indicated that students felt the semester project positively impacted learning course concepts and applying theoretical knowledge to solving real-world problems.

DFSS was utilized by Yeung (2014) to redesign the curriculum at a university in Hong Kong. A key focus of this research was to reduce the variation in how the program was delivered and improve consistency. The curriculum was redesigned following the DFSS methodology by aligning the accreditation requirements with learning outcomes to develop course modules that supplemented traditional lectures.

Mahasneh and Thabet (2017) employed DFSS as a decision-aid framework to add soft skills to the construction curriculum. The proposed framework was assessed using a fixed mixed-method design with quantitative and qualitative data. In order to develop the framework, three case studies were used, which employed the Delphi method, a statistical-based approach, and a quality management system within the DFSS methodology of DMADV. The resulting framework identifies soft skills at various curriculum levels, prioritizes the soft skills, tests instructional alternatives, and proposes a soft skills instructional curriculum.

3. Research Methodology

The research followed the DMADV methodology. DFSS consists of five interconnected phases, known as DMADV. The first phase is defined, where the problem is defined, and the opportunities for improvement in a new product, process, or service are identified. Common tools used in the define phase include the project charter, stakeholder analysis, and data collection plan. The next phase is measure. In this phase, the current baseline is determined by gathering market and customer data. In addition, the VOC is collected to identify opportunities for improvement further. Tools such as VOC, Kano model, and failure modes and effects analysis are frequently used in this phase. In the third phase, the data is analyzed to identify relationships between key variables, generate new product concepts, and select a new product architecture from the various alternatives. Subsequently, this phase often uses quality function deployment, design of experiments, and Pugh's concept selection matrix. The fourth phase is design, when the new detailed product elements are developed and integrated to meet customer requirements. In this phase, common tools include mistake proofing (i.e., poke-yoke), design for x, and tolerance design. Finally, in the verify phase, the DFSS team validates that the new design meets the customer's requirements through tools such as statistical process control, control plans, and process capability.

3.1. Define

With any project, a proper understanding of the background and task is necessary to set clear and obtainable objectives. The first step in defining a project is establishing a charter outlining the details, as shown in Table 1. This project focused on implementing gamification into an undergraduate course to promote learning and attendance by all enrolled students. The benefits of such actions, regardless of attendance outcome, would aid student comprehension of the course during lectures and tests through games. Adding a competitive element to an otherwise mundane aspect of the curriculum will give students more drive to understand the material and be more engaged. Further, using games will incentivize students with either potential extra credit or simply due to an individual's competitive spirit or drive for excellence.

The course being redesigned is a core undergraduate course required by all students in a <degree program removed for review> program at <university removed for review>. The course is offered every semester, and enrollment is approximately 45-60 students per semester. Further, the students are typically juniors and seniors. As an upper-level class, attendance was not regularly tracked prior to starting the project. However, it is estimated that 15-20 percent of the students were absent in any given class period. Therefore, the attendance and engagement aspects of implementing gamification were targeted as part of the course redesign.

Table 1. Project Charter

Project Name	**Course Gamification**
Project Statement	Students will sometimes not attend class for excused personal and family reasons. However, more often than not, students simply do not attend because they do not want to. This project aims to incentivize students to attend class and improve their understanding of quality through games. Incorporating the Kano model will allow for a better perspective of what students prefer.
Customers	Current and future students in an undergraduate course on quality. In addition, potential future employers.
Goal of the Project	DFSS and the Kano model should be used to tailor course activities that will increase student engagement and attendance.
Project Scope	This project will focus solely on students enrolled in the undergraduate course on quality. Students and faculty outside of this course will not participate in the survey or appear in the data of this project.
Projected Benefits	The successful implementation of these games will increase the number of students who attend and participate in class through games. These games will review the material assigned as readings in previous or current lectures. In addition, test review material will be used as a competitive learning game that will allow for better comprehension of the course material.

3.2. Measure

In order to achieve the project benefits, it is necessary to select and implement the appropriate gaming elements for the students. This step in defining the project required gathering the VOC obtained using the Kano model. Using the Kano model, a series of attributes were selected and then used as part of a survey to obtain the customer's perspective on the attributes listed in Table 2. The attributes selected for the Kano survey were identified through the literature review.

Table 2. Attribute List

Attribute 1	Games used to help study in this course
Attribute 2	Games used to help review before tests
Attribute 3	Games included as part of the final course grade
Attribute 4	Attendance checked through games
Attribute 5	Extra credit was given by checking attendance through games
Attribute 6	Games were able to be completed on a smartphone
Attribute 7	Review games were like Jeopardy
Attribute 8	Review games have calculations
Attribute 9	Review games have questions from homework and previous tests
Attribute 10	Games played as individuals or teams
Attribute 11	Attendance games conducted at the beginning of class
Attribute 12	Attendance games conducted at the end of class
Attribute 13	Games contained achievement recognition (e.g., badges, trophies, real gifts, awards)
Attribute 14	Games contained challenges (e.g., levels, competition, quests, missions, time constraints, competition)
Attribute 15	Games were narrated (e.g., role play, storyline, narrative)
Attribute 16	Games have a graphical interface (e.g., avatars, characters, animations, simulation)
Attribute 17	Games have a leaderboard
Attribute 18	Games have clear goals and rules
Attribute 19	Games have player turns

Unlike other surveys, the Kano model forms questions in a positive and negative manner to gauge a reaction to the use of each attribute. Forming the survey questions in such a manner allows the individual customer to express requirements based on the attributes presented into one of five categories. The five classifications of requirements are determined for each attribute overall through a compilation of all respondents. These classifications include must-be (M), attractive (A), one-dimensional (O), reverse (R), and indifferent (I). Must-be attributes are those aspects that must be present to satisfy the customer's expectations. If they are not present, the customer will be very dissatisfied. Attractive attributes are the characteristics that delight the customer when they are present because they are not expected; therefore, attractive attributes do not disappoint the customer if they are not present since it is not required. Customer satisfaction is directly proportional to the level provided by a one-dimensional attribute. The more this attribute is provided, the more satisfied the customer will be. On the other hand, customers become more dissatisfied the more a reverse attribute is provided. Finally, customers are neither satisfied nor dissatisfied when an indifferent attribute is included.

The Kano survey presents each attribute as a paired set of statements. Each set includes a functional and dysfunctional form of a statement. The functional form asks the respondent how they would feel if an attribute is present, while the dysfunctional form asks how they feel if the same attribute was not present. The possible options to select by the respondent for each statement included: 1) I like it that way, 2) It must be that way, 3) I am neutral, 4) I can live with it that way, and 5) I dislike it that way. In addition, demographic questions were asked at the beginning of the survey to understand the respondent's gaming habits. Once the Kano survey was completed, Institutional Review Board approval was obtained before distributing the survey.

3.3. Analyze

The survey was distributed over two semesters to ensure an adequate sample size. There were 99 respondents, a 90.8% response rate (109 students enrolled). The majority of respondents were between the ages of 21 and 23 (72.7%), of which 27.3% were female, 71.7% were male, and 1% preferred not to answer. Other information gathered for this project consisted of how many hours of games (e.g., video, board, card) an individual plays each week and how many hours of studying one does on average. Approximately half of the respondents (50.51%) played games for 0-5 hours per week, while 27.3% played games for 6-10 hours, 13.1% played games for more than 20 hours, 8.1% played games for 11-15 hours, and 1.0% played games for 16-20 hours per week.

Similarly, respondents were asked to provide how many hours they studied per week. The highest response was 39.4% at 6-10 hours of studying per week. Further, 28.3% studied 11-15 hours, 13.1% studied 16-20 hours, 12.1% studied 0-5 hours, and 7.1% studied more than 20 hours per week.

The next step in the analysis was to determine the overall number of responses for each category based on the responses. The responses correlate to classification, as shown in Table 3, and Table 4 provides the total number of responses in each category per attribute.

Table 3. Kano Evaluation Table

Customer Requirements	**Dysfunctional Form**					
		1. I like it that way	2. It must be that way	3. I am neutral	4. I can live with it that way	5. I dislike it that way
Functional Form	1. I like it that way	Q	A	A	A	O
	2. It must be that way	R	I	I	I	M
	3. I am neutral	R	I	I	I	M
	4. I can live with it that way	R	I	I	I	M
	5. I dislike it that way	R	R	R	R	Q

Table 4. Attribute Responses

No.	Attribute	Category Totals					
		Q	M	O	A	I	R
1	Games used to help study in this course	4	0	1	55	30	8
2	Games used to help review before tests	3	1	1	62	24	7
3	Games included as part of the final course grade	0	0	1	27	39	31
4	Attendance checked through games	2	1	1	36	42	16
5	Extra credit was given by checking attendance through games	0	1	11	67	15	3
6	Games were able to be completed on a smartphone	0	5	22	47	19	5
7	Review games were like Jeopardy	3	0	2	44	38	11
8	Review games have calculations	2	4	2	24	51	15
9	Review games have questions from homework and previous tests	4	8	16	44	25	1
10	Games played as individuals or teams	16	2	4	20	37	19
11	Attendance games conducted at the beginning of class	2	1	3	30	45	17
12	Attendance games conducted at the end of class	2	0	3	22	52	19
13	Games contained achievement recognition (e.g., badges, trophies, real gifts, awards)	1	1	4	38	50	4
14	Games contained challenges (e.g., levels, competition, quests, missions, time constraints, competition)	0	1	7	48	37	5
15	Games were narrated (e.g., role play, storyline, narrative)	0	1	2	22	47	26
16	Games have a graphical interface (e.g., avatars, characters, animations, simulation)	0	0	6	35	50	7
17	Games have a leaderboard	0	1	6	40	41	10
18	Games have clear goals and rules	2	18	35	28	15	0
19	Games have player turns	1	0	4	24	55	14

This information is then used to determine the overall category of each attribute and the corresponding strength, as shown in Table 5. The category strength values show the difference in the top category versus the second, which helps determine a better/worse disposition. If the effort is put into a particular attribute, how much better will the customer perceive the value, or how much will the value fall if ignored? The results indicate eight attractive or one-dimensional requirements, while the other 11 are indifferent. Six of these eight requirements were attractive, potentially improving satisfaction by over 50%. These attributes consisted of numbers: one, two, five, six, seven, and fourteen. Attribute nine is also attractive and can potentially improve customer satisfaction by 34.5%. Attribute eighteen is one dimensional, meaning the more it is provided, the more satisfied the customer.

Table 5. Category Strengths

No.	Attribute	Final Category	Category Strength	Total Strength	Better	Worse
1	Games used to help study in this course	A	25.5%	57.1%	65.1%	1.2%
2	Games used to help review before tests	A	38.8%	65.3%	71.6%	2.3%
3	Games included as part of the final course grade	I	8.2%	28.6%	41.8%	1.5%
4	Attendance checked through games	I	3.1%	38.8%	46.3%	2.5%
5	Extra credit was given by checking attendance through games	A	53.1%	80.6%	83.0%	12.8%
6	Games were able to be completed on a smartphone	A	25.5%	75.5%	74.2%	29.0%
7	Review games were like Jeopardy	A	6.1%	46.9%	54.8%	2.4%
8	Review games have calculations	I	27.6%	30.6%	32.1%	7.4%
9	Review games have questions from homework and previous tests	A	19.4%	69.4%	34.5%	25.8%
10	Games played as individuals or teams	I	17.3%	26.5%	38.1%	9.5%
11	Attendance games conducted at the beginning of class	I	15.3%	34.7%	41.8%	5.1%
12	Attendance games conducted at the end of class	I	30.6%	25.5%	32.5%	3.9%
13	Games contained achievement recognition (e.g., badges, trophies, real gifts, awards)	I	12.2%	43.9%	45.2%	5.4%
14	Games contained challenges (e.g., levels, competition, quests, missions, time constraints, competition)	A	11.2%	57.1%	59.1%	8.6%
15	Games were narrated (e.g., role play, storyline, narrative)	I	21.4%	25.5%	33.3%	4.2%
16	Games have a graphical interface (e.g., avatars, characters, animations, simulation)	I	15.3%	41.8%	45.1%	6.6%
17	Games have a leaderboard	I	1.0%	48.0%	52.3%	8.0%
18	Games have clear goals and rules	O	7.1%	82.7%	65.6%	55.2%
19	Games have player turns	I	31.6%	28.6%	33.7%	4.8%

A better-worse graph was constructed using the eight attributes that were attractive, one-dimensional, or indifferent to represent satisfaction and achievement visually. As shown in Figure 1, all points provide some sense of satisfaction above the normal range. However, based on the worse values (X-axis), only a select few have the potential to alter customer satisfaction. These three points would be attributes six, nine, and eighteen. Specifically, these attributes deal with the clarity of the game's rules or directions, smartphone capabilities, and the use of previously used test material in reviews.

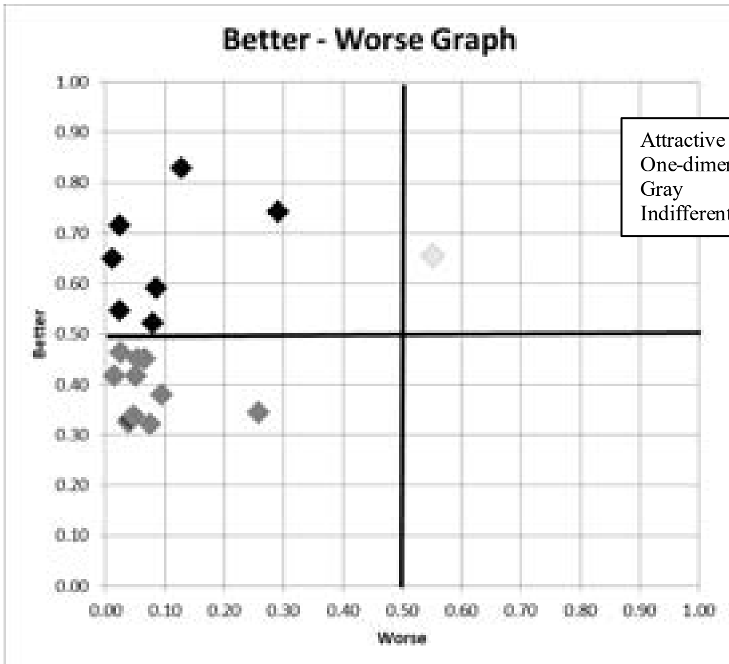

Figure 1. Better - Worse Graph

The values for better and worse fall between 0 and 1. As the better values for an attribute approach 1, this suggests that satisfaction can be improved by providing this attribute. However, as worse values approach 1, this indicates that the attribute will only prevent customer dissatisfaction. Further, the values close to 0 have little effect on customer satisfaction or dissatisfaction.

3.4. Design

With the information provided by the students, design elements for the use of gamification were developed. These requirements, taken from the Kano Model, were placed into the QFD matrix, as shown in Figure 2. QFD shows the relationships between the VOC and chosen design elements.

Each of the nine customer requirements is aligned with functional requirements, or design elements, chosen to fulfill the customers' desires. The items chosen to fulfill the requirements are then compared to the customer's desires and given a score based on importance and level of fulfillment. As noted in Figure 2, the customer requirements are ranked with an importance score and the level to which the design fulfills the requirements. Therefore, the highest-ranking items are the possibility of extra credit for attendance, smartphone capabilities, and clear directions or rules. These requirements will be fulfilled mainly by using a learning tool known as Kahoot!, which will take advantage of smartphone capabilities and address the clarity of rules for its usage. Kahoot! is a tool that uses a smartphone application with unique game pins to take online quiz games. This application is a clicker with multiple-choice options and a running timer. Points are awarded for correct answers, and more points are given for faster answers. The other design item that will take care of most of the customer requirements will be a test review game in the form of Team Jeopardy.

No.	Max Relationship Value in Row	Relative Weight	Weight/Importance	Demanded Quality (i.e., customer requirements or wants)	Quality Characteristics (i.e., functional requirements or hows)					
					Kahoot! Lecture review	Attendance	Scoreboard	Review game style	Former test material	Team participation
1	3	14.7	8.1	Extra credit for attendance		M		M		
2	9	12.6	7.0	Smartphone capabilities	H					
3	9	11.9	6.6	Clarity of rules/directions	M			H	H	
4	9	11.4	6.3	Games in the course	H			H		
5	9	11.2	6.2	Challenges	L		M	H	M	
6	9	10.9	6.1	Previous material review	M			H	H	
7	9	9.9	5.5	Jeopardy style review				H		M
8	1	9.4	5.2	Graphical user interface (GUI)	L		L			
9	9	8.0	4.4	Leaderboard			H		L	

Figure 2. QFD Matrix

These two items form the backbone of the design, but as always, there is a risk of failure in implementation. Two design FMEAs were created to analyze and prepare for any issues that may arise during initial implementation. Some of the most significant risk issues unique to Kahoot! (Table 6) dealt with the use of the leaderboard, attendance, and material review. Kahoot! requires the use of nicknames on the leaderboard, but should students use unidentifiable nicknames, attendance tracking would be difficult and the leaderboard pointless. As such, corrective action should be taken to verify the name list prior to the start of the game or mandate that students use a unique identifier known to the instructor. Concerning the material review, there is the issue of students not completing a question before a timer finishes and locks out the students' answers. A potential action would be to adjust the time so students have longer for quantitative material and slightly less for qualitative, allowing adequate time to answer questions.

As with Kahoot!, the FMEA for Jeopardy (Table 7) had several items that provided large risk priority numbers (RPNs). Two items had RPN values over 250, which consisted of issues with the leaderboard, logistics, and test material review. The two issues in question dealt with the layout of the rooms, team composition, and distance from the buzzers. Due to informal groups that formed during the semester, many teams were formed with closely acquainted individuals. On the other hand, other teams near the back of the classroom did not know one another and sat further away from the buzzer. As such, students could not buzz in quickly due to physical distance from the buzzer or never received the opportunity due to the large team size. Recommended actions to correct this in the future consisted of using a different classroom where the layout may be adjusted to accommodate more teams of smaller sizes. In addition, the other issue that had a high RPN involved the material review itself. Jeopardy, while often considered fun and exciting, quickly jumps around between categories. As such, it is challenging to properly review material since topics may change at any moment. The review may prove ineffective for many students due to quickly changing between topics and difficulties; therefore, recommended actions involved sending out the jeopardy questions and answers following the conclusion of the review session. Doing so allows students to review the items presented in the day's lecture at their own pace without the added pressure of competition and speed.

Table 6. Kahoot! FMEA

Design Function	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Potential Cause(s)/ Mechanism(s) of Failure	Occurrence	Detection	RPN	Recommended Action(s)
Material review	Not enough questions	The review does not cover enough material	3	Oversight by the instructor creating the Kahoot!	1	3	9	Provide a broad range of questions from the previous lecture
Material review	Not enough time to answer questions	Students do not finish their answer(s) in time	6	Difficult calculation questions or confusing wording	3	4	72	Adjust time so that calculations have more time than qualitative questions.
Material review	No internet or poor connection	Kahoot! Is inoperable	8	Hardware issues, software issues, environmental mishaps	1	1	8	Contact technical support
Leaderboard and attendance	Nicknames that do not provide adequate identifiers	Unable to identify students or leaderboard is not correct	5	Operator error, inattentiveness	5	4	100	Verify name list prior to start
Smartphone capability	Connection issues from individual phones	Students may be unable to join the game and consequently lose out on Kahoot! points	8	Technology error, operatory error	2	2	24	Demonstration of how to connect to the game

Table 7. Review Game FMEA

Design Function	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Potential Cause(s)/ Mechanism(s) of Failure	Occurrence	Detection	RPN	Recommended Action(s)
Challenges	Material not challenging enough	Review is deemed inadequate	5	Misunderstanding of the student's level of knowledge	3	4	60	Varying levels of challenge in questions for the review
Challenges	Inadequate knowledge among team members	Certain teams will have an advantage while others lag behind	3	Niches, student attentiveness, student attendance	6	6	108	Mix groups/students from different sections of the classroom
Leaderboard	Reveal the answer and student wagers early	Students know their stance in comparison	7	Instructor error	3	1	21	Poka-yoke, computer program or electronic based

		to other teams						rather than hand-written
Leaderboard	Poor recording of the results	Students may not have a sense of where the team sits in relation to others	2	Instructor error	4	6	48	Electronic recording system
Leaderboard	Teams are too large or spread out.	Students who know the answer may not be able to buzz in due to the physical location of the buzzer	8	Poor classroom layout, no seating adjustment possible	7	6	336	Use a different classroom where the layout may be adjusted
Leaderboard	Unable to identify each buzzer's sound	There may be difficulty in identifying which team arrived at the answer first	8	Large classrooms, extraneous noise, similar sounding buzzers	4	4	128	Use a system where buzzers lock out one another
Material Review	Incorporate wrong material	Students will not be as prepared for the exam	8	Oversight by the individual designing the review	1	2	16	Check and edit prior to the review session
Material Review	Jeopardy does not cover enough of the testable material	Students will not be as prepared for the exam	7	Oversight by the individual designing the review	2	4	56	Check and edit prior to the review session
Material Review	Jeopardy changes categories quickly	Students have difficulty following along with each question and answer	8	A difference in knowledge levels will allow some questions to be finished quickly and not allow others to finish their notes	4	8	256	Send out the review slides after the class to allow students to review at their own pace

3.5. Verify

After this implementation, a secondary survey was released to the students for feedback and potential improvements. The survey consisted of a simple Likert-style scale regarding specific aspects of the gamification elements. The survey responses are presented in Table 8, detailing the perception of each attribute questioned.

Table 8. Feedback Survey

	Overall use of Games	Use of Kahoot	Points for correct Kahoot! answers	A leaderboard in Kahoot!	Smartphone Capability	Style of review game	Test-Style Jeopardy Questions	Jeopardy Teams
Very Dissatisfied	34	1	1	0	0	0	1	0
Dissatisfied	0	0	1	2	1	1	6	4
Neutral	2	14	17	16	13	9	11	13
Satisfied	7	21	16	19	13	17	16	14
Very Satisfied	4	11	12	10	20	20	13	16
Total	**47**	**47**	**47**	**47**	**47**	**47**	**47**	**47**

Several conclusions may be drawn from the survey results. First and foremost, students did not enjoy the overall use of the games. Whether this is due to issues that arose during implementation or simple dislike, several aspects of the project were favorable. The most prevalent examples of this should be the satisfaction experienced with smartphone usage, Kahoot!, the Jeopardy-style material review, and team participation. This finding poses no surprise as the responses to the Kano Model indicated many of these attributes as the most attractive elements available to them.

Regardless, several items require adjustment based on the issues during implementation. The most probable cause of dissatisfaction for the students entails the Jeopardy review session. The major issues that restricted the effectiveness of the review involved the team composition, layout, and buzzers system, which are addressed in the FMEA. During the initial introduction of Jeopardy, the team composition saw niches and friends joining together on teams, which caused half the teams to be excellent at the review and the other half uncompetitive. In order to rectify this situation, the reviews will have to be in classrooms that allow for smaller teams and re-adjustment of the seating. Doing so should enable the niches to be split up and provide more academic diversity in each team. In addition to composition and layout, the buzzer system requires technical improvements. The various sounds and locations for each buzzer in the classroom created difficulty in discerning which team truly "buzzed" first. As such, the optimal solution would be to establish an electronic system that locks out the other buzzers so that only one signal is seen and heard.

Regarding Kahoot!, several minor changes are still required to perform the quiz games at optimum capacity. Many students reported that calculations and time were hindered on the secondary feedback surveys. While calculations are not designed to be complex, difficulty arises when a time crunch is present. Therefore, as was listed in the FMEA, adding more time for any questions involving calculations will provide more satisfaction to the students and consequentially improve the perceived value of the system. The gaming elements implemented should run smoothly with these issues and correct any undiscovered problems. In general, the gamification of this undergraduate course shows the capability of being an excellent learning aid.

4. Conclusions, Limitations, and Future Research

The Kano model was used to understand the students' perceptions related to gamification within the university classroom. Six elements related to gaming were found to be attractive, including games used to help study in the course, games used to help review before tests, extra credit given by checking attendance through grades, games able to be completed on the smartphone, review games like Jeopardy, review games having questions from homework and previous tests, and games that contained challenges. The students did not expect these attributes but would delight them if present. One element, games having clear goals and rules, was found to be a one-dimensional element, meaning that students would be more satisfied when the goals and rules are clearer and less satisfied when they are not. The students perceived several elements as indifferent attributes when considering gamification in higher education. Those would not cause a difference in the students' satisfaction. The highest-ranking items to be designed for the course were the possibility of extra credit for attendance, smartphone capabilities, and clear directions or rules. These requirements were to be fulfilled using a learning tool called Kahoot!.

The Design for Six Sigma methodology provided an excellent application of the design process for reviewing the course and incorporating games into the course based on the voice of the students. Some of the limitations of this research are that the results were focused on this Quality class and may not be generalizable to other courses, subjects, programs, or majors. Future research can expand the Design for Six Sigma methodology and gamification tools and techniques to different classes, subjects, programs, and majors to broaden the appeal and generalizability of the results.

5. Disclaimer Statements

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6. References

Antony, J. (2002). Design for Six Sigma: A breakthrough business improvement strategy for achieving competitive advantage. Work Study, 51(1), 6–8. https://doi.org/10.1108/00438020210415460

Antony, J., Kumar, M., & Madu, C. N. (2005). Six Sigma in small- and medium-sized UK manufacturing enterprises: Some empirical observations. International Journal of Quality & Reliability Management, 22(8), 860–874. https://doi.org/10.1108/02656710510617265

Castillo-Parra, B. (2022). Gamification in higher education: A review of the literature. World Journal on Educational Technology: Current Issues, 14(3), 797-816.

Creveling, C. M., Slutsky, J., and Antis, D. (2002). Design for Six Sigma in Technology and Product Development. Upper Saddle River, NJ: Prentice Hall Professional.

Cudney, E., and Agustiady, T. (2016). Design for Six Sigma: A practical approach through innovation. New York, NY: CRC Press.

Cudney, E., Elrod, C., & Stanley, S. (2014). A systematic literature review of Six Sigma practices in education. International Journal of Six Sigma and Competitive Advantage, 8(3/4), 163–175. https://doi.org/10.1504/IJSSCA.2014.067552

Cudney, E., and Furterer, S. (2012). Design for Six Sigma in Product and Service Development. New York, NY: CRC Press.

Cudney, E., and Kanigolla, D. (2014). Measuring the impact of project-based learning in Six Sigma education. Journal of Enterprise Transformation, 4(3), 272-288. https://doi.org/10.1080/19488289.2014.930546

Gené, O. B., Núñez, M. M., & Martín-Fernández, L. (2019). Enhancing fun through gamification to improve engagement in MOOC. Informatics (Basel), 6(3), 28. https://doi.org/10.3390/informatics6030028

Gironella, F. (2023). Gamification pedagogy: A motivational approach to student-centric course design in higher education. Journal of University Teaching & Learning Practice, 20(3).

Gremyr, I., and Fouquet, J. (2012). Design for Six Sigma and lean product development. International Journal of Lean Six Sigma, 3(1), 45-58. https://doi.org/10.1108/20401461211223722

Hess, J. D., and Benjamin, B. A. (2015). Applying Lean Six Sigma within the university: Opportunities for process improvement and cultural change. International Journal of Lean Six Sigma, 6(3), 249-262. https://doi.org/10.1108/IJLSS-12-2014-0036

Johnson, J.A., Gitlow, H. Widener, S. & Popovich, E. (2006). Designing New Housing at the University of Miami: A "Six Sigma" DMADV/DFSS Case Study. Quality Engineering, 18(3), 299–323. https://doi.org/10.1080/08982110600719399

Koch, P. N., Yang, R. –J, and Gu, L. (2004). Design for Six Sigma through robust optimization. Structural and Multidisciplinary Optimization. 26(3-4), 235-248. https://doi.org/10.1007/s00158-003-0337-0

LeMahieu, P. G., Nordstrum, L. E., and Cudney, E. (2017). Six Sigma in education. Quality Assurance in Education. 25(1), 91-108. https://doi.org/10.1108/QAE-12-2016-0082

Mahasneh, J. K. and Thabet, W. Y. (2017). Utilising design for Six Sigma to implement soft skills in construction education. International Journal of Six Sigma and Competitive Advantage, 10(3/4), 157-178. https://doi.org/10.1504/IJSSCA.2017.086575

Mandahawi, N., Al-Shihabi, S., Abdallah, A. A., and Alfarah, Y. (2010). Reducing wait time at an emergency department using Design for Six Sigma and discrete event simulation. International Journal of Six Sigma and Competitive Advantage, 6(1/2), 91-104. https://doi.org/10.1504/IJSSCA.2010.034858

Molina-Carmona, R., & Largo, F. L. (2020). Gamification and advanced technology to enhance motivation in education. Informatics (Basel), 7(2), 20. https://doi.org/10.3390/informatics7020020

Shokri, A., and Nabhani, F. (2015). LSS, a problem solving skill for graduates and SMEs: Case study of investigation in a UK business school curriculum. International Journal of Lean Six Sigma, 6(2), 176–202. https://doi.org/10.1108/IJLSS-06-2014-0014

Subhash, S., & Cudney, E. (2018). Gamified learning in higher education: A systematic review of the literature. Computers in Human Behavior. https://doi.org/10.1016/j.chb.2018.05.028

Suartama, I. K., Simamora, A. H., Susiani, K., Suranata, K., Yunus, M., & Tisna MS, G. D. (2023). Designing Gamification for Case and Project-Based Online Learning: A Study in Higher Education. Journal of Education and E-Learning Research, 10(2), 86–98.

Sunder, V. J. (2016). Lean Six Sigma in higher education institutions. International Journal of Quality and Service Sciences, 8(2), 159-178. https://doi.org/10.1108/IJQSS-04-2015-0043

Svensson, C., Antony, J., Ba-Essa, M., Bakhsh, M., and Albliwi, S. (2015). A Lean Six Sigma program in higher education. International Journal of Quality & Reliability Management, 32(9), 951-969. https://doi.org/10.1108/IJQRM-09-2014-0141

Taner, M. T., Sezen, B., and Antony, J. (2007). An overview of Six Sigma applications in healthcare industry. International Journal of Healthcare Quality Assurance, 20(4), 329-340. https://doi.org/10.1108/09526860710754398

Treichler, D., Carmichael, R., Kusmanoff, A., Lewis, J., and Berthiez, G. (2002). Design for Six Sigma: 15 lessons learned. Quality Progress. 35(1), 33-42.

Uluskan, M. (2016). A comprehensive insight into the Six Sigma DMAIC toolbox. International Journal of Lean Six Sigma, 7(4), 406–429. https://doi.org/10.1108/IJLSS-10-2015-0040

Yadav, G., and Desai, T. N. (2016). Lean Six Sigma: A categorized review of the literature. International Journal of Lean Six Sigma, 7(1), 2-24. https://doi.org/10.1108/IJLSS-05-2015-0015

Yeung, S.M. (2014). Integrate DLDDC into DFSS for reducing variations in programme delivery. International Journal of Six Sigma and Competitive Advantage, 8(3-4), pp. 203–226. https://doi.org/10.1504/IJSSCA.2014.067542

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THE BALDRIGE ANALYSIS OF PERFORMANCE AND LEADERSHIP

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Abstract

Leadership within an organization is crucial to its performance, growth, and future success in the industry. While the existing literature explores the impact of leadership on organizational performance, there remains a notable gap in research specifically addressing the leadership systems and trends within organizations awarded the Baldrige Performance Excellence award. To better understand whether themes exist within high-performing organizational leadership, applications (N = 9) from Baldrige Performance Excellence award winning organizations were analyzed using deductive content analysis to identify thematic similarities within the organization's leadership systems. The results indicated congruence between the Baldrige Leadership categories and the leadership systems' procedures of establishing the vision, values, and mission within high-performing organizations.

Keywords: *Leadership; Performance; Accountability; Deductive Content Analysis*

1. Introduction

Successful organizations continuously evolve and shift their priorities to mirror current society's needs and values. Modern organizations place greater emphasis on employee performance and emphasize objective performance evaluation methods, developing adequate performance tracking metrics, and examining what factors that influence the elevation or degradation of performance (Dessler, 2014). In 1988, the Baldrige Performance Excellence Award was introduced as a tool for organizations to help improve performance, increase the competitiveness of U.S. based organizations in the global economy, and identify any high-performing role model organizations (NIST, 2022). The Baldrige Model defines Performance Excellence as an organizational performance management approach that utilizes integration to deliver value to customers and stakeholders, add to an organization's ongoing success, and result in the improvement of an organization's effectiveness, capabilities, and overall learning for people within its workforce (Baldrige, 2021).

The Baldrige Performance Excellence Framework consists of seven process categories that are continuously evaluated and annually improved: leadership, strategy, customers, measurement analysis and knowledge management, workforce, operations, and results (Baldrige, 2021). These criteria are based on the core values and concepts of high-performing organizations that create a basis for measuring key performance. Because the Baldrige criteria are results-focused, these core values and concepts combine into the operational requirements of an organization's results, providing a clear direction for actionable improvements, clear feedback, and methods to grow future success. These criteria serve as global benchmarks for other quality award programs, internal

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organizational programs, state and local community programs, and more. Over the course of 34 years, more than 1,715 organizations have applied for the award, with only 124 recognized as winners of the Baldrige Performance Excellence award (NIST, 2022). The Baldrige Performance Excellence website contains the applications of the award-winning organizations and their responses to the Baldrige performance criteria.

The organizational profile in the Baldrige model provides the background context for an organization and identifies unique organizational processes based on its core values and concepts (see Figure 1). It contains a leadership triad that analyzes the importance of leadership on an organization's strategy and customers, a results triad that focuses on workforce, operational processes, performance, and the integration between both triads (Baldridge, 2021). These triads are further evaluated through thorough measurement, analysis of dimension scores, and implementation of effective knowledge management strategies for organizations to enhance their performance and competitiveness.

Figure 1. The integration of core concepts and values on organizational profile

The leadership dimension has the largest impact on the overall performance excellence score among the Baldrige dimensions. It is further subdivided into two categories: senior leadership and governance systems (Baldrige, 2021). Further, the leadership dimension has the greatest influence on the total cumulative performance score of an organization and is highly integrated within the other dimensions. The extent to which senior leaders create a vision for the organization, emphasize customer focus, demonstrate clear organizational values and ethics, and set and maintain high expectations for the workforce contributes to their overall visionary leadership in the Baldrige Model. Given the importance of leadership, this research focuses on the leadership dimension and what factors contribute to its overall rating in high-performing organizations.

The purpose of this research was to analyze the applications of high performing organizations and their leadership processes for any trends present within the selected text from application winners. This research will identify any trends or patterns within high-performing organizations and their specific leadership processes (e.g., Plan, Do, Check, Act (PDCA), continuous improvement, and Lead) to assess any trends or patterns. The results of this research will help managers and organizations implement and improve their leadership processes based on current leadership trends in high-performing organizations. An additional contribution of this work is further insight into the utilization of Lean Six Sigma by high-performing organizations. We, therefore, asked the following question:

What themes in leadership criteria can be identified among high-performing organizations?

2. Leadership

2.1. Leadership Vision and Values

Organizational leadership is displayed through individual role models that establish and uphold an organization's values, visions, and expectations. Successful leadership prioritizes the needs of the organization and its employees and adapts to any particular situation that an organization may face. A lack of vision and organizational values in a company's leadership can leave employees feeling powerless, often resulting in employee retaliation to poor management (Leonard and Pakdil, 2016). The strategies by which senior leadership establishes a company's vision and values and promotes ethical behavior are imperative in the overall picture of how they lead the organization (Baldrige, 2021). Identifying ethical and unethical behavior is a highly subjective construct; therefore, organizations should provide a clear description to employees about what constitutes ethical and unethical behavior within the organization (Kuenzi et al., 2020). This ethical context provides employees with the structure and guidance to determine if there are unethical actions occurring within the workplace. Senior leadership actions demonstrating ethical commitment, corporate wrongdoing, or corruption contribute to the perceptions of an organization's ethical climate. These factors are taken into consideration when assessing an organization's Leadership dimension in the Baldrige model of performance.

2.2. Leadership Vision and Communication

Communication between supervisors and subordinates is a key component of effective leadership within an organization. When assessing effective leadership styles, extant research suggests that transformational and participative leadership are the most effective styles from leaders inspiring their subordinates (e.g., transformational) and involving them in decision-making processes (e.g., participative), promoting an open communication environment that encourages creativity and problem-solving. A lack of effective communication and leadership can result in the "hierarchical mum effect" where individuals feel reluctant to communicate negative feedback to their superior even at the expense of task accomplishment (Bouma et al., 2023). The extent to which senior leaders in an organization encourage open communication, motivate their workforce, and communicate key corporate decisions and changes is taken into consideration in the Baldrige model of performance (Baldrige, 2021).

2.3. Leadership Mission and Organizational Culture

Senior leadership can influence an organization's culture contingent upon the nature of the environment that leaders create by reinforcing equity, inclusion, and employee engagement or by stifling those aspects. Each organization has a culture comprising of deep-rooted values, symbols, and rituals that are difficult to change, but leaders are able to use hierarchical power and influence the culture directly and indirectly (Dalia et al., 2021). Further, successful leaders can create a prosperous culture that promotes the organization's mission, fosters customer and workforce engagement, and ensures the succession of future leaders (Baldrige, 2021). This strategic planning allows leaders within an organization to assess their strengths and weaknesses and determine what changes need to occur to achieve their desired direction (Dessler, 2014). Prior research has demonstrated that effective strategic planning can positively impact organizational performance, as people feel connected to their day-to-day work, committed to the organization's mission, and involved in the strategic planning process (Krier, 2022). How well a leader creates an environment for success and promotes the organization's mission is a critical element of senior leadership that is assessed in the Baldrige model of performance.

2.4. Leadership and High Performance

Leadership can be defined as a process involving group coordination to solve a collective challenge (Spark et al., 2023). Prior literature suggests that the quality of the relationship between an employee and their manager can potentially enhance employee performance (Hassan & Hatmaker, 2015). Efficient leadership can facilitate high performance within organizations, leading to higher financial success, increased organizational growth, and overall higher levels of employee satisfaction within the workplace. High-performing organizations continually produce astounding results through commitment to success and high levels of employee satisfaction (Blanchard, 2010). They are responsive and flexible to situational circumstances that allow them to set themselves up for future success and consist of visionary leadership that supports innovation, collaboration, and employee involvement. By contrast, inadequate leadership can negatively impact organizational performance, even if an organization is excelling in other aspects. The Leadership category within the Baldrige model of performance evaluation contributes the most points in the overall evaluation of organizational performance.

3. Method

Thematic analysis is a qualitative analysis method for identifying, analyzing, and reporting themes within data (Braun & Clarke, 2006). This method is used regularly because of its flexible nature while at the same time providing a systematic approach of inductive and deductive thematic analysis. For this research, the deductive approach, or theoretically-driven coding, was chosen as it uses theory and conceptual frameworks to direct data analysis (Saunders et al., 2009). Five steps constitute the deductive data-analysis approach that were followed: 1) developing attributes and code themes from the Baldridge Model of performance excellence scoring descriptions, 2) preparing data for analysis, 3) developing and refining code themes, and 4) presenting and interpreting the data.

Hence, deductive content analysis was used from the Baldrige Model of performance excellence and scoring descriptions to apply the performance excellence theory to the text transcription of nine award-winning applications. This methodology was used because deductive content analysis is useful when a priori theory/framework (i.e., the Baldrige Model) exists regarding a phenomenon, thereby providing an operational lens for further text analysis (Sandström et al., 2015). The attributes and coding themes were developed based on the original criteria provided by the Baldrige Model on the leadership dimension (Baldrige, 2021).

Specifically, the Baldrige Model criteria for senior leadership consists of eight categories that evaluate how well senior leadership leads an organization. The senior leadership dimension consists of three general categories: vision and values, communication, and mission and organizational performance (see Table 1). These general categories of attributes provided descriptive insight into high performance leadership and depicted a clear theoretical framework and were used as the first departure point for developing the coding themes for the deductive analysis.

Table 1. Visionary Leadership

Attributes	Definition
Vision and Values	Senior leaders deploy the organization's vision and values to the workforce, customers, stakeholders, and key suppliers/partners. The actions of senior leaders demonstrate their commitment to legal and ethical behavior while promoting the organizational environment.
Communication	Senior leaders with visionary leadership encourage two-way communication, communicate key decisions and needs for organizational change, and directly motivate the workforce towards high performance with a customer and business focus.
Mission and Organizational Performance	Senior leaders create an environment that achieves the company mission. They create and reinforce organizational culture that values customer and workforce engagement, equity, and inclusion. They cultivate organizational agility, resilience, accountability, organizational and individual learning, innovation, and intelligent risk taking. They participate in succession planning and the development for future organizational senior leaders. Senior leaders create a focus on action that improves the organization's performance, identifies needed actions, sets performance expectations, demonstrates personal accountability for corporate actions, and creates and balances values for customers and stakeholders.

Within these three categories are five subcategories calling on 'action' concerning senior leadership vision and values (e.g., establishing vision and values, promoting legal and ethical behavior), communication, and mission and organizational performance (e.g., creating an environment for success, creating a focus on action) (see Table 2).

The 'action' subcategories within the Baldrige criteria provided additional context to the leadership framework and allowed researchers to analyze and compare organizational applications at an action level. These action subcategories were then used to develop the coding scheme by including concrete, in-text examples that entailed the criteria (i.e., senior leaders promote legal and ethical behavior to deploy the organization's vision and values). The data was then prepared for thematic analysis for efficient coding in an Excel sheet. Code themes were reviewed and discussed by the research team and refined. The identified theme codes were then used to compare the text transcriptions of the award-winning applications to the leadership framework extracted from the Baldrige Senior Leadership criteria (Baldrige, 2021). The results of the deductive analysis depict the specific criteria from the Baldrige model assessment examples and the most frequent words found among the award-winning applications.

Table 2. Leadership Thematic Analysis

Attribute	Actions	Code Theme	Top 5 Most Frequent Words
Senior Leadership Vision and Values	Establishing Vision and Values	Deploy the vision and values	1. Values 2. ELT: Executive Leadership Team 3. MVV: Mission Vision Values 4. Employees 5. Culture
		Leader's actions reflect commitment to values	
		Strategic objectives and action plans	
	Promoting Legal and Ethical Behavior	Leaders' actions demonstrate commitment to legal/ethical behavior	1. Ethical 2. Legal 3. Behavior 4. Compliance 5. Employees
Senior Leadership Communication	Communication	Encourage two-way communication	1. Communication 2. Key 3. Meetings 4. Employees 5. Customer/ Performance/ Two-way
		Communicate key decision	
		Motivate the workforce	
		Communicate/engage volunteer workforce	
		Customer/workforce digital communication forms	
		Internal/external communication through social media	
Senior Leader Mission and Organizational Performance	Creating an Environment for Success	Create an environment for success	1. Culture 2. Process 3. Leadership 4. Learning 5. Organizational
		Reinforce organizational culture	
		Culture fosters engagement, equity, & inclusion	
		Learning, innovation, accountability, and intelligent risk-taking	
		Succession planning	
	Creating a Focus on Action	Focus on action	1. Action 2. Focus 3. Goals 4. Performance 5. Create
		Improve organization's performance	
		Create value for customers and stakeholders	
		Demonstrate accountability	

4. Procedure

The applications of nine former Baldrige Performance Excellence Award winning organizations were analyzed using deductive content analysis from the formerly established Baldrige performance excellence criteria (Table 1) and thematic analysis to develop a code scheme (Table 2) based on the original criteria for leadership dimension within the Baldrige Model (Baldrige, 2021). Each application contained a section for Leadership that was analyzed and compared to the criteria listed for each category and subcategory. Any text stated in an organization's application that was similar to the criteria text was extracted from the application and placed in a data sheet for further analysis. To determine whether there were any prevalent themes among high-performing organizations, word frequency was used to analyze the themes pulled from each application.

5. Results

To determine if any common themes were present within the leadership systems of nine Baldrige Performance Excellence award-winning organizations, an online word frequency analysis software was used to extract the top five most frequent words in each application for each criteria section of leadership. The results indicated that Values, ELT (Executive Leadership Team), MVV (Mission, Vision, and Values), Employees, and Culture were the most frequent words for establishing vision and values. The most frequent words for promoting legal and ethical behavior among applications were Ethical (35), Legal, Behavior, Compliance, and Employees. The most frequent words for establishing communication were Communication, Key, Meetings, Employees, and Customer/Performance/Two-way. The most frequent words used to create an environment for success were Culture, Process, Leadership, Learning, and Organizational. For creating a focus on action, the most frequent words were Action, Focus, Goals, Performance, and Actions.

6. Discussion

The purpose of this study was to examine the applications of the former Baldrige Performance Excellence award-winning organizations to identify common themes among their leadership systems as a trend within high-performing organizations. Results identified a frequency of words for establishing vision and values suggesting that leadership (i.e., ELT) within high-performing organizations focuses on organizational values, mission, and culture when establishing the vision and values to employees. Results also indicated a frequent theme for how leadership promotes legal and ethical behavior which suggests that leadership within high-performing organizations ensures legal and ethical compliance and behaviors among the organization and its employees. These results align with the extant literature on successful leaders being the pivotal driving factor in upholding an organization's vision and values (Leonard and Pakdil, 2016) while ensuring that ethical and legal behavior expectations are upheld and known to all employees (Kuenzi et al., 2020). The results for leadership establishing communication identified a frequent theme in which leaders within high-performing organizations communicate key information with employees and customers through frequent essential meetings. Similarly, the results identified a trend of frequent words for creating an environment of success and a focus on action, suggesting that leadership within high-performing organizations creates an environment of success that focuses on actions by creating goals that enhance culture, organizational learning, and performance. These trends are similar to prior literature in that leadership can influence and encourage communication (Bouma et al., 2023), strategically identify areas needed for improvement and actions needed (Dessler, 2014), and propel an organization towards high performance (Blanchard, 2010).

This research is important because it examines leadership processes within successful, high-performing organizations. Low-performing organizations are often the byproduct of inadequate leadership resulting in employees being reluctant to communicate even at the expense of the task (Bouma et al., 2023), toxic organizational culture, and general task inefficiency from low performance. Understanding the leadership processes within high-performing organizations and identifying common themes among their leadership systems will provide a framework for future organizations to learn from and adapt to. Successful leadership systems can positively impact employee engagement, performance, and satisfaction, leading to greater overall organizational success.

This study analyzed nine applications from former award-winning organizations, which was a limitation to this research. Future research should perform a frequency analysis on additional applications to confirm our findings. Additionally, future research wants to examine the second leadership aspect of governance since that subcategory contributes to the organization's total overall leadership score. This research provides a first glimpse into the thematic similarities within the leadership systems of high-performing organizations.

7. Disclaimer Statements

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8. References

Baldrige Performance Excellence Program. 2021. 2021-2022 Baldrige Excellence Framework: Proven Leadership and Management Practices for High Performance. Gaithersburg, MD: U.S. Department of Commerce, National Institute of Standards and Technology. https://www.nist.gov/baldrige.

Blanchard, K. H. (2010). Leading at a higher-level Blanchard on leadership and creating high performing organizations (Rev. and expanded ed.). FT Press.

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Bouma, D., Canbaloğlu, G., Treur, J., & Wiewiora, A. (2023). Adaptive network modeling of the influence of leadership and communication on learning within an organization. Cognitive Systems Research, 79, 55–70. https://doi.org/10.1016/j.cogsys.2023.01.003

Dalia, S., Asta, M., Lina, D., & Kyriakopoulos, G. (2021). Assessment of the role of a leader in shaping sustainable organizational culture. Amfiteatru Economic, 23(57), 483–503. https://doi.org/10.24818/EA/2021/57/483

Dessler, G. (2014). A framework for Human Resource Management. Pearson.

Hassan, S., & Hatmaker, D. M. (2015). Leadership and performance of public employees: effects of the quality and characteristics of manager–employee relationships. Journal of Public Administration Research and Theory, 25(4), 1127–1155. https://doi.org/10.1093/jopart/muu002

Krier, L. (2022). A framework for shared leadership: A perspective on strategic planning for academic libraries. The Journal of Academic Librarianship, 48(6), 102503–. https://doi.org/10.1016/j.acalib.2022.102503

Kuenzi, M., Mayer, D. M., & Greenbaum, R. L. (2020). Creating an ethical organizational environment: The relationship between ethical leadership, ethical organizational climate, and unethical behavior. Personnel Psychology, 73(1), 43–71. https://doi.org/10.1111/peps.12356

Leonard, K., & Pakdil, F. (2016). Performance leadership (First edition.). Business Expert Press.

Sandström, B., Willman, A., Svensson, B., & Borglin, G. (2015). Perceptions of national guidelines and their (non) implementation in mental healthcare: A deductive and inductive content analysis. Implementation Science: IS, 10(1), 43–43. https://doi.org/10.1186/s13012-015-0234-0

Saunders, M., Lewis, P., & Thornhill, A. (2009). Research Methods for Business Students (Fifth edition.). India: Pearson Education

Spark, A., Schweitzer, D., & Ting, J. (2023). Leveraging personality science to enhance junior doctor well-being, leadership and performance: It's not just about who we are, but also how we act. Internal Medicine Journal, 53(7), 1100–1104. https://doi.org/10.1111/imj.16158

"Three organizations win 2021 Baldrige awards for performance excellence." (2022), NIST, https://www.nist.gov/news-events/news/2022/03/three-organizations-win-2021-baldrige-awards-performance-excellence

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A CONCEPTUAL FRAMEWORK FOR THE SUCCESSFUL IMPLEMENTATION OF RAPID IMPROVEMENT EVENTS

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Abstract

Rapid Improvement Events (RIE) are the most common application of Lean principles and practices in the Higher Education (HE) environment to remove waste and improve the flow of university processes. But not all RIE are successful. The literature was reviewed to identify how the steps taken before, during, and after the execution of an RIE may influence its outcomes. Findings highlight several potential errors that may contribute to the failed implementation of RIE and broader concerns about the applicability of Lean in HE.

Keywords: *Rapid Improvement Event, RIE; Lean Success; Lean Failure; Lean Higher Education*

1. Introduction

Krafcik (1988) introduced the term Lean to describe the principles and practices of the highly successful Toyota Production System that emphasizes "continuous improvement and respect for people as key to strategic business philosophy" (Balzer et al., 2016, p. 442). Key principles include defining value from the customer's perspective, understanding the value stream, creating smooth flow, responding to pull, and perfection across all processes of the organization. The Lean management system expanded from the automotive industry to include every industry sector such as manufacturing, healthcare, government, service and transaction-based industries, and higher education (Balzer et al., 2019).

Interest in implementing Lean in higher education (LHE) has increased over time, resulting in a worldwide footprint (Balzer, 2020; Thomas et al., 2015). The application of Lean principles and practices at HE institutions includes 5S (organizing and managing an effective workplace), Daily Lean (day-to-day work practices by teams to manage and improve work), Hoshin Planning (integrated strategic planning and deployment), and Structured Problem Solving (standardized approach for effectively solving problems (see Balzer, 2020, pp. 157-160). Our focus, however, is on the Rapid Improvement Event (RIE; also referred to as kaizen, kaizen blitz, and more) to remove waste and improve the flow of processes. The RIE is an especially important area of study given its almost universal use in HE (i.e., Balzer (2020, Chapter 3) reports that 92% of the LHE initiatives across sixteen HE institutions were RIEs) and its rich application in non-academic support processes (e.g., admissions, hiring) and natural extension to core academic processes (e.g., teaching and learning; Balzer, 2015; Emiliani, 2015; Wiegel, 2020).

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Despite its ubiquity, not all RIE are successful, and the causes of their failure are difficult to diagnose (and hopefully remedy in the future). With rare exceptions (e.g., Cano et al., 2014; Shannon, 2020; Waterbury, 2011), RIE failures are difficult to find and document. For example, Cano et al. (2014) found that their initial roll out of RIE to eliminate waste in administrative processes was not fully successful due, in part, to misperceptions of lean philosophy, inadequate leadership support, and inadequate LHE training and support. Numerous authors (Albliwi et al., 2014; Antony & Gupta, 2019; Secchi & Camuffo, 2019) have speculated on the broad causes of the failure of Lean across all sectors (including HE); evidence, however, is limited. Our research question focused on identifying whether decisions made before, during, and after the execution of RIE may impact negatively on their outcomes. This paper proposes a framework for understanding how characteristics of the RIE may affect its failure or success. We apply this framework to catalog activities that may limit RIE success and suggest potential countermeasures that project sponsors and RIE practitioners may use to improve RIE outcomes. We conclude with limitations to our study as well as implications for future RIE practice and research.

2. Design/Methodology Approach

This paper presents a conceptual framework for considering the critical-to-quality activities which are common to most RIE. The framework proposes three RIE phases that are critical to the implementation of LHE: Phase I – Before the RIE (planning for the event); Phase II – During the RIE (doing the event); and Phase III – After the RIE (implementing the outcomes of the event). This framework, based on Balzer's (2020, Chapter 5) integration of RIE models across a large number of universities, is used to review the literature and document the critical role of actions or decisions directly related to each of the phases of the RIE that may limit RIE implementation, outcomes, and their overall success.

The authors conducted a literature review by searching the Emerald Insight, Proquest Research Library, and Taylor and Francis databases for peer reviewed articles published between 2010 and 2019 using the following keyword combinations: lean, failure, higher education; and kaizen, failure, higher education. Findings resulted in very few peer-reviewed articles on LHE during that time frame, and none of them specifically looked at RIE. The search was then widened to include books published by academic publishers and conference proceedings. The lack of empirical data available as a limitation is elaborated upon further in the Limitations and Future Research Opportunities section, while also noting that research benefits from practitioner insight (Chakraborty & Leyer, 2013).

3. RIE Success – and Failure

Numerous studies document the successful application of RIEs to processes and activities across all businesses and organizations (Balzer et al., 2019). In contrast to these positive reports, speculations on Lean failure rates have ranged from 50% to as high as 95% (Richter, 2011; Scoggin, 2017). Like other industry sectors, HE institutions also may be reluctant to publicize their failures (Albiwi et al., 2014; Balzer, 2020, pp. 365-369; Farris et al., 2008). In addition, the review process at research journals generally preferences studies where positive outcomes are reported (Rosenthal, 1979). This is disappointing because applying a rigorous LHE-structured problem-solving approach (e.g., Five Whys, Cause-and-Effect Diagram) to understand the root causes of failure can identify better approaches for future implementations of RIE, including the identification of countermeasures in anticipation of potential challenges (Balzer, 2020; Emiliani, 2017).

Factors that are commonly acknowledged to contribute to RIE failure include lack of leadership involvement/leadership resistance (Albliwi et al., 2014; Antony & Gupta, 2019; Secchi & Camuffo, 2019) and organizational culture/climate (Glover et al., 2015; Liker, 2004, Chapter 2; Shinkle et al., 2004, Chapter 5; Womack et al., 1991, Chapter 4). These factors are equally prominent in the HE literature as well (Balzer, 2020, Chapter 4; Bennett & Perkins, 2020; Maciag, 2019). Some studies reported on specific factors that may contribute to RIE failure including the lack of knowledge of Lean either through poor team selection or poor training programs (Antony & Gupta, 2019; Jadhav et al., 2014; Secchi and Camuffo, 2019; Sreedharan et al., 2018), poor project selection (Albliwi et al., 2014), and the application of LHE as an amalgam of disconnected projects and tools rather than a coherently implemented business strategy (DeLuzio, 2020).

Overall, while these authors make important contributions to a growing catalog of possible factors for RIE success or failure, there is limited empirical evidence supporting the causality of these suggested factors (Secchi & Camuffo, 2019), nor an organizing conceptual framework or model to guide our thinking on the critical factors contributing to RIE implementation and continued sustainability. To help advance RIE practice and research, we present a conceptual framework that proposes how aspects of the RIE itself may influence implementation. The goal of this framework is to provide a useful model for a coordinated investigation into which factors may be most critical to RIE failure, where “failure” has been described in the literature as both outright failure or suboptimal implementation. The conceptual framework that follows documents activities before, during, and after RIE that may improve their overall probability of success.

4. Exploration of Process Steps in RIE Failure

Figure 1 presents our conceptual framework for exploring how the actions or decisions at many points of an RIE may contribute to failure. Problems with many activities at any phase of the RIE may limit its success and directly contribute to overall failure of the institution’s LHE initiative. The three chronological phases in our proposed RIE process framework are based on Balzer’s (2020) consolidation of the phases employed at seven US and UK universities: (a) Phase I involves the selection of the process to be improved and preparation for the RIE; (b) Phase II includes those activities that occur during the RIE; and (c) Phase III are activities that follow the conclusion of the RIE. These activities are embedded in the larger context of institutional practices that are pervasive and can directly influence RIE process and outcomes. In the sections that follow, we discuss both institutional practices and the decisions or actions related to each activity during the three phases of the RIE that may contribute to its failure. Examples are drawn from published research, practitioner experiences, and informed conclusions from our review of the literature. Overall, this conceptual framework presents a more systematic examination of how institutional practices and actions taken before, during, or after the RIE may limit the immediate implementation of improvements to a process and effectiveness in sustaining RIE outcomes.

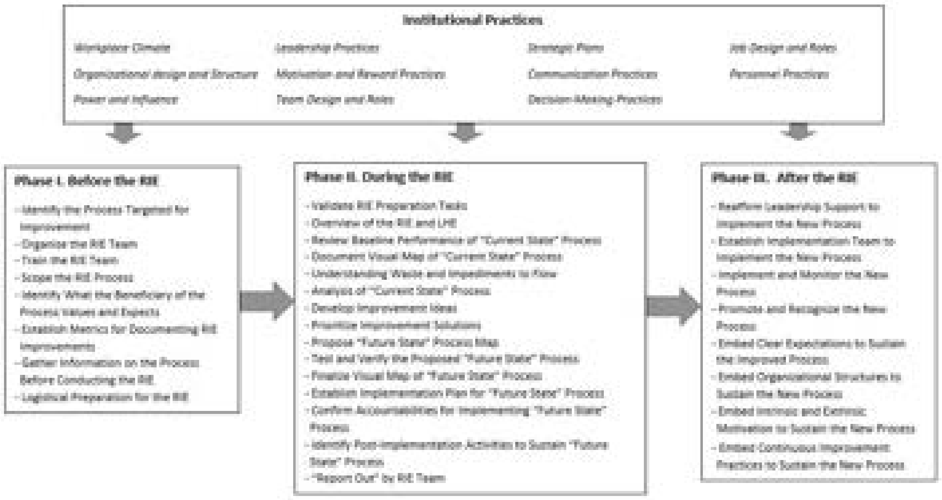

Figure 1. Conceptual Framework: The Role of the RIE in Lean Failure

4.1. Institutional Practices

According to our conceptual framework, the actions and activities taken during an RIE occur within a larger context of existing institutional practices that, individually and together, influence workplace perceptions, attitudes, and behaviors (Balzer, 2020, Chapter 4). Table 1 identifies eleven institutional practices (e.g., organizational design and structure, job design and roles, team design and roles) that work together in an interlocking fashion to influence what employees do. Several of these institutional practices are known or hypothesized to be associated with RIE success or failure. For example, there is an extensive body of research linking both organizational culture and leadership practices to RIE success/failure (e.g., Bennett & Perkins, 2020; Glover et al., 2015; Liker, 2004; Rother, 2010; Shinkle et al., 2004; Womack et al., 2007). Other institutional practices may also impact RIE success: communication practices that fail to underscore the need for change (Fiume, 2007, p. 64); the misalignment of organizational design and structure to support the implementation of RIEs (Womack & Jones, 2005, Chapter 8); and failure to redesign jobs and roles so that incumbents have more autonomy and responsibility to implement changes that flow from the RIE (Balzer, 2020, Chapter 4). Individually or together, these eleven institutional practices can positively or negatively influence an RIE event or general effectiveness of a broader RIE program. The factors leading to lean failure presented at the beginning of this section (e.g., climate/culture, team selection, and leadership practice) are engrained in, and influenced by, institutional practices. Overall, we propose that these institutional practices may directly or indirectly affect the three chronological phases of the RIE process.

4.2. Phase I: Activities That Occur Before the RIE That May Contribute to RIE Failure

Identify the Process Targeted for Improvement. RIEs may fail because of inadequate methods for identifying the processes targeted for improvement (Albliwi et al., 2014; Sony et al., 2019; Sunder, 2013; Waterbury, 2015). Selecting processes that do not align with the priorities of the institution or unit may fail to garner necessary support to implement and sustain any significant improvements identified through the RIE (Albliwi et al., 2014; Waterbury, 2015). Farris et al. (2008) also suggest that the success of the RIE may be limited if its goals are presented in a top-down manner from senior leadership and without involvement by the RIE team. The lack of an explicit method and established criteria for identifying the targeted process may result in the politicization of LHE, contributing to perceptions that LHE is arbitrary and capricious (Farris et al., 2008).

Organize the RIE Team. Poor selection of team members may contribute to RIE failure (Antony & Gupta, 2019). For example, appointing a team where no (or few) member possesses deep knowledge of the process may provide limited insight into the "current state" process. The failure to include representation from key areas to improve a cross-functional process may limit the appropriateness and acceptability of the team's solution and reduce the likelihood of post-event implementation (Albliwi et al., 2014; Farris et al., 2008).

Train the RIE Team. The content, design, and delivery of LHE training may contribute to the failure of the RIE (Albliwi et al., 2014; Antony & Gupta, 2019; Secchi & Camuffo, 2019; Sony et al., 2019; Sreedharan et al., 2018; Waterbury, 2015). Training content that is deficient (e.g., examples of waste are not tailored to the HE environment), poorly designed (e.g., information on process mapping is incomplete or unclear with limited practice and feedback), and delivered inconsistently (e.g., rushed during the RIE) could affect the quality of work done during the RIE.

Scope the RIE. The project scoping step during the RIE may contribute to RIE success or failure (Antony & Gupta, 2019; Robinson, 2020). Inadequate scoping may result in outcomes that are too broad or nebulous, making them hard to measure and achieve (Sony et al., 2019). Similarly, narrowly limiting the RIE scope may cause it to be misaligned with the goals of the unit(s) sponsoring the RIE, affecting only a negligible number of constituents and resulting in no or low demonstrable ROI.

Identify What the Beneficiary of the Process Values and Expects. RIEs may fail when they inadequately articulate the needs of the beneficiaries or fail to include the right people (i.e., process owners, beneficiaries of the process, employees who perform the process) in establishing RIE goals and outcomes (Radnor & Osborne, 2013; Robinson, 2020; Womack, 2020; Sony et al., 2019). Overpromising, or failing to recalibrate unrealistic expectations prior to conducting the RIE (e.g., frustrating RIE team members with unachievable improvement goals), may also contribute to RIE failure (Farris et al., 2008; Sony et al., 2019).

Establish Metrics for Documenting RIE improvements. RIE failure may occur if it does not include adequate metrics (e.g., quality, operational delivery, financial, employee experience) to assess and document improvements to the process (Radnor & Osborne, 2013; Sony et al., 2019). For example, failure to include cycle or lead time as an important metric will make it difficult for team members to prioritize improvement solutions relevant to this metric.

Gather Information on the Process Before Conducting the RIE. Failure may occur if there is inadequate baseline data gathered on established metrics. In the absence of documented change from the current to new process on established metrics, sponsors may conclude there is no ROI (Albliwi et al., 2014). In addition, the lack of qualitative and quantitative evidence of the baseline performance of the process pre-RIE may also lead to poor prioritization of where improvements are needed as well as whether the actions implemented following the RIE resulted in improvement.

Logistical Preparation for the RIE. RIE failure may occur when there is inadequate investment of resources (e.g., people, space, technical, financial, and local management commitment) to prepare, conduct, and implement a successful RIE (Albliwi et al., 2014; Farris et al., 2008; Secchi & Camuffo, 2019; Sony et al., 2019). This may be particularly problematic for an institution just beginning its LHE journey with no established model of RIE logistical support, resulting in RIE failure due to under-resourcing (Waterbury, 2015).

4.3. Phase II: Activities That Occur During the RIE That May Contribute to RIE Failure

Validate RIE Preparation Tasks. As noted earlier, activities prior to conducting the RIE can contribute to failure. Inadequate sharing and verification of earlier foundational work with the RIE team can contribute to RIE failure (e.g., "scope creep" by team members during the RIE, an unclear understanding of what the beneficiary wants or expects). An extended amount of time between pre-RIE activities and the start of the RIE that can lead to training decay and team member attrition may also contribute to failure.

Overview of the RIE and LHE. Failure to provide a clear overview to team members and key constituencies (project sponsors, and others who will serve as resources during the RIE) of the RIE and its place in the larger institutional context of LHE can lead to RIE failure (Albliwi et al., 2014). For example, if RIE liaisons from ITS or legal affairs are unavailable for "on demand" consultation to the RIE team, their inadequate support may limit the effectiveness of the RIE.

Review Baseline Performance of "Current State" Process. RIE failure can occur if team members have a limited or inaccurate understanding of the baseline "current state" performance of the process targeted by the RIE. Team members, for example, may fail to grasp significant process issues based on a cursory review of a small sample of quantitative metrics and without supplemental qualitative information to enrich their interpretation.

Document Visual Map of "Current State" Process. RIE failure can occur when team members are not actively engaged in creating the visual map (e.g., team members defer the mapping to an overzealous RIE facilitator, the visual map is created by a subset of team members, an inexperienced facilitator is unable to guide the team's capture of an accurate and understandable visual map). Shortcomings during the mapping process can limit team members' contributions to recommending solutions to improve the targeted process.

Understand Waste and Impediments to Flow. RIE failure can occur when team members lack a useful framework for identifying waste and impediments to flow. For example, the rubric provided for understanding the various types of wastes may not be tailored to the process being studied (e.g., manufacturing descriptions of waste misaligned with HE processes). In addition, the self-serving cognitive biases of RIE team members may make it difficult for them to see how their own roles in the process are wasteful or impede flow, thereby failing to surface all wastes and impediments for removal.

Analyze the "Current State" Process. RIE failure can occur when the analysis of the current state process is superficial and fails to bring all wastes and impediments (and their root cause) to the surface (Albliwi et al., 2014; Antony & Gupta, 2019). Rushing the analysis, limited training, and poor facilitation may contribute to a more limited understanding of the current state process (and subsequent solutions generated). In addition, choosing to ignore politically or personally sensitive waste in the current process (e.g., a process step that adds no value but is favored by a senior administrator) may undercut the integrity of the RIE and the general perception of LHE by employees and leaders alike.

Develop and Prioritize Improvement Ideas. RIE failure can occur when the quantity and quality of prioritized improvement ideas are incomplete or biased. For example, it is not uncommon for RIE team members (as well as sponsors and others) to propose well-intentioned improvement ideas before a comprehensive analysis of the current state process is completed, and these early ideas may fail to address root causes or align with the what the beneficiary of the process values and expects. Balzer (2020) reports that technology is frequently suggested to improve a process before the process is rid of waste and impediments to flow.

Propose, Test, Verify, and Finalize "Future State" Process. RIE failure can occur when the RIE team fails to integrate proposed solutions and validate that the new process will deliver the expected results. A pitfall of the validation process is to believe that expected results will occur without a full exploration as to whether the revised process will achieve the desired state (i.e., problems are overlooked or glossed over), resulting in a failed RIE that reflects negatively on the application and benefits of LHE.

Establish Implementation Plan and Confirm Accountabilities for Implementing the "Future State" Process. RIE failure can occur when the implementation plan and those accountable for making and monitoring the new process are inadequate for creating the changes required by the "future state" process. The RIE team may underestimate the challenge of "selling" the actions required to implement the new process to affected stakeholders who were not on the RIE team (i.e., the owner of the process and the employees who perform the process). In addition, team members documentation of the implementation plan for the redesigned process may fail to provide adequate detail for those were not closely involved in developing it but are expected to enact it..

Identify Post-Implementation Activities to Sustain "Future State" Process. Regression or backsliding to the former current state process is a concern. RIE failure can occur if the team fails to provide a clear and comprehensive roadmap for those charged with implementing the "future state" process following the team's disbandment. For example, failing to deliver a well-documented process that is fully endorsed by senior leadership and monitored by an accountable party on metrics that matter is likely to regress back to the original process.

"Report Out" by RIE Team. RIE failure can occur if the report out by the RIE team fails to generate interest and support from local leaders who will be critical to implement and sustain the "future state" process. This can occur when report outs are not held, are not attended by key leaders and administrators, or when they are not presented in a clear and concise manner and fail to show actual or expected improvements on metrics of importance to leaders that are connected to institutional strategy.

4.4. Phase III: Activities That Occur After the RIE that May Contribute to LHE Failure

Reaffirm Leadership Support to Implement the New Process. RIE failure can occur when local leadership support for the new "future state" process decays over time or is withdrawn (Albliwi et al., 2014; Antony & Gupta, 2019; Secchi & Camuffo, 2019; Sony et al., 2019). Lack of leadership support for the new process may indicate that earlier concerns were not identified or the level of improvements expected is unmet.

Establish Implementation Team to Implement the New Process. RIE failure may occur if the implementation team does not possess the right skills and knowledge to implement the new process (Balzer, 2020, p. 258). Likewise, delegating RIE implementation to Lean experts rather than the process owner and employees who conduct the process can negatively impact commitment to implementing the new process (Secchi & Camuffo, 2019, p.152; Shannon, 2021, p. 39).

Implement and Monitor the New Process. Lack of immediate follow through with implementing RIE results may sap enthusiasm and momentum and contribute to RIE failure. Poor knowledge transfer from the RIE, due to insufficient documentation (e.g., new process map, action plan, RACI chart) and inadequate metrics to track the success of the new process (and implement countermeasures if needed) may also lead to RIE failure.

Promote and Recognize the New Process. RIE failure can occur if there is not clear communication and appropriate support to sustain the newly implemented process. While the RIE team develops a deep understanding and need for the "future state" process, in the absence of a plan to promote the new process many (including those with a role in the new process) will only learn of changes during implementation, limiting buy in and support from the wider university community.

Embed Clear Expectations to Sustain the New Process. RIE failure may occur due to unclear or unrealistic expectations of leaders and employees needed to sustain the "future state" process. Confusion over responsibilities (e.g., lack of clarity in the process map or RACI chart) can contribute to backsliding to the former "current state" process. In addition, the absence of ongoing support from leaders may inadvertently send the message that RIE implementation is no longer a priority.

Embed Organizational Structures to Sustain the New Process. RIE failure may occur when there is no office or person responsible to oversee its successful short- and long-term implementation. The lack of post-RIE monitoring of the new process on critical performance metrics to reinforce accountability and success can also contribute to RIE failure (Albliwi et al., 2014, p. 1022; Antony & Gupta, 2019; Sony et al., 2019).

Embed Intrinsic and Extrinsic Motivation to Sustain the New Process. RIE failure may occur if people are not motivated to sustain the new process. Many of the earlier activities discussed can reduce both intrinsic (e.g., no acknowledgement of employee effort during the change process) and extrinsic motivation (e.g., no promotion of the RIE or celebration of achievement by the university, no accountability for RIE outcomes among senior staff) (Albliwi et al., 2014, p. 1022).

Embed Continuous Improvement Practices to Sustain the New Process. RIE failure may occur if the university lacks LHE awareness and education by a critical number of employees at all levels to ensure continuous improvement practices are widely understood, implemented, and supported. The RIE may also fail if it is viewed as a one-off activity and not in the broader context of strategic improvement goals for the HE institution to be successful.

5. Summary and Discussion

The Lean literature suggests numerous factors contribute to the failed implementation of RIE, arguably the most ubiquitous Lean application in LHE. However, the absence of an available framework for organizing, understanding, and addressing the role that each may play in RIE effectiveness has stymied progress in recognizing and improving RIE practice and research. Our conceptual framework (Figure 1) systematically examined how decisions or activities at each step of the RIE may contribute to LHE success or failure. Whether under the control of an established protocol for conducting RIE, or the idiosyncratic choices of RIE sponsor and/or facilitator in the absence of an established protocol, our framework and supporting arguments suggest that each RIE phase and its associated steps can affect the failure – or success – of the application of RIE and their short- and long-term impact on critical processes and activities in the HE workplace. While the list of potential errors discussed is not exhaustive, and supportive research for all components is lacking at this time, it is reasonable to speculate that some of these errors before, during, or after RIE may be so egregious that their occurrence will result in the failed implementation of RIE and the broader credibility of LHE.

Our framework in Figure 1 also acknowledges how the broader set of Institutional Practices, which are not directly referenced in an established RIE protocol or idiosyncratic to particular RIE sponsors and/or facilitators, may affect (positively or negatively) the before, during, and after phases of the RIE. Leadership practices, workplace climate/culture, and other Institutional Practices may influence one or more of the three phases of the RIE process. For example, the institution's strategic plan may provide very clear guidance on identifying the process targeted for improvement (Phase I:

Before the RIE). As a second example, Hackman (2011) provides strong evidence that team design and role practices are critical to ensuring successful team performance (Phase I: Organize the RIE Team). Thus, these overarching Institutional Practices affect the successful implementation of RIE and are worthy of further study.

6. Implications for Practice

RIE sponsors and facilitators should give careful thought when conducting the before, during, and after phases of the RIE. Figure 1 includes those critical steps and activities that are commonly included to support RIE success. While evidence-based guidance is lacking, LHE authors offer many best practices. Balzer (2020; Chapters 4 and 5) synthesizes best practices when preparing, conducting, implementing, and sustaining RIE. Yorkstone (2020) includes recommended approaches (e.g., training) and tools (e.g., project scoping) for successful RIE. Numerous RIE publications outside HE provides additional views on best practices that may be easily adaptable in HE settings (Cunningham, 2007; Hafey, 2017; Imai, 1997; Lareau, 2003).

Recognition of potential points of failure across the three RIE phases can help project sponsors and RIE facilitators anticipate and respond to problems that could derail its successful implementation. For example, limited interest and support from leaders critical to the implementation of the "future state" during the report out by the RIE team can significantly affect short- and long-term RIE success. By analyzing the report out phase using a risk reduction tool such as Failure Mode Effects and Analysis (FMEA), the sponsor/facilitator can identify both unforeseen failure modes and actions to mitigate the chance of RIE failure (e.g., deploying countermeasures to increase leader support). In circumstances where unanticipated failure does occur, a rigorous structured problem-solving approach using Lean tools (e.g., Five Whys, cause-and-effect diagram) can be used to identify root causes of this failure to prevent its reoccurrence in the future (Emiliani, 2017). Together, these efforts can improve the experiences of students, employees, and other HE constituents, burnish the role of RIE in increasing the value and performance of critical HE processes, and support the broader successful application of LHE.

Finally, our conceptual framework and review focuses almost exclusively on the RIE, the most common application of Lean in HE. The RIE, however, is one component of a more comprehensive LHE management system including strategic planning and deployment, organizing and standardizing the workplace, day-to-day work practice by employees to manage and improve their work, a systematic approach to structured problem solving, and more (Balzer, 2020, Chapter 5). In addition, conducting RIE without incorporating both Lean pillars of "Continuous Improvement" and "Respect for People" may provide initial short-term benefits that are unlikely to lead to the long-term transformation to the Lean Management System (Chartier & Paoli, 2012, cited in Balle' & Garcia-Mella, 2021). As they note, the full benefits of Lean come not from the successful application of RIEs but the development of a true learning culture which teaches and empowers all employees to find better ways to meet the expectations of the beneficiaries they serve (e.g., current and prospective students and parents, faculty and staff, alumni and donors, etc.). The RIE, while important, must be part of the bigger picture of a total Lean implementation to assure success.

7. Limitations and Future Research Opportunities

We present a useful conceptual framework for understanding RIE failure and success drawn almost exclusively from qualitative sources (e.g., cases studies, reviews, position papers) and insights based on the authors' own experiences as practitioners (as well as suggestions received from practitioners and researchers when an earlier version of this paper was presented at an international conference). The authors recognize that more rigorous, empirically based research is needed in LHE generally (Balzer, 2015; Balzer, 2020, Chapter 9; Balzer et al., 2016). While such efforts may be beyond the expertise and resources of RIE sponsors and facilitators, LHE practitioners can collaborate with researchers (e.g., faculty and graduate students) to establish more robust and reliable data. It is also important to note that even the definition of 'failure' is loose, with some defining failure as not achieving all the intended benefits (e.g., Antony et al., 2023). Others may consider that to be at least a partial success.

Future efforts to design and conduct studies to assess potential points of failure at the three RIE phases (before, during, and after) and whether and how existing Institutional Practices (e.g., workplace climate, leadership practices) may moderate the relation between RIE activities and the successful implementation of RIEs are needed. In particular, aspects of Institutional Practices unique to higher education (e.g., academic freedom, historical structure of higher education institutions, etc.; Emiliani, 2015; Yorkstone, 2017) may be uniquely important to RIE success and failure in higher education, especially when core academic processes are the target of improvement (Balzer, 2020; Chapter 7). Consideration of the unique culture of HE also may be beneficial (e.g., Kluse & Shannon, 2022). Further empirical research can inform the value of RIE to HE and serve to validate why RIE should continue as the primary vehicle for lean in HE.

8. Disclaimer Statements

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9. References

Albliwi, S., Antony, J., Lim, S. A. H., & van der Wiele, T. (2014). Critical failure factors of Lean Six Sigma: A systematic literature review. International Journal of Quality and Reliability Management, 31(9), 1012-1030. https://doi.org/10.1108/IJQRM-09-2013-0147

Antony, J., & Gupta, S. (2019). Top ten reasons for process improvement project failures. International Journal of Lean Six Sigma, 10(1), 367-374. https://doi.org/10.1108/IJLSS-11-2017-0130

Antony, J., Sony, M., McDermott, O., Swarnakar, V., Galli, B., Doulatabadi, M., & Kaul, R. (2023). An empirical study into the reasons for failure of sustaining operational excellence initiatives in organizations. The TQM Journal, 35(7), 1569-1587. https://doi.org/10.1108/TQM-05-2022-0176

Balle', M. & Garcia-Mella, A. (2021, June 24). What is a real Lean transformation? Planet Lean: The Lean Global Network Journal. https://planet-lean.com/lean-transformation/

Balzer, W. K. (2015, September 10). Where is the evidence-based support for Lean higher education? The research, the challenge, and the opportunities [Conference session]. Lean HE Hub Conference, University of Waterloo, Ontario CA.

Balzer, W. K. (2020). Lean Higher Education: Increasing the value and performance of university processes (2nd ed.). New York: Routledge. https://doi.org/10.4324/9781351216944

Balzer, W., Brodke, M., Kluse, C., & Zickar, M. (2019). Revolution or thirty-year fad? A role for I-O psychology in Lean management. Industrial and Organizational Psychology, 12(3), 215-233. https://doi.org/10.1017/iop.2019.23

Balzer, W. K., Francis, D. E., Krehbiel, T. C., & Shea, N. (2016). A review and perspective on Lean in higher education. Quality Assurance in Education, 24(4), 442-462. https://doi.org/10.1108/QAE-03-2015-0011

Bennett, N., & Perkins, J., (2020). Developing a culture: The essentials for continuous improvement. In S. Yorkstone (Ed.), Global Lean for Higher Education: A themed anthology of case studies, approaches, and tool (pp. 343-360). Boca Raton, Florida: Taylor and Francis Group, LLC. https://doi.org/10.4324/9780429399688-21

Cano, M., O'Reilly, E., and Kourouklis, A. (2014, August 29). Lean second time around: Lessons learned for higher education. 17th Toulon-Verona International Conference on Excellence in Services, Liverpool, England. http://sites.les.univr.it/eisic/wp-content/uploads/2018/07/Cano-O%E2%80%99Reilly-Kourouklis.pdf.

Chakraborty, A., & Leyer, M. (2013). Developing a six sigma framework: Perspectives from financial service companies. The International Journal of Quality & Reliability Management, 30(3), 256-279. https://doi.org/10.1108/02656711311299836

Cunningham, J. (2007). Lean application in accounting environments. In J. Stenzel (Ed.), Lean accounting: Best practices for sustainable integration (pp. 211-213). Hoboken, NJ: John Wiley and Sons. https://doi.org/10.1002/9781119196808

DeLuzio, M. C. (2020). Flatlined: Why Lean transformations fail and what to do about them. New York: Routledge. https://doi.org/10.4324/9780429284342

Emiliani, B. (2015). Lean university: A guide to renewal and prosperity. Wethersfield, Connecticut: CLBM, LLC.

Emiliani, B. (2017, January 21). Reusable processes. BobEmiliani.com. https://bobemiliani.com/reusable-processes

Farris, J.A., Van Aken, E.M., Doolen, T.L., & Worley, J. (2008). Learning from less successful kaizen events: A case study. Engineering Management Journal, 20(3), 10-20. https://doi.org/10.1080/10429247.2008.11431772

Fiume, O. (2007). Lean strategy and accounting: The role of the CEO and CFO. In J. Stenzel (Ed.), Lean accounting: Best practices for sustainable integration. Hoboken, NJ: John Wiley and Sons. https://doi.org/10.1002/9781119196808.ch3

Glover, W.J., Farris, J.A., & Van Aken, E.M. (2015). The relationship between continuous improvement and rapid improvement sustainability. Industrial Journal of Production Research, 53(13), 4068-4086. https://doi.org/10.1080/00207543.2014.991841

Hackman, J.R. (2011). Collaborative intelligence: Using teams to solve hard problems. San Francisco: Berrett-Koehler Publishers, Inc.

Hafey, R.B. (2017). Lean safety. In T. H. Netland & D. J. Powell (Eds.), The Routledge companion to Lean management. New York: Routledge. https://doi.org/10.4324/9781315686899

Imai, M. (1997). Gemba kaizen: A commonsense, low-cost approach to management. New York: McGraw-Hill.

Jadhav, J. R., Mantha, S. S., & Rane, S. B. (2014). Exploring barriers in lean implementation. International Journal of Lean Six Sigma, 5(2), 122-148. https://doi.org/10.1108/IJLSS-12-2012-0014

Kluse, C., & Shannon, C. J. (2022). Challenges to the implementation of lean practices in higher education: Is the culture in higher education conducive to adoption of lean principles and philosophy? Journal of Management & Engineering Integration, 15(2), 80-91. https://doi.org/10.62704/10057/24827

Krafcik, J. (1988). Triumph of the lean production system. Sloan Management Review, 30(1), 41-51.

Lareau, W. (2003). Office kaizen: Transforming office operations into a strategic competitive advantage. Milwaukee, WI: ASQ/Quality Press.

Liker, J. (2004). The Toyota way: 14 management principles from the world's greatest manufacturer. New York: McGraw-Hill Publishing Company.

Maciag, J. (2019). Lean culture in Higher Education: Towards continuous improvement. Cham, Switzerland: Palgrave Macmillan. https://doi.org/10.1007/978-3-030-05686-5

Radnor, Z., & Osborne, S. P. (2013). Lean: A failed theory for public services? Public Management Review, 15(2), 265-287. https://doi.org/10.1080/14719037.2012.748820

Richter, L. (2011). Cargo cult Lean. Human Resources Management & Ergonomics, 5(2), 84-93. https://frcatel.fri.uniza.sk/hrme/files/2011/2011_2_07.pdf

Robinson, M. (2020). BOSCARD: A Scoping Tool for Lean Continuous Improvement Projects. In S. Yorkstone (Ed.), Global Lean in Higher Education: A themed anthology of case studies, approaches, and tools (pp. 181-196). Boca Raton, Florida: Taylor and Francis Group, LLC. https://doi.org/10.4324/9780429399688-11

Rosenthal, R. (1979). The “file drawer problem” and tolerance for null results. Psychological Bulletin, 86(3), 838-841. https://doi.org/10.1037/0033-2909.86.3.638

Rother, M. (2010). Toyota kata: Managing people for improvement, adaptiveness, and superior results. New

York: McGraw-Hill Education.

Scoggin, S.C. (2017). The interdependency of Lean implementation and organization development (Publication No. 10263384) [Doctoral dissertation, Chicago School of Professional Psychology]. ProQuest Dissertations Publishing.

Secchi, R., & Camuffo, A. (2019). Lean implementation failures: The role of organizational ambidexterity. International Journal of Production Economics, 210, 145-154. https://doi.org/10.1016/j.ijpe.2019.01.007

Shannon, C. (2020). Lessons from implementing Lean at the veterinary teaching hospital. In S. Yorkstone (Ed.), Global Lean for Higher Education: A themed anthology of case studies, approaches, and tools (pp. 311-328). Boca Raton, Florida: Taylor and Francis Group, LLC. https://doi.org/10.4324/9780429399688-19

Shannon, C. (2021). Collaborating problem solving: A guide to improving your workplace. New York: Routledge. https://doi.org/10.4324/9781003095057

Shinkle, G., Gooding, R., & Smith, M. (2004). Transforming strategy into success: How to implement a Lean management system. New York: Productivity Press.

Sony, M., Naik, S., & Therisa, K.K. (2019). Why do organizations discontinue Lean Six Sigma initiatives? International Journal of Quality & Reliability Management, 36(3), 420-436. https://doi.org/10.1108/IJQRM-03-2018-0066

Sreedharan, R. V., Gopikumar, V., Nair, S., Chakraborty, A., & Antony, J. (2018). Assessment of critical failure factors (CFFs) of Lean Six Sigma in real life scenario. Benchmarking: An International Journal, 25(8), 3320-3336. https://doi.org/10.1108/bij-10-2017-0281

Sunder, M. V. (2013). Synergies of Lean Six Sigma. The IUP Journal of Operations Management, 17(1): 22-31.

Thomas, A. J., Antony, J., Francis, M., & Fisher, R. (2015). A comparative study of Lean implementation in higher and further education institutions in the UK. International Journal of Quality and Reliability Management, 32(9): 982-996. https://doi.org/10.1108/IJQRM-09-2014-0134

Waterbury, T. 2011. Educational Lean for higher education: Theory and practice. Raleigh, NC: Lulu Press.

Waterbury, T. (2015). Learning from the pioneers: A multiple-case analysis of implementing Lean in higher education. International Journal of Quality & Reliability Management, 32(9), 934-950. https://doi.org/10.1108/IJQRM-08-2014-0125

Wiegel, V. (2020). Lean in the classroom: The powerful strategy for improving student performance and developing efficient processes. New York: Routledge/Productivity Press. https://doi.org/10.4324/9780429837012

Womack, J. P., Jones, D. T., & Roos, D. (1991). The machine that changed the world: How Japan's secret weapon in the global auto wars will revolutionize western industry. New York: Free Press.

Womack, J. P., & Jones, D. T. (2005). Lean solutions: How companies and customers can create value and wealth together. New York: Free Press.

Womack, J. P., Jones, D. T., & Roos, D. (2007). The machine that changed the world. New York: Free Press.

Yorkstone, S. (2017). Lean universities. In T. H. Netland & D. J. Powell (Eds.), The Routledge companion to Lean management (pp. 449-462). New York: Routledge. https://doi.org/10.4324/9781315686899

Yorkstone, S. (Ed.). (2020). Global Lean for Higher Education: A themed anthology of case studies, approaches, and tools. Boca Raton, Florida: Taylor and Francis Group, LLC. https://doi.org/10.4324/9780429399688

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MEASURING FOOD SAFETY CULTURE IN FOOD MANUFACTURING THROUGH DIFFERENT METRICS

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Abstract

The author of this case study partnered with a food manufacturing facility with fourteen locations internationally and in the United States of America. The facility produces food products that are sold in the retail market. This case study analyzed metrics to measure the food safety culture in the food manufacturing industry.

Keywords: *Food Safety; GFSI; Food Safety Culture*

1. Introduction

The concept of quality food safety culture has received increased attention in the food manufacturing industry in recent years from the FDA (Food and Drug Administration), auditing bodies, and industry. In the field of food safety today, there is much documentation about specific food-borne pathogens, time/temperature processes, post-process contamination, and food safety plans that could be called "hard sciences". However, there has been little information or discussion about human behavior and culture referred to as the 'soft science" until recently. If we review food-borne disease trends in the food industry, it is visible that there are challenges. There is still a lot to do to improve to reduce food-borne incidents, and human behavior is a factor (Yiannas, 2009).

Companies can have a "food safety culture" that can be positive or negative. In a positive culture, food safety is an important business objective, and there is compliance with documented systems. In a negative culture, food safety is not perceived as critical, with other business priorities often dominant, and there is poor compliance with food safety requirements (Griffith, 2010).

This document will investigate how the Food Industry challenges related to Quality and Food safety culture are reasons to measure it to improve an organization's food safety performance, recognizing the challenges with peoples' behaviors. Trying to improve food safety performance is trying to change peoples' behaviors, as Yiannas (2009) states" food safety equals behavior" (p.02).

Methods used to measure Quality and Food Safety Culture include performance standards and awards, social cognitive models, and maturity models (Jespersen, 2014). Internal audits will not provide a full measure of Quality and Food Safety Culture; however, they could be an essential component of a food safety culture metric, and the applications of safety audits will be investigated. The best strategy is to combine multiple food safety metrics.

The research method used was a cross-sectional secondary data analysis using data from a group of food manufacturing plants using several performance metrics that were proposed to describe the

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overall company performance in food safety and selected based on dimensions of the food safety culture as defined by the Global Food Safety Initiative (GFSI).

2. Literature Review

The Global Food Safety Initiative (GFSI) defines food safety cultures as "shared values, beliefs, and norms that affect mindset and behavior toward food safety in, across, and throughout an organization." The definition is derived from existing literature on organizational and food safety culture and made practical and applicable through the group's work (GFSI, 2018).

Food-safety incidents disrupt impacted markets, cause the destruction of edible products, shake consumer confidence, and impose economic losses upon participants across the implicated supply chain (Spalding, et al, 2023). Some of the reasons of food safety recalls include undeclared allergens, pathogens, and foreign materials (Beach, 2023). These are some of the consequences of a poor safety culture.

The model proposed by The Global Food Safety Initiative (GFSI) includes several dimensions as described in Table 1. These dimensions are vision and mission, people, consistency, adaptability, hazards, and risk analysis. Vision and mission communicate a business's reason for existence and how it translates this into expectations and specific messaging for stakeholders. People are a critical component of any food safety culture. Our behavior and activities, from processes on the farm to practices in the kitchen, as well as consumer habits before eating the food, contribute to food safety and potentially decrease or increase the risk of foodborne illness. Consistency refers to the proper alignment of food safety priorities with requirements on people, technology, resources, and processes to ensure the consistent and effective application of a food safety program that reinforces a culture of food safety. Adaptability refers to the ability of an organization to adjust to changing influences and conditions and respond within its current state or move to a new one. This dimension differentiates food safety culture from the broader organizational culture. Recognizing actual and potential hazards and risks at all levels and functions represents a key element to building and sustaining a food safety culture. Basic scientific and technical information should be accessible and understandable to everyone. As a company, it is essential to keep current on the latest industry changes, including market incidents, changes to food safety legislation, significant new technology, and analytical advances. Keeping updated with the industry and regulations will broaden awareness and understanding of potential risks and hazards.

Griffith et al., 2010 describes as having six indicators of safety culture as applicable to studying food safety culture in relation to food safety performance. These are management systems, style and processes, leadership, communication, commitment, environment and risk awareness, perception and risk-taking behavior.

Nayak & Waterson (2016) concluded that food safety culture would vary based on the "characteristics of the work tasks, locations, people involved, etc." Different roles and types of food businesses will call for different attitudes towards food safety, making the measurement of food safety culture more exclusive and difficult.

The implementation of food safety management systems along with other management tools such as Ishikawa, Pareto, and others could help the food industry to avoid the lack of good hygiene practices issues and to effectively and proactively monitor the critical control points (CCPs) and food safety controls. Training of all employees will play an important factor in the positive food safety culture, minimizing any likely risks, hazards, obstacles, and constraints. These steps will be beneficial not only for the company but also for the consumers who will enjoy safe food (Lee, et.al., 2021).

The FDA (Food and Drugs Administration) released a systematic review of the scientific literature on food safety culture (FSC) as a foundation for the FDA's work on food safety culture with industry. The FDA believes that to make improvements in reducing foodborne illnesses, it needs to do more to influence the beliefs, attitudes, and behaviors of people and the actions of the companies. A strong food safety culture is a prerequisite to effective food safety management (FDA, 2022).

3. Problem Statement

In the field of food safety today, there is documentation about food-borne pathogens, lethal control measures, recontamination, and food safety plans that could be called "hard sciences". There has been less information or focus on the human behavior and food safety culture referred to as the "soft science". Food recall activity on the FDA's database for food and beverage has increased during the past years, with 17 recalls in 2020, 74 in 2021, 221 in 2022, and 232 in 2023. Therefore, a need exists to understand the impact of human behavior culture on the number of food-borne incidents in the food processing industry.

4. Research Questions

Q1. Is there any significant difference between the proposed food safety culture metrics among the plants?

Q2. Is there any significant difference between the proposed food safety culture metrics among the region (International and USA)?

Q3. Is there a correlation between performance metrics with maturity matrix score for food safety culture?

Q4. To What extent does the metrics measure food safety culture?

5. Methodology

The research method utilized was cross sectional secondary data analysis. This method collects existent data at a particular point in time for the variables in question. For this research, data from a 12-month time frame was gathered from a group of food manufacturing plants. The company has 14 manufacturing plants, seven international plants, and seven within the USA. The facilities are currently evaluating themselves according to the maturity matrix scores; however, a quantitative measure based on performance is proposed to complement this score due to the limitations of being a self-evaluation by the plant's management team only. Several performance metrics were proposed to describe the overall company performance in food safety. The proposed metrics as indicators of food safety culture are included below in Table 1, indicating the dimension of the food safety culture related to the GFSI Food safety culture model (Vision and Mission, People, Consistency, Adaptability, and Hazard and Risk Analysis).

6. Variable Descriptions

The company has 14 manufacturing plants, seven international plants, and seven within the USA. The facilities are currently evaluating themselves according to the maturity matrix scores; however, a quantitative measure based on performance is proposed to complement this score due to the limitations of being a self-evaluation by the plant's management team only. Several performance metrics are proposed to describe the overall company performance in food safety.

HACCP CAPAs Hazard Analysis and Critical Control Points (CCP) Corrective and Preventive Actions (CAPAs). A HACCP Plan per SQFI (Safe Quality Food Institute), is a document prepared in accordance with the CODEX HACCP method to ensure control of hazards that are significant for food safety or the identification of quality threats for the product under consideration (SQFI, 2020). Corrective and preventive actions are required for deviations from this program. This variable is the total number of CAPAs during the last 12 months.

EMMP CAPAs - **Environmental Microbiological Monitoring Program Corrective and Preventive Actions.** Per SQFI (Safe Quality Food Institute), EMMP is a risk-based environmental monitoring program that is in place for all food manufacturing processes and immediate surrounding areas that impact manufacturing processes. A program that includes pathogen or indicator swabbing as appropriate to detect risks in the sanitary conditions in the processing or food handling environment. Corrective and preventive actions for out-of-specification results in this program are required. This variable is the total number of CAPAs during the last 12 months.

ATP Swabs Compliance Rate (ATP: Adenosine Tri Phosphate Swabs). ATP devices are used to detect the presence of bacteria and organic/food residues on surfaces. ATP swabs are a monitoring parameter for the food, beverage, and healthcare industries (Neogen, 2015). The rate of passing swabs is tracked. The scale for ATP swabs is calculated by counting the number of passing swabs divided by the total number of swabs on food contact surfaces.

Internal Audit Score. The internal audit is conducted unannounced by a corporate auditor; it is based on plant observations and documentation review and covers the following modules: Quality Management, Training and Education, Personnel Practices, Vendor Sourcing and Approval, Grounds, Exterior of Building, Receiving, Handling, Storage and Shipping, Infrastructure & Maintenance, Sanitation, Pest Control, Food Safety - Food Quality/HACCP, Food Safety - Allergen Control, Food Safety - Foreign Material Control, Control of Non-Conforming Materials, Product Tracking, Rework Control and Recall, Food Defense, Regulatory Compliance & Other Process Controls, Document Management & Control. The score is based on the evaluation of risk as follows. The internal audit score is calculated as 100-N, where N is -1 for minor non-conformances, -5 for major non-conformance, and -20 for critical non-conformance.

External Audit Score. The external audit score is based on an external party GFSI certification audit (SQF-Safe Quality Food Program for the plants in question). The internal audit is conducted unannounced; it is based on plant observations and documentation review and covers the following modules: Management Policy, Management Responsibility, Food Safety and Quality Management System, Management Review, Document Control, Records, Food Legislation, Food Safety Fundamentals, Food Safety Plan, Food Quality Plan, Product Release, Validation and Effectiveness, Verification and Monitoring, Corrective and Preventative Action, Internal Audit, Product Identification, Product Trace, Product Withdrawal and Recall, Food Defense, Training Program and Prerequisites programs (SQFI, 2020). The score is based on the following factors: 0 - aspect meets the criteria, 1 - aspect does not meet the criteria due to minor variations (minor non-conformance), 5 - aspect does not meet the criteria (major non-conformance), 50 - aspect does not meet the criteria (critical non-conformance). The score is calculated as (100 – N) where N is the sum of the individual rating criteria (minor or major non-conformances).

Maturity Matrix. Jespersen (2014) developed a maturity matrix model with five capability areas with a scale from 1 to 5 stages.

The five capabilities are: **Perceived Value (A1)** describes the extent to which food safety is seen as only a regulatory must (stage 1) or as critical to business performance (stage 5). **People Systems (A2)** describe if an organization is task-based with signs of misinterpreted accountabilities (stage 1) or responsibilities or if it sets accountability in behavior-based working groups (stage 5). **Process**

Thinking (A3) describes how problems are solved as independent tasks (stage 1), or problem-solving is seen as an iterative process built on critical thinking and data (stage 5). **Technology Enabled (A4)** describes how the organization turns data into information, manually and independently (stage 1) compared to automatically and as part of a company-wide information system (stage 5). **Tools and Infrastructure (A5)** can be illustrated by whether an employee needs to walk far to a sink (stage 1), or sinks are conveniently located (stage 5). Each plant's management team, led by the plant manager and quality manager, self-evaluated the maturity matrix scores.

Table 1. Food Safety Culture and Proposed Metrics

GFSI-Food Safety cultural dimension	Vision and mission	People	Consistency	Adaptability	Hazard and risk analysis.
Metrics	Vision and Mission communicate a business's reason for existence and how it translates this into expectations and specific messaging for its stakeholders (structure, leadership, direction)	People are the critical component of any food safety culture. Our behavior and activities, from processes on the farm to practices in the kitchen, as well as consumer habits prior to eating the food, contribute to the safety of food and potentially decrease or increase the risk of foodborne illness (communication, learning)	Consistency refers to the proper alignment of food safety priorities with requirements on people, technology, resources and processes to ensure the consistent and effective application of a food safety program that reinforces a culture of food safety (performance, documentation)	Adaptability refers to the ability of an organization to adjust to changing influences and conditions and respond within its current state or move to a new one (Crisis Management, problem solving)	Recognizing actual and potential hazards and risks at all levels and functions represents a key element to building and sustaining a food safety culture (Risk awareness, employee engagement).
Internal audit	Covered	Covered	Covered	Covered	Covered
External audit	Covered	Covered	Covered	Covered	Covered
HACCP CAPAs		Covered	Covered	Covered	Covered
EMMP CAPAs		Covered	Covered	Covered	Covered
ATP swab compliance		Covered	Covered	Covered	Covered
Maturity Matrix	Covered	Covered	Covered	Covered	Covered

7. Results

To answer the research questions, several t-tests Paired with Two Sample for Means were conducted to test if there was a significant difference in performance metrics and maturity index scores based on the regions (International Vs. USA). An ANOVA, Single Factor test for Performance Metrics and Maturity Matrix scores and coefficient of determination (r2) between performance metrics and maturity Matrix scores were also used.

Table 2 summarizes the internal and external audits. The manufacturing plants were sorted by region, International, and USA locations. The plants' locations are anonymous in Table 2. Scores for internal audits are lower than external audits for the same plant.

Table 2. Audit Report Scores

Region	Plant	Internal Audit (0-100)	External Audit (0-100)
International	PI1	85	95
International	PI2	91	96
International	PI3	89	96
International	PI4	77	85
International	PI5	84	97
International	PI6	74	95
International	PI7	96	98
US	PU1	65	95
US	PU2	75	92
US	PU3	85	97
US	PU4	79	95
US	PU5	66	93
US	PU6	66	94
US	PU7	89	98

Table 3 shows the performance scores for the parameters available ATP swab compliance (A), Internal Audit (B), and External Audit (C). These scores are raw data collected for each manufacturing plant; for comparison, the scores were transformed to a scale from 1 to 5. Table 4 has the performance scores on a scale of 1-5, adding the maturity matrix scores from self-evaluation.

Table 3. Food Safety Scorecard for 12 Months

Region	Plant	HACCP CAPA's	EMMP CAPA'S	ATP Swabs Compliance
Int.	PI1	15	28	94.3
Int.	PI2	1	41	96.1
Int.	PI3	2	2	100
Int.	PI4	16	60	95.9
Int.	PI5	3	2	95.5
Int.	PI6	2	3	87.8
Int.	PI7	0	49	98.6
US	PU1	1	41	95.3
US	PU2	0	27	97.3
US	PU3	1	18	95.5
US	PU4	0	28	94.9
US	PU5	1	58	97.6
US	PU6	1	82	99.5
US	PU7	0	41	95.3

Table 4. All Scores Converted to a 1 – 5 Scale

Region	Plant	HACCP CAPA	EMMP CAPA	ATP Swabs	Internal Audit	External Audit	Value (A1)	People (A2)	Process (A3)	People (A4)	Tools (A5)	P = Performance Score	M = Maturity Avg.	Overall Score
Int.	PI1	3	4	4.7	4.3	4.8	3	2	3	2	2	4.1	2.4	3.3
Int.	PI2	5	2	4.8	4.6	4.8	3	3	3	3	3	4.2	3	3.6
Int.	PI3	5	5	5.0	4.5	4.8	3	2	2	3	2	4.9	2.4	3.6
Int.	PI4	3	2	4.8	3.9	4.3	2	2	3	3	3	3.6	2.6	3.1
Int.	PI5	5	5	4.8	4.2	4.9	3	3	3	3	3	4.8	3	3.9
Int.	PI6	5	5	4.4	3.7	4.8	3	3	3	3	3	4.6	3	3.8
Int.	PI7	5	2	4.9	4.8	4.9	3	3	3	3	3	4.3	3	3.7
US	PU1	5	2	4.8	3.3	4.8	3	2	2	3	3	4.0	2.6	3.3
US	PU2	5	4	4.9	3.8	4.6	3	2	2	3	3	4.4	2.6	3.5
US	PU3	5	4	4.8	4.3	4.9	3	2	3	3	3	4.6	2.8	3.7
US	PU4	5	4	4.7	4.0	4.8	3	2	3	3	3	4.5	2.8	3.6
US	PU5	5	2	4.9	3.3	4.7	2	2	2	3	3	4.0	2.4	3.2
US	PU6	5	1	5.0	3.3	4.7	3	2	3	3	3	3.8	2.8	3.3
US	PU7	5	2	4.8	4.5	4.9	3	3	3	3	3	4.2	3	3.6

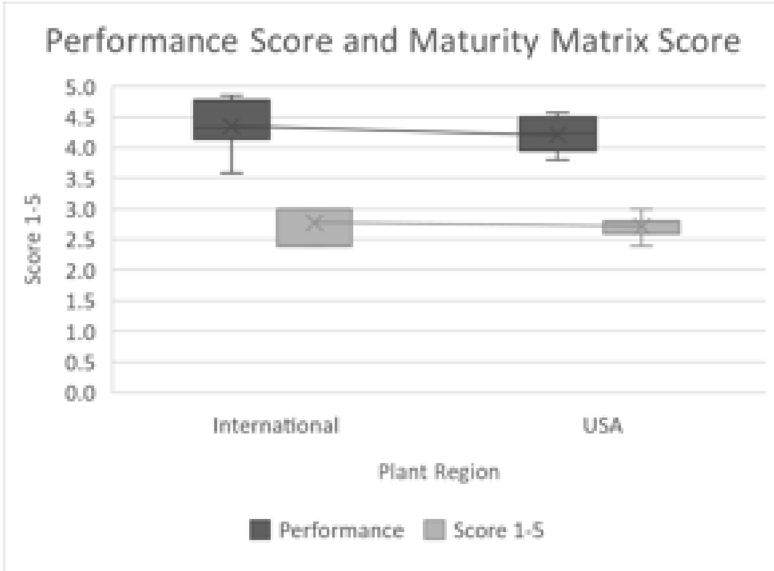

Figure 1. Performance and Maturity Scores by Region (Int. vs USA)

Table 5. Paired Two Sample for Means f (Int. vs USA)

	Int.	USA
Mean	4.437	4.206
Variance	0.214	0.094
Observations	7	7
Pearson Correlation	-0.067	
Hypothesized Mean Difference	0	
df	6	
t Stat	1.0692	
P(T<=t) one-tail	0.163	
t Critical one-tail	1.943	
P(T<=t) two-tail	0.326	
t Critical two-tail	2.447	

The t-statistic is 1.069 with 6 degrees of freedom. The corresponding two-tailed p-value is 0.326, which is greater than 0.05. We conclude that the mean difference of performance metric is not different from 0. Although Figure 1 shows some differences, these are not significant.

Table 6. Paired Two Sample for Means for Maturity Matrix Scores (Int. vs USA)

	Int.	USA
Mean	2.771	2.714
Variance	0.086	0.038
Observations	7	7
Pearson Correlation	-0.05	
Hypothesized Mean Difference	0	
df	6	
t Stat	0.420	
P(T<=t) one-tail	0.345	
t Critical one-tail	1.943	
P(T<=t) two-tail	0.690	
t Critical two-tail	2.446	

The t-statistic is 0.42 with 6 degrees of freedom. The corresponding two-tailed p-value is 0.689, which is greater than 0.05. We conclude that the mean difference of maturity matrix is not different from 0. Although Figure 1 shows some differences, these are not significant.

Table 7ab. ANOVA Single Factor

Groups	Count	Sum	Average	Variance
Performance score	14	60.506	4.322	0.157
Total Maturity	14	38.4	2.743	0.058

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	17.452	1	17.452	162.642	1.07E-12	4.225
Within Groups	2.790	26	0.107			
Total	20.243	27				

We can see that the F value > F-critical value. So, we can reject the null hypothesis. This means that the score for performance and the score for maturity score are not the same.

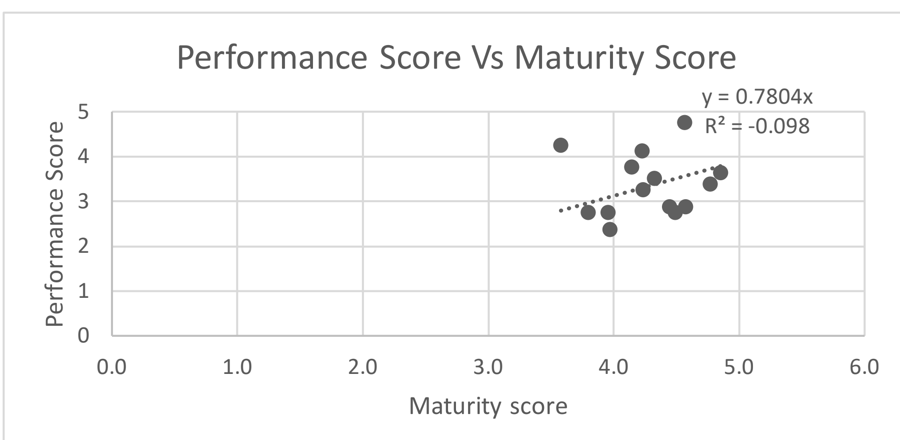

Figure 2. Performance Score Vs Maturity Matrix Score

The coefficient of determination (r2) is shown in Figure 2. This statistic measures the statistical relationship, or association, between the two variables, Performance score and Maturity Score. This coefficient measures the association between variables of interest, and it gives information about the magnitude of the association and the direction of the relationship. The coefficient value indicates an increase in the value of one variable is associated with an increase in the other variable.

8. Discussion and Conclusions

Combining performance metrics with maturity matrix scores to measure the food safety culture was evaluated using the GFSI cultural dimensions, which provided some conclusions. The performance metrics considered HACCP CAPAs (A), EMMP CAPAs (B), ATP swabs compliance (C), Internal Audit scores (D), and External Audit scores (E) combined with a maturity matrix score of Perceived Value (A1), People systems (A2), Process thinking (A3), Technology Enabler (A4), Tools and Infrastructure (A5) covered many food safety culture characteristics, however, more is needed based on the literature review and data analysis for the fourteen food plants evaluated. There were differences in these performance metrics between the fourteen plants; there was no significant difference between the international and USA plant groups.

The research questions were: 1) Was there any significant difference between the proposed food safety culture metrics among the plants; based on the ANOVA test for performance scores and Maturity Matrix scores, since the p-value is less than $\alpha = .05$, we reject the null hypothesis of the one-way ANOVA and conclude that we have sufficient evidence to say that not all group means are equal. 2) Was there any significant difference between the proposed food safety culture metrics among the region (International and USA)? the corresponding two-tailed p-value was greater than 0.05 for the student test, and it can be concluded the mean difference of maturity score and performance is not different from 0 for both regions (International and USA). 3) Is there a correlation between performance metrics and maturity matrix scores for food safety culture? based on the correlation coefficient, there was a strong positive correlation between performance and maturity scores. 4) To What extent do the metrics measure food safety culture? Based on the dimensions in the GFSI Food safety culture model (Vision and Mission, People, Consistency, Adaptability, and Hazard and Risk Analysis), the performance and maturity scores overlap with these dimensions.

The comparison of the plant scores for performance and maturity score for each plant shows some strong positive association, indicating that they are measuring some of the same dimensions. The limitation is that some of the components of the performance score as the audit scores are measured only once per year. However, the overall metrics combining performance and maturity scores could be used to measure the food safety culture performance and, most importantly, to identify areas of opportunities to improve compliance, reduce the company's risk, and produce safe food.

Although the maturity matrix score for this research was based on management self-evaluation, Jespersen (2014) conducted a survey to determine the maturity score for each plant that provided additional information from all companies' levels. The survey that was used had 96 questions, and the recommendation was to modify the survey and reduce its length. The survey could be modified with fewer questions to avoid this possible limitation in future research. Overall, the increased awareness and research in the field of food safety culture in the food industry will continue to improve in reducing foodborne illnesses.

9. Disclaimer Statements

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Conflict of interest: None

10. References

Beach, C. (2023). Food Safety News - Marler Clark: Report finds an enormous increase in the number of food items recalled in 2022. https://www.foodsafetynews.com/2023/03/report-finds-enormous-increase-in-number-of-food-items-recalled-in-2022/

FDA (2022). Advancing Food Safety Culture as Science Not a Slogan: A Systematic Literature Review. https://www.fda.gov/food/cfsan-constituent-updates/advancing-food-safety-culture-science-not-slogan-systematic-literature-review

GFSI. (2018). A Culture of Food Safety: A Position Paper from the Global Food Safety Initiative (GFSI). https://mygfsi.com/wp-content/uploads/2019/09/GFSI-Food-Safety-Culture-Full.pdf.

Griffith, C. J., Livesey, K. M., & Clayton, D. (2010). The assessment of food safety culture. British Food Journal, 112(4), 439-456. https://doi.org/10.1108/00070701011034448.

Jespersen, L (2014). Measuring Food Safety Culture in Food Manufacturing. https://atrium.lib.uoguelph.ca/server/api/core/bitstreams/361a3301-25ac-4840-bebf-78f59d50a1ba/content.

Lee, J. C., Daraba, A., Voidarou, C., Rozos, G., Enshasy, H. A. E., & Varzakas, T. (2021). Implementation of food safety management systems along with other management tools (HAZOP, FMEA, Ishikawa, pareto). the case study of listeria monocytogenes and correlation with microbiological criteria. Foods, 10(9), 2169. https://doi.org/10.3390/foods10092169.

Maguire, J., Fisher, A., Harouaka, D., Rakala, N., Lundi, C., Yambot, M., Viehmann, A., Stiber, N., Gonzalez, K., Canida, L., Buhse, L., & Kopcha, M. (2023). Lessons from CDER's quality management maturity pilot programs. The AAPS Journal, 25(1), 14-14. https://doi.org/10.1208/s12248-022-00777-z.

Nayak, R, & Waterson, P. (2016). The assessment of food safety culture: An investigation of current challenges, barriers and future opportunities within the food industry. Food Control, https://doi.org/10.1016/j.foodcont.2016.10.061.

Neogen. (2015). NSF report reveals critical differences between ATP hygiene monitoring systems. Food Safety Magazine.

Robinson, J. S., & Heidolph, B. B. (2009). Food safety--a current perspective for stakeholders: Creating a food safety culture through audits and best practice sharing. Cereal Foods World, 54(6), 248-252. https://doi.org/10.1094/CFW-54-6-0248.

Spalding, A., Goodhue, R. E., Kiesel, K., & Sexton, R. J. (2023). Economic impacts of food safety incidents in a modern supply chain: E. coli in the romaine lettuce industry. American Journal of Agricultural Economics, 105(2), 597-623. https://doi.org/10.1111/ajae.12341.

SQFI Institute (2020). Food Safety Code: Food Manufacturing Edition 9. https://www.sqfi.com/the-sqf-code/choose-your-code/library-of-codes/code/food-manufacturing.

Taylor, E., & Teare, R. (2015). An industry perspective A new model of food safety culture excellence and the impact of audit on food safety standards. What action can government take to improve food safety in a diverse and multi-cultural hospitality industry? (). Emerald Publishing Limited. www.emeraldinsight.com/1755-4217.htm

Yiannas, F., & ProQuest (Firm). (2009;2008;). Food safety culture: Creating a behavior-based food safety management system (1st ed.). Springer. https://doi.org/10.1007/978-0-387-72867-4.

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MACHINE LEARNING (ML) IN AEROSPACE AND DEFENSE (A&D) INDUSTRIES: A SYSTEMATIC LITERATURE REVIEW

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Abstract

In recent years, Machine Learning (ML) has made significant technical progress due to increased availability of larger data sets, more powerful computing performance, and greater budget allocations. However, ethical, political, and societal implications relate to successful and global implementation of ML in Aerospace and Defense (A&D) environments. Such challenges could result in unpredictability or inexplicability of the ML-enabled operation. This study provides a systematic review of published material on ML methods, limitations, and current and potential applications of ML in A&D. Records from 2012 to 2021 were found using multiple databases and showed ample research in missions changing from manned to semi-autonomous or autonomous; specifically in areas related to surveillance, reconnaissance, logistics, intelligence, and command and control. The results also emphasize the implementation of ML is deemed both threatening and promising.

Keywords: *Machine Learning; Learning Algorithms; Military; Defense Industries*

1. Introduction

1.1. ML and the Third Offset Strategy

The transformation and implementation of Artificial Intelligence (AI) has rapidly increased as a result of advancements in its subfields, specifically ML, and a notable rise in commercial investments (Allen & Chan, 2017). Increasing investments in academia and the private sectors resulted in quicker and less expensive AI development from such organizations (Schuetz, 2018). These trends have led to strong beliefs of AI impacting United States (US) national security and the need for on-going sponsorship by the government for numerous AI studies (Allen & Chan, 2017).

The Third Offset Strategy was constructed in 2014 due to this intersection between US defense and technological advancements (Knox, 2020). The goal of this strategy is for the Pentagon to connect warfighters with AI experts and incorporate innovations derived from commercial domains into applicable military usage. For example, long-range deliveries using commercial drones or image recognition technology involved with theft can also be used in militarized autonomous systems or surveillance, respectively. Such technologies in A&D sectors can result in increased scale and speed of military actions, more informed decision-making (Sigala, 2019), and reduction of the cognitive

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burden on the warfighter (Williams & Lawson, 2020). Other potential benefits include achieving overall military, information, and economic superiority through ML-based transformative military technologies within nuclear, aerospace, cyber, and biotechnology fields (Allen & Chan, 2017). The Pentagon and the Third Offset Strategy discusses AI technology acquisition and innovation being critical to US national security and superiority in these areas (Allen & Chan, 2017). Further, the Department of Defense (DOD) 2012 Autonomy Report identified ML as the most critical component of advancing smart autonomous systems (Wei et al., 2020).

1.2. Implementation Concerns

Although there are benefits to implementing ML in A&D, there are also several challenges and difficulties involved. Examples of challenges include the lack of an established and globally recognized definition of autonomy (Bouanna, 2020), limited available information regarding the approach on autonomous weapons from other nations, the need for US defense acquisition reforms, and the potential vulnerable forms of manipulation involved with ML (Sigala, 2019). There are also difficulties in societal acceptance related to accountability, responsibility, and ethical decision-making of ML-enabled machines (Lewis, 2019).

Based on the articles obtained during this review, improvements related to policy guidance (Bouanna, 2020), human-to-machine interactions (Allen & Chan, 2017), and ethical laws for research and integration (Sigala, 2019) are needed to further innovate and implement ML technology in A&D.

The present study focuses on ML in A&D environments. The main objective of this article is to discuss the current applications as well as known issues and challenges of successful implementation. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol was used for this systematic review; the PRISMA guidelines include 27 items which aim to reliably examine and detail applicable scientific evidence (Liberati et al., 2009). This paper is organized as follows: the methodology section explains the Research Questions (RQs) and search strategy, the results discussion provides details on the chosen material, and the discussion and follow-up sections answer each defined RQ while elaborating on limitations and future research.

2. Research Methodology

The present literature review evaluates current applicable research on ML within A&D organizations. The following RQs were formulated for this review:

RQ1: What are the current applications of ML in A&D?
RQ2: What are the issues and challenges involved with ML in A&D?
RQ3: What will aid in current and future successful implementation of ML in A&D?

The assessment followed the PRISMA guidelines (Liberati et al., 2009), which was used to define the above RQs and develop the search strategy. The goal of the search strategy was to identify and review relevant scientific materials for applicability to this paper.

This multi-faceted topic results in focusing on aspects related to aerospace organizations, defense industries, military, artificial intelligence, and the various types and applications of ML. Because of this, generating appropriate keywords to identify applicable articles was important. During the exploration stage, the following set of keywords was used to discover relevant articles in Google Scholar and Compendex:

Table 1. The First Set of Keywords Used in The Present Review

Row	Set
Keywords 1	"aerospace" OR "defense industry"
Keywords 2	"machine learning" OR "ML"
Keywords 3	"artificial intelligence" OR "AI"
Search	#1 AND (#2 OR #3)

This first set of keywords was then used to develop a new set of key words to discover additional articles related to ML and A&D. The second set of key words is shown in Table 2.

Table 2. The Second Set of Keywords Used in The Present Review

Row	Set
Keywords 1	"aerospace" OR "military" OR "DOD" OR "defense industries"
Keywords 2	"military computing" OR "military operations"
Keywords 3	"machine learning" OR "artificial intelligence" OR "learning algorithms"
Search	(#1 OR #2) AND #3

The search utilized many academic databases, including Compendex, ProQuest, Google Scholar, IEEE Xplore, EBSCOhost, and Science Direct. Sources from these databases included peer-reviewed journal articles, conference proceedings, and reference books within the scope of ML and A&D. Additional records, such as published theses and DOD technical reports, were also identified through the the Defense Technical Information Center (DTIC). All these sources provided ample information regarding ML in A&D. The initial search resulted in 962 publications being identified. Duplicate records were then removed, which resulted in 928 titles remaining.

A formal screening process was then used to narrow down the literature with the goal of identifying information relevant to the defined RQs. This screening process included applying both exclusion and inclusion criteria.

The exclusion criteria were as follows:

- Papers, upon review, were found to not be related to the RQ(s)
- Letters, posters, newspaper articles
- Papers written in other languages
- Papers which were classified or For Official Use Only (FOUO)

The inclusion criteria were as follows:

- Papers written in English
- Papers related to the RQ(s)
- Papers published from 2012 to 2021
- Papers identifying or describing AI/ML in A&D
- Papers which were open access, unclassified, and not FOUO

The above criteria were then applied and the abstracts for the remaining papers were read for applicability. After removing irrelevant titles, 78 were analyzed by reading the entire texts. A total of 63 records met all eligibility requirements and inclusion criteria. These records, which were chosen for the review, were published between 2012 and 2021. Figure 1 depicts a flow chart outlining this material selection process.

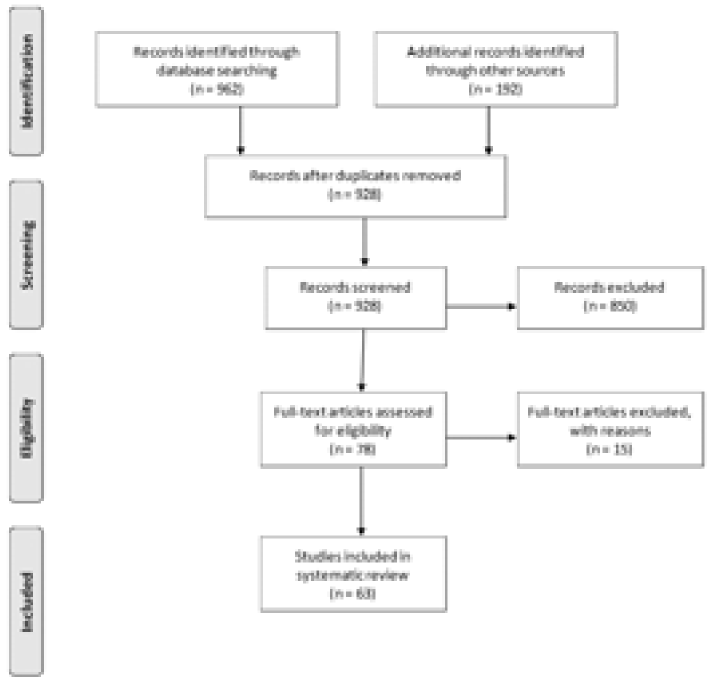

Figure 1. PRISMA Flow Diagram Detailing the Selection Process Used in The Present Review

It is important to mention the risk of bias in selection of relevant papers. In this review, bias could occur through the application of the exclusion/inclusion criteria and determining applicability to the systematic review. Additionally, one researcher reviewed and selected the papers based on the inclusion and exclusion criteria. To address the potential bias, the clear and objective RQs were considered throughout the selection process.

3. Research Results

The map of co-occurrence of terms found in the included papers is shown in Figure 2. The links and respective thickness depict the strength of co-occurrence of the terms while size represents frequency and nodes indicate specific terms.

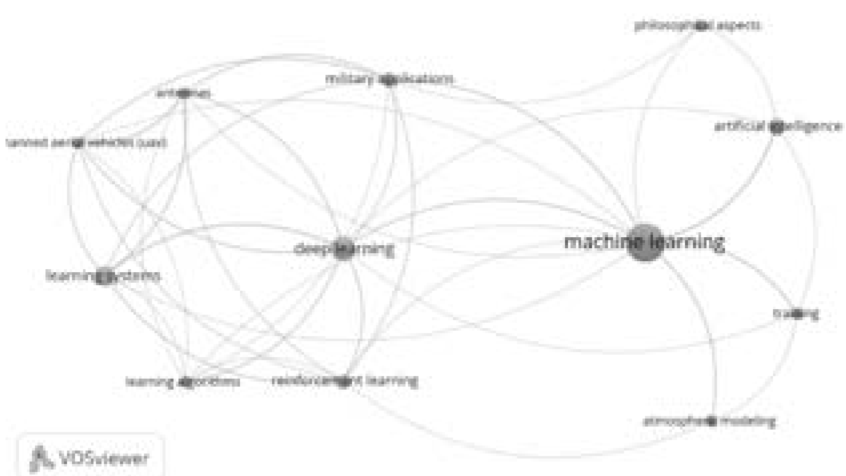

Figure 2. The Map of Co-Occurrence of Terms

All included publications were organized and summarized according to scope, strengths, limitations, and overall findings. The acronyms used in the records and within the summaries are listed in Table 3.

Table 3. Acronym List

Abbreviation	Meaning
AI	Artificial Intelligence
AIMS	Artificial Intelligence in Medical Sciences
ANN	Artificial Neural Networks
ATR	Automatic Target Recognition
CA	Cognitive Architecture
CNN	Convolutional Neural Network
DAS	Defense Acquisition system
DCNN	Deep Convolutional Neural Network
DDPG	Deep Deterministic Policy Gradient
DIB	Defense Innovation Board
DL	Deep Learning
DOD	Department of Defense
DQN	Deep Q Network
DRL	Deep Reinforcement Learning
EOD	Explosive Ordnance Disposal
FAA	Federal Aviation Authority
GPU	Graphics Processing Units
IML	Integrated Machine Learning
IoT	Internet of Things
JAIC	Joint Artificial intelligence Center
KG	Knowledge Graph
KNN	K-Nearest Neighbor
LAW	Lethal Autonomous Weapon
MADDPG	Multi-Agent Deep Deterministic Policy Gradient
MARDPG	Multi-Agent Reinforcement Deterministic Policy Gradient
ML	Machine Learning
NN	Neural Network
PL	Parallel Learning
PPO	Proximal Policy Optimization
RAS	Robotic Autonomous Systems
RAS	Rapid Acquisition System
RF	Random Forests

RL	Reinforcement Learning
SAR	Search and Rescue
SDM	Semantic Data Model
SL	Supervised Learning
SVM	Support Vector Machines
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Aerial Vehicle
UCSC	Unmanned Swarm Communication Systems
UK	United Kingdom
UL	Unsupervised Learning
UN	United Nations
US	United States
USA	United States of America
USS	Unmanned Swarm Systems
XAI	Explainable Artificial Intelligence

3.1. Relationship to AI and ML Techniques

Prior to discussing ML in relation to the A&D sector, much of the resulting papers aimed to discuss the relationship and distinguish the differences between AI and ML. AI is considered the overarching concept of designing and developing intelligent systems while ML is a specific branch of AI in which machines use data to evolve and adapt to processes or tasks without being manually programmed to do so (Choi & Cha, 2019). Further, the ML-based machines can actively learn new concepts (Hellstrom, 2013) and are able to identify patterns (Maass & Storey, 2019) based on certain characteristics within the data. Within the ML domain, there are many types of learning algorithms, such as Neural Networks (NN), which are used based on the goal and application of the system. There are also various ML methods based on the characteristics of the algorithm being used. For example, Deep Learning (DL) uses more complex algorithms which do not require precise design features (Sharma et al., 2019) and are modeled on the human brain; Reinforcement Learning (RL) models are more adaptable (Yue et al., 2020) due to the use of reward functions and goal-oriented algorithms (Bruton et al., 2021). The combination of using RL with Deep NN is referred to as Deep Reinforcement Learning (DRL) (Nasrabadi, 2019), which can combine visual and tactile devices (Nampoothiri et al., 2019), and therefore is used for more robust applications.

Many of the included papers also elaborated on classification of ML models based on the input data being provided to the algorithm. For example, Supervised Learning (SL) uses labeled data which is then imported into ML models to obtain known outputs, Unsupervised Learning (USL) models use input data but do not result in corresponding output data, and Semi-Supervised Learning (SSL) results in partial input data being labeled as output data (Carpenter, 2013).

In this section and the following subsections, RQ1, What are the current applications of ML in A&D?, is answered.

3.2. Definition of ML and Autonomy

The included papers reiterate the lack of a uniformly accepted definition of autonomy, especially involving intelligent systems used in A&D applications. A 2018 Brookings Institution provides a definition of AI through describing essential characteristics: intentionality, which relates to the design of algorithms to make human-like decisions, intelligence, referring to using data and ML to make more informed decisions, and adaptability, or the ability to learn as decisions are made and/or as information is compiled (Lawless et al., 2019). The National Defense Authorization Act (NDAA) offered another definition through providing concepts and features of AI, including the capability to actively learn and improve through experiences and to perform tasks with human-like perception without human oversight (Lawless et al., 2020).

Although there is no agreed-upon definition, the Pentagon released a more succinct definition through providing a singular characterization which can be implemented across the US armed services. This 2019 Pentagon definition describes AI machines as being capable of experiential learning (Nian et al., 2020), pattern recognition, predictability, decision-making, concluding, and taking affirmative action (Knox, 2020). Further, the decision-making capability of AI stems from data analytics or ML (Bouanna et al., 2020), where there are three distinct classes of decision-making: operational, tactical, and strategic (Dixit et al., 2020). This is executed through four major stages: determining the high-level objective, collecting appropriate data, identifying the model architecture, and choosing the optimum strategy. In each of these phases, human intelligence and collaboration is critical (Brunton et al., 2021).

3.3. Goal of ML in A&D

The literature suggests many goals of implementing ML in A&D including improved decision-making, increased efficiency and agility of processes and operations, decreased overall costs, and less cognitive burden on personnel. For example, the Army has saved over $100 million per year due to implementing tailored maintenance schedules and algorithm-based logistics plans for the Stryker fleet (Knox, 2020). Following the launch of Project Maven in 2017, there was a decrease in the amount of time human analysts dedicated to filtering drone footage due to increasing automation (Knox, 2020).

Studies have shown using ML algorithms can reduce testing and operational times through discovering fundamental relationships (Choi & Cha, 2019) while surpassing human performance in more complex tasking (Nian et al., 2020). Specific to ML-enabled autonomous or semiautonomous vehicles, such technologies can identify objects, recognize obstacles (Coluccia et al., 2021), learn the surrounding environments, communication, and navigation planning (Wang et al., 2020) while minimizing tracking errors or overshooting (Choi & Cha, 2019). These unmanned systems are also intended to aid personnel in more challenging environments, such as those which are deemed dangerous, damaged, or unpredictable to people. In general, the goals of ML-based technologies in A&D involve increasing operational efficiencies using real-time analysis of the battle environment which improves the speed, accuracy, safety, and quality of wartime decision-making (Huang et al., 2018).

3.4. Funding Organizations and Considerations

The DOD leverages Research and Development (R&D) from various research-based and academic organizations, as well as agencies such as the Intelligence Advance Research Projects Agency (IARPA) and Defense Advanced Research Projects Agency (DARPA) (Slayer, 2020).

In the 1960s, DARPA developed a program to begin researching the early stages of ML. By the

1970s, DARPA was the main supporter of ML research in the US and established a multitude of intelligent programs tied to military actions (Wang et al., 2020).

Due to the high cost of innovation (Foster & Arnold, 2020), R&D efforts estimating more than 15 million dollars annually require coordination with the Joint Artificial Intelligence Center (JAIC) – an organization stemming from the Third Offset Strategy framework (Knox, 2020). In addition, projects directly related to addressing military operational challenges must be overseen by the National Mission Initiatives (NMI) (Slayer, 2020).

In 2018, following the generation of the Third Offset Strategy, DARPA planned to invest two billion dollars over the next five years to support the US armed forces implementation of AI/ML (Wang et al., 2020). In 2019, the US Army contributed 72 million dollars in collaborative projects involving battlefield AI concepts and universities (Wang et al., 2020). In 2020, an 800-million-dollar contract was awarded to the JAIC with the intent to further increase AI/ML in battlefield domains (Slayer, 2020) and an expected 16.5 billion dollars is expected to be spent on military robotics by 2025 (Allen & Chan, 2017).

3.5. ML Applications in A&D

Although mission specific use of ML-enabled machines may be classified or held by the DOD (Wei et al., 2020), there are several publicly known AI and ML research initiatives in progress. Current applications of A&D ML include surveillance, target acquisition, weapons delivery, intelligence, reconnaissance, command and control, cyberspace, logistics, information operations, and autonomous or semi-autonomous vehicles (Slayer, 2020). Studies have also shown ML can be used for communication amongst various robotic systems (Alsamhi et al., 2020) and fraud detection (Bastian, 2021), and DL can be applied for real-time remote sensing, object classification, and object recognition (Aziz et al., 2020). Efforts in a few of these domains are farther along due to the availability of larger datasets from human-gathering, drone reconnaissance, or from satellite imagery (Knox, 2020).

More specific applications can be seen as the US A&D works to incorporate ML within semiautonomous and autonomous vehicles including naval vessels, various size drones, fighter aircrafts, satellites, rockets, and numerous ground vehicles. Regardless of the type of vehicle, there is an active DOD directive requiring all autonomous or semiautonomous weapons systems including the capability to use human judgement over the use of force. The US Air Force (USAF) Research Lab has completed two phases of testing for this concept on its Loyal Wingman program, where older uninhabited fighter jets (such as the F-16) are paired with an inhabited fighter jet (such as the F-35). The Army and Marine Corps also finished prototype testing on unmanned vehicles and automated gun turrets (Knox, 2020) and concluded successful execution of battlefield tasks, such as surveillance or removal of explosive devices (Wang et al., 2020). In addition, although the vessel is not yet fielded, the Navy tested the ability to autonomously coordinate missions with other unmanned vessels while navigating through open waters (Wang et al., 2020). Specific to space applications, examples of ML usage can be seen with the ability to classify and detect components in real-time (Mahendrakar et al., 2021) and with autonomous navigation around uncooperative space matter (Mahendrakar et al., 2022).

There are numerous configurations of ML-based UAVs and Unmanned Aerial Systems (UAS), all of which help with real-time monitoring, data collection, processing, and prediction in wireless A&D applications. In military domains, this technology is used to detect, track, and classify flying objects at more accurate, safer, and quicker rates using ML (Meyer et al., 2020). Specific to the intelligence and reconnaissance sector, the US Army use of the Gray Eagle as a multipurpose platform used for multi-domain operations and the Pentagon's Project Maven utilized ML algorithms to collect, analyze, and organize footage from UAVs with the intent to determine hostile activity for targeting (Bouanna et al., 2020).

The DOD is also actively testing the concept of swarming. Swarming involves the collaboration of various-sized autonomous vehicles "to provide electronic attack, fire support, and localized navigation and communication nets for ground trop formations" (Wang et al., 2020). In 2018, the Navy successfully intercepted an intruding vessel using a swarm of five uninhabited boats. Another effort, Project Perdix, through the Strategic Capabilities Office (SCO) tested a swarm of 103 micro-drones which were air dropped. Studies have shown using trained and defensive swarm technology has increased mission effectiveness (Schuety et al., 2018) due to the accurate and rapid identification of threats (Wei et al., 2020).

From the warfighter perspective, studies have shown ML-enabled wearable sensors can properly perform gait assessments on military personnel, specifically with the intent to evaluate and assess fatigue or injuries resulting from load-carrying operations (Ahamed et al., 2021). Other studies have shown ML can be implemented into A&D logistics and planning (Ajakwe et al., 2020); currently, the USAF and US Army make use of ML-enabled approaches for military logistics. Predictive maintenance involving the F-35 employs predictive algorithms to help maintenance personnel determine which aircraft components to inspect or repair, and the Army Stryker uses algorithms for tailored maintenance using time-versus-cost analyses for delivering supplies to the fleet (Knox, 2020). The US Navy has also used ML to support Vessel scheduling and obsolescence management (Rainey & Harguess, 2018). All these efforts have resulted in increased operational efficiency.

Centralized planning and execution of air, space, cyberspace, sea, and land operations using AI/ML is also being investigated and developed through DOD initiatives. A recent effort in 2015 involved launching the Commander's Virtual Staff (CVS), where determining operational processes for the Army was accomplished through decision-making support (Wang et al., 2020). These intelligent command and control systems allow for a single and common operating frame that provides "a comprehensive picture of friendly and enemy forces and automatically resolving variances form input data" (Wang et al., 2020). In addition, ML-based methods have improved satellite communications during spacecraft missions (Vazquez et al., 2021) as well as increased collaboration between the human user and virtual assistance. This effective human to machine integration has proven greater performance results compared to either system working alone (Marin & Selva, 2020).

There are also theoretical applications of ML in A&D, such as those within the LAWS (Lethal Autonomous Weapon Systems) classification of defense systems. LAWS are considered controversial based on the algorithms being capable of identifying, engaging, and destroying the intended target without human control of the system. Although there are no known LAWS in the US DOD inventory, there are also no policy restrictions preventing their development (Wang et al., 2020). Further, there are published statements discussing the future role of weaponized autonomous systems (Noyes, 2019). With respect to societal acceptance, a 2021 survey resulted in participants being against AI/ML for lethal weapons, such as LAWS, but minimal opposition for the use of AI/ML in A&D applications (Zhang et al., 2021).

3.6. Societal and Economic Impact

Economic impacts of more available advancing technologies results in increased use and decreased prices, which also enables wide-spread adoption in a variety of applications. This increased adoption of ML in A&D results in less economic demand for human labor and less importance on population size (Allen & Chan, 2017). Although this can benefit smaller nations with developing more powerful militaries, it can also result in fewer causalities in the field (Wei et al., 2020). Additionally, ML can be applied to military medicine and civilian care through ensuring intelligent machines or UAVs are able to provide required image diagnostic or deliver medical supplies when specialty providers are not available (Crump & Schlachta-Fairchild, 2020). On the other hand, work displacement as a result of increased automation can have negative impacts on emerging markets and economies, especially in job which require low skills and can be more easily automated (Dwivedi et al., 2021). Overall, the societal and economic impact during this phase of AI/ML evolution should be continuously assessed.

3.7. Societal and Personnel Concerns

In this section and the following subsections, RQ2, What are the issues and challenges involved with ML in A&D?, is answered. Limitations involved with successful implementation of A&D ML include apprehensions with human integration and collaboration with the machine, particularly involvement in decision-making (Wei et al., 2020), where there is concern of potentially replacing human judgement with algorithmically derived choices (Lewis et al., 2016). There are also concerns associated with not trusting and over-trusting ML-enabled machines stemming from the unpredictable or inexplicable features of the system. Risks of not trusting the machine are dependent on understanding the overall functionality or output of the system, while over-trusting the system stems from high confidence the system will function as intended. Therefore, it is important for users to understand the inputs and rationale involved in the algorithm based decision-making process (Lawless et al., 2020).

Another societal challenge is the fear of the machine eventually developing its own agenda after initially behaving ethically. Researchers found this fear stems from concerns about innate human behavior and the survival mechanisms which cause humans to act unethically. However, others have argued that ML allows for the opportunity to create systems which do not include this predisposition and can perform even more ethically than humans (Novak, 2021). This lack of trust amongst human users can also result from challenges with control. For example, LAWs, which are unaffected by emotional stress, remove humans from “kill control” (Umbrello et al., 2020) or the system being able to override human-determined demands (Beckerle et al., 2017). Another challenge with implementation is the number of cultural years of manned aircrafts and the warfighter mentality on such (Williams & Lawson, 2020). A solution to these above issues is designing the ML-based technology to use and predict human knowledge while adapting to meet specific mission needs (Carpenter, 2013).

3.8. Theft, Hacking, and Cybersecurity

Specific to information operations, ML-enabled technologies have allowed for more realistic imagery, audio, and video forgeries. While ML helps with quicker detection and evaluation of vulnerabilities, such tools can be used against the US and US allies to promote societal discourse, erode public trust, blackmail officials, or generate false news reporting (Knox, 2020). Although there are DARPA initiatives to identify AI/ML-produced falsifications, these systems are capable of being trained to outsmart the forensic tools (Knox, 2020). Further vulnerabilities within ML-enabled systems include data-poisoning attacks, hacking or gaining access for malicious purposes, and intentional attacks on the ML system intended to trick the algorithms into functioning in unanticipated ways. Particularly in A&D applications, which utilize the wireless capabilities for essential communication (Ha et al., 2019), such susceptibilities pose great risks.

There are also limitations involved with the sharing of intelligence assets within the cyber domain. Particularly seen with privacy concerns linked involved with using UAV facial recognition capabilities (Knox, 2020) and with espionage efforts by Chinese hackers of the F-35, which heavily influenced the Chinese J-31.

Although ML methods can serve as countermeasures in the realm of IoT threats, there must be useable data to determine the effectiveness of such protection systems. Researchers found most of the above risks are a result of inconsistency in data collection methods, the quality of data, and the quantity of data (Zaman et al., 2021). Other suggestions include implementing defensive algorithms (Liu et al., 2018), decentralized technologies (Miglani & Kumar, 2021), or establishing a well-defined security assessment standard (Liu et al., 2018). Decentralized frameworks, such as Blockchain (Miglani & Kumar, 2021), aid in sharing secured information across networks. Specific to A&D applications, this method has also been able to provide estimations for overall wartime readiness and mission reliability (Mohril et al., 2021).

3.9. Collection and Analysis of Data

There are both benefits and drawbacks related to ML technologies requiring larger data sets. For example, there are opportunities due to the availability of data but potential challenges in analyzing, drawing conclusions, and finding importance within the collected data (Maher & Orlando, 2019). The data can also be difficult and time-consuming to obtain in the required quantities due to the data space being too large (Li et al., 2017), which can lead to ML inefficiencies. In addition, there are limitations involved with potential bias, the quality of data acquired, and dependence on input parameters (Meyer et al., 2020) for these data-driven models. In A&D applications, experiments with UAVs have shown challenges in motion control due to incomplete or inaccurate observations being used in the ML models (Xie et al., 2020).

3.10. Responsibility and Ethical Considerations

ML-enabled technologies are becoming increasingly complex due to their inherent purpose of successfully performing increasingly complicated tasks. Completion of more complicated tasks drives ongoing discussions whether intelligent systems should share the ethical responsibilities alongside their human counterpart; some researchers suggest this discussion should be included in the technical design process (Noorman, 2014) and recommended combining both human judgement and machine logic for optimum ethical performance.

Previous research has focused on ethical issues centered on the human use of machines and the human applications of such technology. However, due to the increasing use of complex manufacturing systems, including those which utilize intelligent machines and ML, ethical dimensions involving machines should now be included. This inclusion allows for shared ethical responsibility between personnel and machines, especially during decision-making processes. The USAF exhibits this concept of shared responsibility and human-machine collaboration through fighter planes having the ability to take over if the human pilot passes out because of performing hi-G maneuvers (Knox, 2020).

Because of the constantly evolving definition of acceptable behavior of AI/ML systems, there are challenges in defining globally accepted ethical codes. However, in 2020, the US DOD adopted a set of ethical principles for use on AI. These guidelines were built on the military's existing ethics initiative and apply to both combat and non-combat functions. Although the existing ethics framework does provide the foundation for ethical behavior, there are new guidelines addressing recent challenges relating to ensuring responsible use of AI military systems (Zhang et al., 2021). These standards aim for ML systems that are responsible, equitable, traceable, reliable, and governable.

3.11. Commonalities

Following the Third Offset Strategy of using commercial ML-enabled systems for A&D use, there will be barriers for smooth transitions of developed intelligent systems into the DOD. For instance, standards relating to ethics, safety, performance, accountability, and acquisitions rarely align in civilian and defense realms. In addition, adjustments in data, terminology, and language of the respective algorithms may be required depending on application. Further, ML applications are often proprietary and cannot be generalized (Lawless et al., 2020). For example, compared to commercial semiautonomous vehicles which often include an accurate and reliable GPS (Global Positioning System) system, military ground vehicles will need the system to operate even when adversary jamming results in GPS interruptions (Wang et al., 2020).

3.12. Future ML in A&D Efforts

In this section and the following subsections, RQ3, What will aid in current and future successful implementation of ML in A&D?, is answered.

General improvements for ML include more testing and fielding of multi-agent coordination (Vorm, 2020), increased learning and human-like perception during use, less data intensive algorithms, need to respond to feedback from the human user (Vorm, 2020), and algorithms requiring less power consumption (Meyer et al., 2020). Many of these efforts are underway, including assessments on ensuring high quality input data (Jang et al., 2019), developing algorithms for speech recognition and geo-locating images which do not require large data sets, and using decentralized methods to address privacy and security concerns related to ML algorithms (Meyer et al., 2020).

Future efforts can involve further studies on specific ML applications. For example, additional research relating to creating a realistic digital 'footprint' of a specified individual to generate informational or behavioral profiles can be used within information operations. Similarly, understanding the algorithmic ability to act as both offense and defense can prove useful in cyberspace operations for detecting and protecting against anomalies in broad network patterns (Knox, 2020). Specific to A&D, the concept of swarming is being investigated. For example, the US Navy plans to soon test swarms of underwater drones (Wang et al., 2020). These ML-enabled systems can also be used for adaptive recovery of other semiautonomous or autonomous machines after performing further studies. Furthermore, advancements such as controlling UAVs through ML-enabled wearable gloves (Muezzinoglu & Karakose, 2021), target detection using deep NN (Nasrabadi, 2019), improving interaction between multiple agents (Wei et al., 2020), and reduction of training time for intelligent systems (Zuluaga et al., 2018) are in work.

Recommendations for implementation include investing in counter-AI/ML activities for both offense and defense A&D, with continuous emphasis on dual use of AI/ML abilities. This can be promoted through ongoing collaboration with national security agencies and commercial sectors. There should also be prioritized spending in ethical R&D and managing of potential catastrophic risk through establishment of appropriate technical leadership (Allen & Chan, 2017).

3.13. Improvement with Human and Machine Interactions

Additionally, recent studies are now focusing on the design and deployment of ethical machines, with the intent to minimize risks to humans as well as minimizing risks to other machines. There are severe consequences, including harm to personnel or misuse of assets, if this aspect of machine behavior is neglected. To prevent misuse, if conflicting data is concurred with, personnel must explain the rationale for specific decisions. Therefore, knowledge of the machine and its decision-making process is essential. Studies state improving these interactions are essential for ensuring collaborative military environments between personnel and robotics (Carpenter, 2013); however, research also showed increasing the number of humans involved did not generate additional trust or benefits (Gutzwiller & Reeder, 2021). To develop more trust, the human user interface must improve as technology improves (Vorm, 2020). As AI/ML progresses, there is an increased parallel need to focus on human to machine interactions as well (Vorm, 2020). In addition, the need for oversight of ethical development, research, and implementation is needed through defining global policies and for establishing laws for integration into A&D sectors (Sigala, 2019).

3.14. Development of Research Organizations

Many of the included papers advise the development of organizations dedicated to performing cost-benefit analyses, aiding in more applicable R&D, increasing collaboration with commercial industries, and contributing to further concept development and experimentation. There is also a need for more research to ensure ML systems are reliable, safe, and do not introduce new risks nor hazards into existing systems (Vorm, 2020). Suggested studies include determining when it is economical to solely rely on human judgement (Dwivedi et al., 2021) and determining the benefit of analyses of unmanned versus manned systems (Brannen & Griffin, 2014). In general, there should be engagement with industry and academia to ensure there is a balance between commercial and government funding and oversight of all A&D ML concept development and experimentation (Allen & Chan, 2017).

3.15. Ethical Considerations and Global Policy

A&D industries provide a driving force for technology development and advancement due to their applications. With respect to design and production of military assets, ML-enabled systems can aid in reduction of human error and increased ergonomics when functioning as intended. However, beyond developing ethical machines, the applications of these systems should also adhere to ethical principles and guidelines. Such ethical considerations can be simplified if usage of ML devices is specific, and humans are integrated into the intelligent system (Hellstrom, 2013). Specifically in A&D applications, researchers suggest human action should be combined with intelligent weapons technology to ensure increased safety, performance, and ethical usage while preventing the dehumanization of war.

While the guidelines for machine ethics and ML in A&D industries are constantly evolving, there is agreement on the overall need to design ethical intelligent systems and to ethically use such systems. Further, to prevent expanded and unintended use of A&D ML/AI which could result in national security implications, governments should consider establishing a global policy and acquisition reforms (Allen & Chan, 2017).

3.16. Further Advancement for Prevention of Hypothetical Adversaries

As A&D applications of ML advance across the globe, it is important to consider the growth in scale and complexities of international competition. For example, in 2017, both China and Russia announced more developmental programs in which China aims to be the optimal innovative nation in AI/ML by 2030 (Kania, 2017) and Russia hopes to fully automate their combat power using robotic platforms by 2030 (Allen & Chan, 2017). Understanding the state of adversary ML development and potential usage is essential as competitors could vary in ethical and legal policies of such (Allen & Chan, 2017). Although the 2015 and 2016 Certain Conventional Weapons (CCW) meetings provide insight to multiple nations' views on autonomous weapon systems (Lewis et al., 2016), there is still limited information on the countries outside of the US in regard to their approach on autonomous systems (Schuety et al., 2018). Additionally, with increasing AI and ML technologies, potential battlefield interactions or misconceptions between nations can occur (Kania, 2017). Because of this, future efforts should involve governments collaborating to determine a global measure including the expanded use of AI/ML in A&D applications (Allen & Chan, 2017).

4. Conclusion

With the increase of AI/ML technologies in commercial industries and the paralleled advancing systems, the need to promote such innovations in A&D applications has been acknowledged. Through the Third Offset Strategy, the Pentagon aims to work more closely with the academic and commercial sectors to effectively procure, develop, and field these intelligent machines (Knox, 2020). The goal of implementing such technologies in the A&D sector is to increase operational efficiencies through improved decision-making, more automated processes, and less cognitive burden on the warfighter.

However, there are limitations and vulnerabilities such as societal concerns, ethical considerations, manipulation, or misuse which could impact successful implementation of ML in A&D. Although the US armed forces have directives which restrict the development and usage of autonomous systems and require humans be included in the decision-making process where lethal force is involved (Allen & Chan, 2017), there is a need to establish a global policy for designing, developing, and deploying ethical ML-enabled technologies in A&D settings.

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6. References

Ahamed, N. U., Krajewski, K. T., Johnson, C. C., Sterczala, A. J., Greeves, J. P., Wardle, S. L., O'Leary, T. J., Mi, Q., Flanagan, S. D., Nindl, B. C., & Connaboy, C. (2021). Using Machine Learning and Wearable Inertial Sensor Data for the Classification of Fractal Gait Patterns in Women and Men during Load Carriage.Procedia Computer Science 2021 Complex Adaptive Systems Conference, June 16, 2021 - June 18, 2021, Malvern, PA, United states.

Ajakwe, S. O., Nwakanma, C. I., Lee, J. M., & Kim, D. S. (2020, 21-23 Oct. 2020). Machine Learning Algorithm for Intelligent Prediction for Military Logistics and Planning. 2020 International Conference on Information and Communication Technology Convergence (ICTC),

Allen, G., & Chan, T. (2017). Artificial intelligence and national security. Belfer Center for Science and International Affairs Cambridge, MA.

Alsamhi, S. H., Ma, O., & Ansari, M. S. (2020). Convergence of Machine Learning and Robotics Communication in Collaborative Assembly: Mobility, Connectivity and Future Perspectives [Article]. Journal of Intelligent & Robotic Systems, 98(3/4), 541-566. https://doi.org/10.1007/s10846-019-01079-x

Aziz, L., Salam, M. S. B. H., Sheikh, U. U., & Ayub, S. (2020). Exploring Deep Learning-Based Architecture, Strategies, Applications and Current Trends in Generic Object Detection: A Comprehensive Review. IEEE Access, 8, 170461-170495. https://doi.org/10.1109/ACCESS.2020.3021508

Bastian, N. D. (2021). Artificial intelligence for defense applications. Journal of Defense Modeling and Simulation, 18(3), 173-174. https://doi.org/10.1177/15485129211009072

Beckerle, P., Salvietti, G., Unal, R., Prattichizzo, D., Rossi, S., Castellini, C., Hirche, S., Endo, S., Amor, H. B., Ciocarlie, M., Mastrogiovanni, F., Argall, B. D., & Bianchi, M. (2017). A human-robot interaction perspective on assistive and rehabilitation robotics. Frontiers in Neurorobotics, 11(MAY). https://doi.org/10.3389/fnbot.2017.00024

Bouanna, J., Diaz-Valdes, G., Frizzell, L., Hayes, T., Kays, C., Khade, A., Khong, K., Lara, A., Lii, E., & Ring, H. (2020). The World Wide Race for Artificial Intelligence: A Path Forward for US Policy.

Brannen, S. J., & Griffin, C. E. (2014). Sustaining the US Lead in Unmanned Systems. Center for Strategic and International Studies, February.

Brunton, S. L., Kutz, J. N., Manohar, K., Aravkin, A. Y., Morgansen, K., Klemisch, J., Goebel, N., Buttrick, J., Poskin, J., Blom-Schieber, A. W., Hogan, T., & McDonald, D. (2021). Data-driven aerospace engineering: Reframing the industry with machine learning. AIAA Journal, 59(8), 2820-2847. https://doi.org/10.2514/1.J060131

Carpenter, J. (2013). Just doesn't look right: Exploring the impact of humanoid robot integration into explosive ordnance disposal teams. In (Vol. 3, pp. 1354-1380). IGI Global. https://doi.org/10.4018/978-1-4666-4607-0.ch066

Choi, S. Y., & Cha, D. (2019). Unmanned aerial vehicles using machine learning for autonomous flight; state-of-the-art [Article]. Advanced Robotics, 33(6), 265-277. https://doi.org/10.1080/01691864.2019.1586760

Coluccia, A., Fascista, A., Schumann, A., Sommer, L., Dimou, A., Zarpalas, D., Mendez, M., de la Iglesia, D., Gonzalez, I., Mercier, J.-P., Gagne, G., Mitra, A., & Rajashekar, S. (2021). Drone vs. Bird detection: Deep learning algorithms and results from a grand challenge. Sensors, 21(8). https://doi.org/10.3390/s21082824

Crump, C., & Schlachta-Fairchild, L. M. (2020). Achieving a trusted, reliable, AI-ready infrastructure for military medicine and civilian care.Proceedings of SPIE - The International Society for Optical Engineering Artificial Intelligence and Machine Learning for Multi-Domain Operations Applications II 2020, April 27, 2020 - May 8, 2020, Virtual, Online, United states.

Dixit, R., Chinnam, R. B., & Singh, H. (2020). Artificial Intelligence and Machine Learning in Sparse/Inaccurate Data Situations. 2020 IEEE Aerospace Conference,

Dwivedi, Y. K., Hughes, L., Ismagilova, E., Aarts, G., Coombs, C., Crick, T., Duan, Y., Dwivedi, R., Edwards, J., Eirug, A., Galanos, V., Ilavarasan, P. V., Janssen, M., Jones, P., Kar, A. K., Kizgin, H., Kronemann, B., Lal, B., Lucini, B., Medaglia, R., Le Meunier-FitzHugh, K., Le Meunier-FitzHugh, L. C., Misra, S., Mogaji, E., Sharma, S. K., Singh, J. B., Raghavan, V., Raman, R., Rana, N. P., Samothrakis, S., Spencer, J., Tamilmani, K., Tubadji, A., Walton, P., & Williams, M. D. (2021). Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. International Journal of Information Management, 57, 101994. https://doi.org/10.1016/j.ijinfomgt.2019.08.002

Foster, D., & Arnold, Z. (2020). Antitrust and Artificial Intelligence: How Breaking Up Big Tech Could Affect the Pentagon’s Access to AI. Center for Security and Emerging Technology (CSET) Issue Briefing.

Gutzwiller, R. S., & Reeder, J. (2021). Dancing With Algorithms: Interaction Creates Greater Preference and Trust in Machine-Learned Behavior. Human Factors, 63(5), 854-867. https://doi.org/10.1177/0018720820903893

Ha, Q. P., Yen, L., & Balaguer, C. (2019). Robotic autonomous systems for earthmoving in military applications. Automation in Construction, 107, 102934. https://doi.org/10.1016/j.autcon.2019.102934

Hellstrom, T. (2013). On the moral responsibility of military robots. Ethics and Information Technology, 15(2), 99-107. https://doi.org/10.1007/s10676-012-9301-2

Huang, H., Feng, Y., Huang, J., Zhang, J., & Chen, L. (2019). A Reinforcement One-Shot Active Learning Approach for Aircraft Type Recognition. IEEE Access, 7, 147204-147214. https://doi.org/10.1109/ACCESS.2019.2946186

Huang, H., Huang, J., Feng, Y., Liu, Z., Wang, T., Chen, L., & Y, Z. (2018). Aircraft Type Recognition Based on Target Track.Journal of Physics: Conference Series 2018 2nd International Conference on Artificial Intelligence, Automation and Control Technologies, AIACT 2018, April 26, 2018 - April 29, 2018, Osaka, Japan.

Jang, J., Yoon, H. G., Kim, J. C., & Kim, C. O. (2019). Adaptive Weapon-to-Target Assignment Model Based on the Real-Time Prediction of Hit Probability. IEEE Access, 7, 72210-72220. https://doi.org/10.1109/ACCESS.2019.2919794

Kania, E. B. (2017). Battlefield singularity. Artificial Intelligence, Military Revolution, and China’s Future Military Power, CNAS.

Khan, A. I., & Al-Mulla, Y. (2019). Unmanned aerial vehicle in the machine learning environment. Procedia

Computer Science 10th International Conference on Emerging Ubiquitous Systems and Pervasive Networks, EUSPN 2019 and 9th International Conference on Current and Future Trends of Information and Communication Technologies in Healthcare, ICTH 2019, Affiliated Workshops, November 4, 2019 - November 7, 2019, Coimbra, Portugal.

Knox, T. J. (2020). US Military Innovation in the 21st Century: The Era of The "Spin-On".

Lawless, W. F., Mittu, R., & Sofge, D. A. (2020). Introduction: Artificial intelligence (AI), autonomous machines, and constructing context: User interventions, social awareness, and interdependence. In Human-Machine Shared Contexts (pp. 1-22). Elsevier.

Lewis, D. A., Blum, G., & Modirzadeh, N. K. (2016). War-algorithm accountability. Available at SSRN 2832734.

Lewis, L. (2019). AI Safety: An Action Plan for the Navy.

Li, L., Lin, Y., Zheng, N., & Wang, F. (2017). Parallel learning: a perspective and a framework. IEEE/CAA Journal of Automatica Sinica, 4(3), 389-395. https://doi.org/10.1109/JAS.2017.7510493

Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, et al. (2009) The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions: Explanation and Elaboration. PLOS Medicine 6(7): e1000100

Liu, Q., Li, P., Zhao, W., Cai, W., Yu, S., & Leung, V. C. M. (2018). A Survey on Security Threats and Defensive Techniques of Machine Learning: A Data Driven View. IEEE Access, 6, 12103-12117. https://doi.org/10.1109/ACCESS.2018.2805680

Maass, W., & Storey, V. C. (2021). Pairing conceptual modeling with machine learning. Data & Knowledge Engineering, 134, 101909. https://doi.org/10.1016/j.datak.2021.101909

Mahendrakar, T., Ekblad, A., Fischer, N., White, R., Wilde, M., Kish, B., & Silver, I. (2022, March). Performance study of yolov5 and faster r-cnn for autonomous navigation around non-cooperative targets. In 2022 IEEE aerospace conference (AERO) (pp. 1-12). IEEE.

Mahendrakar, T., White, R. T., Wilde, M., Kish, B., & Silver, I. (2021, August). Real-time satellite component recognition with YOLO-V5. In Small Satellite Conference.

Maher, M., & Orlando, R. (2019). Reduce the warfighters cognitive burden.Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 3rd International Conference on Cognitive Computing, ICCC 2019, held as part of the Services Conference Federation, SCF 2019, June 25, 2019 - June 30, 2019, San Diego, CA, United states.

Martin, A. V. I., & Selva, D. (2020). Daphne: A Virtual Assistant for Designing Earth Observation Distributed Spacecraft Missions. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 13, 30-48. https://doi.org/10.1109/JSTARS.2019.2948921

Meyer, E., Robinson, H., Rasheed, A., & San, O. (2020). Taming an Autonomous Surface Vehicle for Path following and Collision Avoidance Using Deep Reinforcement Learning. IEEE Access, 8, 41466-41481. https://doi.org/10.1109/ACCESS.2020.2976586

Miglani, A., & Kumar, N. (2021). Blockchain management and machine learning adaptation for IoT environment in 5G and beyond networks: A systematic review. Computer Communications, 178, 37-63. https://doi.org/10.1016/j.comcom.2021.07.009

Mohril, R. S., Solanki, B. S., Lad, B. K., & Kulkarni, M. S. (2021). Blockchain Enabled Maintenance Management Framework for Military Equipment. IEEE Transactions on Engineering Management.

Muezzinoglu, T., & Karakose, M. (2021). An intelligent humanunmanned aerial vehicle interaction approach in real time based on machine learning using wearable gloves. Sensors, 21(5), 1-25. https://doi.org/10.3390/s21051766

Nampoothiri, M. G. H., Vinayakumar, B., Sunny, Y., & Antony, R. (2021). Recent developments in terrain identification, classification, parameter estimation for the navigation of autonomous robots. SN Applied Sciences, 3(4). https://doi.org/10.1007/s42452-021-04453-3

Nasrabadi, N. M. (2019). DeepTarget: An Automatic Target Recognition Using Deep Convolutional Neural Networks [Article]. IEEE Transactions on Aerospace & Electronic Systems, 55(6), 2687-2697. https://doi.org/10.1109/TAES.2019.2894050

Nian, R., Liu, J., & Huang, B. (2020). A review On reinforcement learning: Introduction and applications in industrial process control. Computers & Chemical Engineering, 139, 106886. https://doi.org/10.1016/j.compchemeng.2020.106886

Noorman, M. (2014). Responsibility practices and unmanned military technologies. Science and engineering

ethics, 20(3), 809-826.
Novak, W. (2021). Artificial Intelligence (AI) and Machine Learning (ML) Acquisition and Policy Implications.
Noyes, M. F. (2019). Autonomous Weapons: The Future Behind Us.
Rainey, K., & Harguess, J. (2018). Report on the second annual workshop on naval applications of machine learning. AI Magazine, 39(4), 69-72. https://doi.org/10.1609/aimag.v39i4.2840
Schuety, C. W., & Will, L. E. (2018). The American Way of Swarm: A Machine Learning Strategy for Training Autonomous Systems.
Schuetz, A. M. (2018). Why the DOD is Losing Its Asymmetric Robotics and Autonomous Systems Advantage: An Argument for the Concept of Autonomous Functioning Within a System.
Sharma, N., Sharma, R., & Jindal, N. (2021). Machine Learning and Deep Learning Applications-A Vision. Global Transitions Proceedings, 2(1), 24-28. https://doi.org/10.1016/j.gltp.2021.01.004
Sigala, A. (2019). United States Air Force Applications of Unmanned Aerial Systems (UAS): A Delphi Study to Examine Current and Future UAS Autonomous Mission Capabilities.
Slayer, K. M. (2020). Artificial Intelligence and National Security.
Umbrello, S., Torres, P., & De Bellis, A. F. (2020). The future of war: could lethal autonomous weapons make conflict more ethical? AI and Society, 35(1), 273-282. https://doi.org/10.1007/s00146-019-00879-x
Vazquez, M. A., Henarejos, P., Pappalardo, I., Grechi, E., Fort, J., Gil, J. C., & Lancellotti, R. M. (2021). Machine Learning for Satellite Communications Operations. IEEE Communications Magazine, 59(2), 22-27. https://doi.org/10.1109/MCOM.001.2000367
Vorm, E. S. (2020). Computer-Centered Humans: Why Human-AI Interaction Research Will Be Critical to Successful AI Integration in the DOD. IEEE Intelligent Systems, 35(4), 112-116. https://doi.org/10.1109/MIS.2020.3013133
Wang, W., Liu, H., Lin, W., Chen, Y., & Yang, J. (2020). Investigation on Works and Military Applications of Artificial Intelligence. IEEE Access, 8, 131614-131625. https://doi.org/10.1109/ACCESS.2020.3009840
Wang, X., Xu, Y., Chen, C., Yang, X., Chen, J., Ruan, L., Xu, Y., & Chen, R. (2020). Machine Learning Empowered Spectrum Sharing in Intelligent Unmanned Swarm Communication Systems: Challenges, Requirements and Solutions. IEEE Access, 8, 89839-89849. https://doi.org/10.1109/ACCESS.2020.2994198
Wei, X., Yang, L., Cao, G., Lu, T., & Wang, B. (2020). Recurrent MADDPG for Object Detection and Assignment in Combat Tasks. IEEE Access, 8, 163334-163343. https://doi.org/10.1109/ACCESS.2020.3022638
Williams, M. D., & Lawson, P. C. (2020). Analyzing the Challenges and Obstacles to Developing and Fielding Autonomous and Semi-Autonomous Systems.
Xie, J., Peng, X., Wang, H., Niu, W., & Zheng, X. (2020). Uav autonomous tracking and landing based on deep reinforcement learning strategy. Sensors (Switzerland), 20(19), 1-17. https://doi.org/10.3390/s20195630
Yue, L., Xiaohui, Q., Xiaodong, L., & Qunli, X. (2020). Deep reinforcement learning and its application in autonomous fitting optimization for attack areas of UCAVs. Journal of Systems Engineering and Electronics, 31(4), 734-742. https://doi.org/10.23919/JSEE.2020.000048
Zaman, S., Alhazmi, K., Aseeri, M. A., Ahmed, M. R., Khan, R. T., Kaiser, M. S., & Mahmud, M. (2021). Security Threats and Artificial Intelligence Based Countermeasures for Internet of Things Networks: A Comprehensive Survey. IEEE Access, 9, 94668-94690. https://doi.org/10.1109/ACCESS.2021.3089681
Zhang, B., Anderljung, M., Kahn, L., Dreksler, N., Horowitz, M. C., & Dafoe, A. (2021). Ethics and governance of artificial intelligence: Evidence from a survey of machine learning researchers. Journal of Artificial Intelligence Research, 71, 591-666. https://doi.org/10.1613/JAIR.1.12895
Zhang, L. A., Xu, J., Gold, D., Hagen, J., Kochhar, A. K., Lohn, A. J., & Osoba, O. A. (2020). Air Dominance Through Machine Learning: A Preliminary Exploration of Artificial Intelligence-Assisted Mission Planning.
Zuluaga, J. G. C., Leidig, J. P., Trefftz, C., & Wolffe, G. (2018). Deep Reinforcement Learning for Autonomous Search and Rescue.Proceedings of the IEEE National Aerospace Electronics Conference, NAECON 2018 IEEE National Aerospace and Electronics Conference, NAECON 2018, July 23, 2018 - July 26, 2018, 2800 Presidential Drive, Dayton, OH, United states.

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IMPLEMENTING AN ENTREPRENEURIAL MINDSET THROUGH ACTIVITIES IN RECYCLING COURSE

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Abstract

There is an urgent need to connect theoretical knowledge acquired in engineering courses with practical, real-world applications to promote knowledge sustainability. To address this need, an entrepreneurially minded learning (EML) approach was implemented in an elective course titled Recycling of Advanced Engineering Materials. This approach enables students to explore the phases and interactions involved in product development by formulating and communicating requirements and solutions that consider both societal benefits and economic constraints, reflecting the entrepreneurial mindset behaviors outlined by the Kern Entrepreneurial Engineering Network (KEEN). The EML activities included hands-on recycling experiences and visits to local recycling companies, emphasizing motivation and overcoming conceptual learning barriers while enhancing students' entrepreneurial knowledge and reasoning skills. This study analyzed students' performance in exams, class discussions, and term projects alongside their perceptions of the engagement activities. Survey questions were designed to assess the impact of these activities on the development of students' entrepreneurial knowledge and abilities, utilizing a Likert scale for responses. Results from survey questions indicated that the EML approach significantly enhanced students' entrepreneurial knowledge and reasoning abilities, motivating them to engage in critical thinking and self-directed learning to address real-world challenges.

Keywords: *Entrepreneurially Minded Learning; Recycling; Self-directed Learning*

1. Introduction

With the dynamic change in global economy recently, purely theoretical and technical education and training are no longer sufficient for engineering graduates since ones need to take market and business pressure into account so that they can understand and contribute at any engineering firms, or to start their own ventures Duderstadt, (2007). For this reason, integrating entrepreneurial education into engineering programs has become crucial. Entrepreneurship has been the fastest-growing subject in many engineering fields for a few years. Implementing an entrepreneurial mindset in engineering education prepares students with essential competencies that help them go beyond theoretical knowledge and technical skills, fostering innovation and technological

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advancement within engineering disciplines Gilmartin et al. (2019). These consist of creativity, resilience, collaboration, leadership, and, more importantly, the ability to identify opportunities, take calculated risks, and drive impactful change Duval-Couetil et al. (2015). Integrating entrepreneurial mindset development into engineering education has been shown to increase students' entrepreneurial intentions Kwapisz, et al. (2022). This shift is essential for fostering a culture of innovation and creativity within engineering programs, allowing students to excel academically and apply their knowledge to real-world entrepreneurial endeavors Jiatong et al. (2021). Instilling this mindset early in undergraduate education nurtures the next generation of innovative engineers who can contribute meaningfully to society through their creations and solutions Udayanganie et al. (2019). By developing these skills, educators prepare students to become inventors, effective team members, leaders, and valuable contributors to existing firms. These qualities align with the evolving needs of industries, where employers value critical thinking, effective collaboration, and an understanding of business aspects. Consequently, incorporating entrepreneurship into engineering programs enables graduates to navigate challenges, identify unmet needs, and drive innovation in modern work environments, whether within their own enterprises or established organizations.

Educators have recognized the importance of incorporating authentic learning experiences that promote the entrepreneurial mindset within engineering classrooms Bosman and Fernhaber (2018). By immersing students in entrepreneurially minded assignments that blend engineering concepts with entrepreneurial processes, students are better prepared to navigate the complexities of the modern professional landscape Bosman and Fernhaber (2018). Initiatives like the Kern Entrepreneurial Engineering Network (KEEN) have underscored the significance of integrating Entrepreneurially Minded Learning into engineering curricula to equip students with the holistic understanding needed to succeed in the 21st-century engineering landscape Gorlewicz and Jayaram (2020). Kern Entrepreneurial Engineering Network (KEEN) is a collaborative partnership with more than 50 universities nationwide with the mission of ingraining and nourishing entrepreneurial mindset in engineering students. KEEN offers these institutions resources and initiatives such as exchanging best practices and co-creation, faculty development, identifying and supporting champions, community catalysts, ambassadors to professional societies, framework development, networking and collaboration, and KEEN rising stars. These aim to prepare students with the necessary skills and mindset so that through engineering work, they can create personal, economic, and societal value KEEN (2023).

Solid resource recovery is now a pivotal practice of waste management due to concerns about health and the environment, limitations on mining operations, increasing demands on new materials, supplies, and supply chains, as well as pressure on product costs. Solid wastes include plastics, papers, cans, cables, composites, ferrous and non-ferrous metals, construction debris, and electronic wastes (gold, silver, and platinum). The processes of solid resource recovery usually involve waste collection and characterization, segregation, collection, categorization, recycling, and safe landfill reclamation. There are several methods of waste segregation, for instance, gravity, electrostatic, optical, magnetic, chemical, hand sorting, bacterial, etc. Ijaola et al (2022), Asmatulu and Asmatulu (2011), aAsmatulu et al. (2013), Erkinay Ozdemir et al. (2021), Overcash et al. (2018), b Asmatulu et al. (2013), Asmatulu et al. (2014), Khan at al. (2022)

In this study, entrepreneurship was successfully integrated into the waste resource recovery course offered in the Department of Mechanical Engineering, Wichita State University, in Fall 2022 since recycling is believed to have added value to the economy and society of Wichita and Kansas. The offered course was Recycling of Advanced Engineering Materials, and it was a graduate level.

Besides traditional teaching methods, EM's activities, such as hands-on recycling experience and trips to local recycling companies in Wichita, Kansas, were also added to the course. The outcome of this entrepreneurship integration was measured by class discussion, and student's performance of assignments, exams, and group projects. Additionally, students' engagement were also collected and analyzed in the form of survey questions to reflect the impacts of entrepreneurial mindset learning on students' knowledge and skills toward entrepreneurship. Likert scale was used to study students' responses to survey questions.

2. Methodology

Resource recovery is an important factor that promotes environmental sustainability. Crucial topics of resource recovery were covered in lecture-based classes, which is a traditional teaching method. To demonstrate the topics to students and help them comprehend them, detailed PowerPoint slides, animations, and visual contents, such as figures, pictures, charts, tables, and videos, were included. Additionally, students received instruction on sustainability, using natural resources, life cycle analysis (LCA), and energy concepts. These are the topics that students usually do not learn in traditional teaching methods. Students had the opportunity to observe and perform some of the fundamental recovery processes in real-time through hands-on experience in laboratories. They were able to take advantage of such experiential learning to gain the ability to think critically, produce and collect measurable evidence, and adapt to changes. Furthermore, students learn valuable teamwork skills and how to work effectively as a team member, which prepares them for future work environments. This course can be used as either freshman design projects, Engineer of 2020 requirements, and capstone projects. Throughout the course, students had the opportunity to engage with local resource recovery companies, which potentially led to summer internships, future employment, and collaborative projects. By observing real-world examples within these firms and applying their experiences to lab-scale experiments, students significantly enhanced their critical thinking and problem-solving skills.

3. Plan for Execution

In order to successfully implement entrepreneurial mindset learning to this course, the plan with four major tasks were designed and executed. These included: Setting Appointments for Local Companies and Lab Setup, Student Training and Involvement, Visiting Local Recycling Companies, and Integrating Entrepreneurship Mindset into Resource Recovery.

Task 1: Setting Appointments for Local Companies and Lab Setup

This task was done prior to the start of the actual semester. Appointments were made with the local resource recovery companies to get to know them and what they could do to schedule the class trips. A small-scale resource recovery laboratory was set up in the College of Engineering. Small separation units, such as gravity, electrostatic, and magnetic separations, and other lab equipment and supplies (e.g., fume hood, furnace, hot plate, and necessary chemicals) were included in this lab.

Task 2: Student Training and Involvement

Approximately 10 students were accepted for the course at the beginning of the semester. They were trained about safety rules and regulations, operating principles, how to use lab equipment, etc. Topics that students learnt in the course include resource recovery, life cycle analysis, sustainability, and energy concepts. Several recovery techniques taught in the lecture were then demonstrated in the lab activities. Students formed groups of 3 or 4 to perform these techniques in the lab, as seen in Figure 1.

Experiments covered in the course include froth flotation for recovery of rare earth elements, styrofoam recycling and use in electrospinning, activated carbon preparation from waste materials for waste-water treatment, and chemical leaching for recovery of silver from automotive parts.

- **Froth Flotation for Recovery of Rare Earth Elements:** Froth flotation is a separation process used to segregate selectively hydrophobic materials from hydrophilic ones by the differences in hydrophobic degree. In this process, air bubbles were introduced into a mixture of finely divided ore or other materials with water and a chemical that aids in attaching the bubbles to the desired material, the hydrophobic particles can be recovered as a froth. Surfactants and wetting agents are commonly added to increase the difference in hydrophobicity. This segregation technique is widely used in paper recovery, wastewater treatment, and wastewater treatment.
- **Styrofoam Recycling and Using in Electrospinning:** Styrofoam was collected from various sources such as cups, plates, packaging peanuts, etc., and then dissolved by an appropriate solvent. The mixture was then used to fabricate micron and submicron size fibers using the electrospinning process, as shown in Figure 1 (c)
- **Activated Carbon Preparation from Waste Materials for Waste-Water Treatment:** Waste materials (e.g., fabric, newspaper, date, and olive fruit seeds) are used to turn into activated carbon through oxygen-free tube furnace burning followed by chemical activation. Later, these activated carbons are used in the water treatment column to clean out the impurities in water.
- **Chemical Leaching for Recovery of Silver from Automotive Parts:** Using sulfuric acid to leach silver from automotive parts and then recovering the silver.
- **Composite Recycling:** Using chemical recycling technique, dipping composite pieces in acids and solvents to separate fibers from resin.

(a) (b) (c)

Figure 1. (a) Chemical Leaching for Recovery of Silver from Automotive Parts; (b) and (c) Recycling of Styrofoam and Electrospinning

In addition to lab activities, students were also assigned to write test reports. These weekly reports enabled students to analyze current recovery techniques, which were introduced by the lecturers. They were expected to brainstorm, create innovative ideas, and techniques to improve each recovery process.

Task 3: Visiting Local Recycling Companies

There are more than 20 different recycling companies in Wichita, KS. Students had opportunity to visit ABC Recycling company and that offered students a lot of opportunities to observe the processes at larger scales.

Task 4: Integrating Entrepreneurship Mindset into Resource Recovery

Entrepreneurship education provided students with the knowledge, skills and motivation to encourage entrepreneurial success in a variety of settings in the recycling business. Students were frequently asked about how they could use the knowledge and skills learned in the lectures, hands-on lab sessions, company visits, and turn them into cash (or setup their own business) during class discussion.

4. Survey Questions and Likert Scale

To evaluate the effectiveness of integrating entrepreneurial training and hands-on experience in an engineering curriculum, a survey was conducted among students enrolled in a course that included diverse educational techniques such as company visits, hands-on experiments, and entrepreneurial training. The survey comprised ten Likert scale questions, assessing various aspects of the students' learning experience. 10 survey questionnaires were designed and given to students so that they could response from the scale from 0 to 5. A Likert scale is a widely used psychometric tool for measuring attitudes, perceptions, opinions, and behaviors in a standardized and economical manner Ho (2017). Likert scales consist of a series of statements or questions with response options typically ranging from "strongly disagree" to "strongly agree". These scales are considered ordinal, providing a relative ranking of responses without implying a specific measurement distance between them Jamieson (2004). The systematic agree-disagree scale is arranged as follows: (1) Strongly disagree; (2) Disagree; (3) Neither agree nor disagree; (4) Agree; (5) Strongly agree.

In this study, a set of 10 questionnaires were written in such a way that could capture students' opinions, perceptions, or intuitions about whether or not entrepreneurial mindset training added any value to their learning of recycling materials. The 10 questionnaires are listed as below:

Question 1: Hands on experience section help you understand more of the recycling concept.

Question 2: Local recycling company visits are beneficial for observing separation and recycling techniques.

Question 3: This class gives me a better understanding of the entrepreneurial concept.

Question 4: Seeing the recycling operation in the companies and experimenting with the same thing in a lab environment increased my critical thinking ability.

Question 5: The instructor introduces many educational techniques (company visits, hands-on experience, videos, PowerPoint slides, animations, group projects) to increase the basic fundamental understanding.

Question 6: Entrepreneurial training provided in this class can turn my ideas to business opportunities.

Question 7: Entrepreneurial training given in this class makes me think creatively.

Question 8: Current recycling and separation techniques are energy efficient.

Question 9: Current recycling and separation techniques are environmentally friendlier.

Question 10: Current recycling techniques yielded good quality of recyclates.

5. Survey Results

The Likert scale results for this study is given in Table 1. All of the students responded to the survey in the agree and strongly agree categories. This indicates agreement with the educational value and efficiency of the entrepreneurial concept in the recycling course.

TABLE 1. Likert Scale Result from Survey Questions

Questions	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
Q1	50	40	10	0	0
Q2	60	30	10	0	0
Q3	60	10	30	0	0
Q4	40	50	10	0	0
Q5	70	10	20	0	0
Q6	60	20	20	0	0
Q7	40	40	20	0	0
Q8	10	60	30	0	0
Q9	20	40	40	0	0
Q10	20	50	30	0	0

The survey results indicate that students overwhelmingly appreciated the hands-on experiences and local company visits, with 90% agreeing that these activities were beneficial. These practical experiences significantly enhanced their understanding of recycling concepts and critical thinking abilities, with no students expressing disagreement and only a small percentage remaining neutral. The course also effectively conveyed entrepreneurial concepts, as evidenced by 70% of students agreeing it provided a better understanding, 80% believing it could turn ideas into business opportunities, and 80% agreeing it encouraged creative thinking. However, the higher neutral response for understanding entrepreneurial concepts (30%) suggests that some students were less confident about this aspect of the course.

Additionally, the diverse educational techniques employed by the instructor received high praise, with 80% of students expressing agreement and none disagreeing, indicating a broad approval of the varied teaching methods used. On the other hand, students had mixed feelings about the efficiency and environmental friendliness of current recycling techniques. While 70% agreed on the energy efficiency and quality of recyclates, only 60% agreed on the environmental friendliness, with a significant 40% remaining neutral on both environmental friendliness and recyclate quality. These mixed perceptions suggest areas where the course or industry practices could be improved to better address student concerns and enhance understanding.

Overall, the hands-on experiences and company visits were particularly effective and appreciated, significantly enhancing learning outcomes related to recycling and critical thinking. The course successfully conveyed entrepreneurial concepts to a majority of students, though some remained uncertain. The educational techniques were well-received, indicating successful instructional methods. However, students' varied perceptions of recycling techniques' efficiency and environmental impact highlight potential areas for further education and improvement.

6. Benefits of Implementing Entrepreneurial Mindset Through Activities in a Recycling Course

Entrepreneurship education is essential for developing a wide range of skills and attitudes among students that are crucial for their personal and professional growth. Through engaging in entrepreneurial activities related to a recycling course, students can enhance their problem-solving skills by creatively addressing recycling challenges and critically analyzing existing recycling systems for areas of improvement Hasan et al. (2017). This approach not only enhances their ability to innovate but also fosters project ownership, thereby increasing their engagement and motivation towards the course Davey et al. (2011). Additionally, participating in entrepreneurial activities provides students with practical experience, enabling them to develop hands-on skills such as project management, organizational skills, and time management Hasan et al. (2017).

Moreover, entrepreneurship education plays a significant role in cultivating key entrepreneurial skills like leadership, teamwork, and effective communication Muofhe and Du Toit (2011). By collaborating on entrepreneurial projects, students learn to work in teams, lead initiatives, and communicate their ideas clearly, both verbally and in writing Muofhe and Du Toit (2011). This not only prepares them for future entrepreneurial pursuits but also equips them with transferable skills applicable in various career paths. An entrepreneurial approach to recycling in educational settings can significantly impact students' awareness of environmental issues and foster a sense of social responsibility and community involvement. By actively engaging students with the community to implement recycling initiatives, they not only gain a deeper understanding of the social and environmental impacts but also enhance their sense of civic engagement and responsibility Verplanken and Wood (2006), Cho, (2019). Social marketing programs have been identified as effective methods to reduce waste and increase recycling, emphasizing the importance of community involvement and behavioral change Özbakır Umut and Nurtanış Velioğlu (2024), Haldeman and Turner (2009). Additionally, successful habit change interventions involve disrupting environmental factors that trigger habitual behaviors, highlighting the need for targeted strategies to promote recycling Verplanken and Wood (2006).

Entrepreneurship education also presents opportunities for potential innovation and start-up ventures for students. By encouraging them to develop ideas that could lead to new recycling businesses or innovative products, students are exposed to economic opportunities and motivated to identify market gaps for sustainable solutions Hasan et al. (2017). Additionally, through entrepreneurial activities, students learn to embrace failure as a learning opportunity, building resilience and adaptability crucial for their future careers Hasan et al. (2017). They also develop agility in pivoting and adapting their ideas based on feedback and changing circumstances, essential skills in any professional setting Hasan et al. (2017). Moreover, collaborating with professionals and entrepreneurs in the recycling industry offers students valuable networking opportunities and practical insights into real-world applications. By engaging with mentors from the recycling sector, students can benefit from guidance and feedback on their projects, enhancing the quality and relevance of their work. These industry connections not only provide a platform for networking but also serve as a source of inspiration and knowledge transfer, bridging the gap between academic learning and practical implementation in the field of recycling. Such collaborations can lead to innovative solutions and foster a deeper understanding of the challenges and opportunities within the recycling industry, ultimately contributing to the development of sustainable practices and technologies. By embedding an entrepreneurial mindset into recycling education, students not only gain valuable skills but also contribute to sustainable development and environmental stewardship Zain et al. (2013).

7. Conclusion

The study highlights the educational advantages of integrating entrepreneurial concepts and hands-on experiences in a recycling course, benefiting both environmental sustainability and student development. By blending traditional lecture-based teaching with dynamic, experiential learning methods, including detailed PowerPoint slides, animations, figures, and videos, students gained a robust understanding of topics like resource recovery, sustainability, and energy concepts often overlooked in standard classes. A significant majority of students (90%) found hands-on laboratory experiences and local company visits valuable, enhancing their critical thinking and problem-solving abilities while providing real-world insights. The course effectively conveyed entrepreneurial concepts, with 70% of students agreeing it provided a better understanding and 80% believing it could foster creative thinking and turn ideas into business opportunities. The diverse educational techniques employed were highly appreciated, with 80% expressing satisfaction. However, students had mixed feelings about the environmental benefits of current recycling techniques, suggesting a need for improved communication. The course plan included practical activities like setting up appointments with local companies and integrating an entrepreneurial mindset into resource recovery, providing students with valuable industry connections and hands-on experience to develop critical skills for future careers.

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9. References

Asmatulu, R., & Asmatulu, E. (2011). Importance of recycling education: a curriculum development at WSU. Journal of Material Cycles and Waste Management, 13, 131-138. https://doi.org/10.1007/s10163-011-0002-4

[a]Asmatulu, E., Twomey, J., & Overcash, M. (2013). Evaluation of recycling efforts of aircraft companies in Wichita. Resources, Conservation and Recycling, 80, 36-45. https://doi.org/10.1016/j.resconrec.2013.08.002

[b]Asmatulu, E., Overcash, M., & Twomey, J. (2013). Recycling of Aircraft: State of the Art in 2011. Journal of Industrial Engineering, 2013(1), 960581. https://doi.org/10.1155/2013/960581

Asmatulu, E., Twomey, J., & Overcash, M. (2014). Recycling of fiber-reinforced composites and direct structural composite recycling concept. Journal of Composite Materials, 48(5), 593-608. https://doi.org/10.1177/0021998313476325

Bosman, L. and Fernhaber, S., 2018. Applying authentic learning through cultivation of the entrepreneurial mindset in the engineering classroom. Education Sciences, 9(1), p.7. https://doi.org/10.3390/educsci9010007

Cho, M. (2019). Campus sustainability: An integrated model of college students' recycling behavior on campus. International Journal of Sustainability in Higher Education, 20(6), 1042-1060.

Davey, T., Plewa, C., & Struwig, M. (2011). Entrepreneurship perceptions and career intentions of international students. Education+ training, 53(5), 335-352.

Duderstadt, J. J. (2007). Engineering for a changing road, a roadmap to the future of engineering practice, research, and education.

Duval-Couetil, N., Kisenwether, E., Tranquillo, J., & Wheadon, J. (2015). Exploring the intersection of entrepreneurship education and ABET accreditation criteria. The Journal of Engineering Entrepreneurship, 6(2), 44-57.

Erkinay Ozdemir, M., Ali, Z., Subeshan, B., & Asmatulu, E. (2021). Applying machine learning approach in recycling. Journal of Material Cycles and Waste Management, 23, 855-871. https://doi.org/10.1007/s10163-021-01182-y

Gilmartin, S. K., Thompson, M. E., Morton, E., Jin, Q., Chen, H. L., Colby, A., & Sheppard, S. D. (2019). Entrepreneurial intent of engineering and business undergraduate students. Journal of Engineering Education, 108(3), 316-336. https://doi.org/10.1002/jee.20283

Gorlewicz, J. L., & Jayaram, S. (2020). Instilling curiosity, connections, and creating value in entrepreneurial minded engineering: Concepts for a course sequence in dynamics and controls. Entrepreneurship Education and Pedagogy, 3(1), 60-85. https://doi.org/10.1177/2515127419879469

Haldeman, T., & Turner, J. W. (2009). Implementing a community-based social marketing program to increase recycling. Social Marketing Quarterly, 15(3), 114-127. https://doi.org/10.1080/15245000903154618

Hasan, S. M., Khan, E. A., & Nabi, M. N. U. (2017). Entrepreneurial education at university level and entrepreneurship development. Education+ Training, 59(7/8), 888-906.

Ho, G. W. (2017). Examining perceptions and attitudes: A review of Likert-type scales versus Q-methodology. Western journal of nursing research, 39(5), 674-689. https://doi.org/10.1177/0193945916661302

Ijaola, A. O., Akamo, D. O., Adekanmi, A. M., Saberi, Q., Koken, D., & Asmatulu, E. (2022). Superhydrophobic and self-cleaning electrospun microfibers from recycled styrofoam. Results in Surfaces and Interfaces, 9, 100086. https://doi.org/10.1016/j.rsurfi.2022.100086

Jamieson, S. (2004). Likert scales: How to (ab) use them?. Medical education, 38(12), 1217-1218. https://doi.org/10.1111/j.1365-2929.2004.02012.x

Jiatong, W., Murad, M., Bajun, F., Tufail, M. S., Mirza, F., & Rafiq, M. (2021). Impact of entrepreneurial education, mindset, and creativity on entrepreneurial intention: mediating role of entrepreneurial self-efficacy. Frontiers in psychology, 12, 724440. https://doi.org/10.3389/fpsyg.2021.724440

Khan, W. S., Asmatulu, E., Uddin, M. N., & Asmatulu, R. (2022). Recycling and reusing of engineering materials: Recycling for sustainable developments. ISBN 0128224622, 9780128224625

Keen. "What is KEEN?" Engineering Unleashed. (n.d.). Accessed: Jun. 11, 2023. https://keenweb-prod.azurewebsites.net/what-is-keen

Kwapisz, A., Schell, W. J., Aytes, K., & Bryant, S. (2022). Entrepreneurial action and intention: the role of entrepreneurial mindset, emotional intelligence, and grit. Entrepreneurship Education and Pedagogy, 5(3), 375-405. https://doi.org/10.1177/2515127421992521

Muofhe, N. J., & Du Toit, W. F. (2011). Entrepreneurial education's and entrepreneurial role models' influence on career choice. SA journal of human resource management, 9(1), 1-15. https://hdl.handle.net/10520/EJC95931

Overcash, M., Twomey, J., Asmatulu, E., Vozzola, E., & Griffing, E. (2018). Thermoset composite recycling–Driving forces, development, and evolution of new opportunities. Journal of Composite Materials, 52(8), 1033-1043. https://doi.org/10.1177/0021998317720000

Özbakır Umut, M., & Nurtanış Velioğlu, M. (2024). A recycling story: Developing recycling behavior in Turkey with social marketing program. Journal of Public Affairs, 24(1), e2900. https://doi.org/10.1002/pa.2900

Udayanganie, W. M. I., Jusoh, M., & Chinna, K. (2019). The role of the cognitive variables on intention to entrepreneurial behavior of engineering undergraduates in Sri Lanka. Journal of Entrepreneurship and Business Innovation, 6(1), 1-12. http://dx.doi.org/10.5296/jebi.v6i1.14927

Verplanken, B., & Wood, W. (2006). Interventions to break and create consumer habits. Journal of public policy & marketing, 25(1), 90-103. https://doi.org/10.1509/jppm.25.1.90

Zain, S. M., Basri, N. E. A., Mahmood, N. A., Basri, H., Yaacob, M., & Ahmad, M. (2013). Innovation in Sustainable Education and Entrepreneurship through the UKM Recycling Center Operations. International Education Studies, 6(1), 168-176. http://www.ccsenet.org/journal/index.php/es

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SMART FACTORY INTEGRATION IN INDUSTRIAL ENGINEERING CURRICULUM: PREPARING STUDENTS FOR INDUSTRY 4.0 CHALLENGES

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Abstract

This paper discusses the integration of Smart Factory technology into Industrial and Systems Engineering education, focusing on its transformative impact and educational implications. Smart factories are revolutionizing the modern manufacturing industry by leveraging Cyber-Physical Systems (CPS) and cutting-edge technologies. Through the integration of Artificial Intelligence (AI) and the Internet of Things (IoT), these factories enhance production efficiency, minimize costs, and elevate the overall quality of their goods and services. Understanding the impact of smart factories and the educational implications that follow from this technology is crucial. Doing so enables us to prepare students for the challenges of the modern manufacturing industry, fostering a more informed, skilled, and adaptable workforce. Therefore, this research highlights the benefits of incorporating smart factory concepts into industrial engineering education to prepare students for "Industry 4.0" challenges. By providing hands-on experience with smart factory technology, this research aims to enhance industrial engineering students' theoretical knowledge and practical understanding of smart factories.

Keywords: *Smart Factory; Engineering Education; Cyber-Physical Systems (CPS); Industry 4.0*

1. Introduction

Manufacturing has undergone a remarkable transformation in the last two decades, partly due to the convergence of technological advancements and globalization. These changes have presented both opportunities and challenges for manufacturers who endeavor to meet the ever-changing demands of consumers in today's global market (Kumar et al., 2019). Additionally, the advancements in manufacturing necessitate that industrial engineering students be equipped with the knowledge and skills to excel in modern manufacturing. This research hypothesizes that integrating smart factory technology into the engineering curricula will enhance students' theoretical and practical education of modern manufacturing systems, thereby increasing their career prospects within industrial engineering.

As competitiveness within manufacturing intensifies, educational institutions can adapt by preparing students for the challenges posed by Industry 4.0. This term, coined by German industrialists, refers to the integration of information and communication technologies within industrial processes to create data-driven production environments (Xu et al., 2018). Industry 4.0 utilizes Cyber-Physical Systems (CPS), Artificial Intelligence (AI), and the Internet of Things (IoT) to increase efficiency, productivity, and automation within factories (Hozdić, 2015). These technologies are highly valuable in the production process, reducing the costs associated with production and making real-time decisions to meet dynamic customer needs (Angelopoulos et al., 2019).

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The objective of this study is to explore how implementing smart factory concepts into engineering courses can better prepare students to navigate automated manufacturing systems. Prior research has demonstrated the importance of practical experience in developing technical skills, but many curricula lack the necessary hands-on exposure to Industry 4.0 technologies (Ghahramani et al., 2020). By implementing smart factory technology within the Industrial and Systems Engineering program, this study aims to assess how these educational tools can improve student learning and skill development in preparation for Industry 4.0 challenges.

Industry 4.0 is designed to be flexible, efficient, and seamlessly integrate digital and physical components. Smart factories are equipped with advanced technologies that enable them to monitor and adjust processes in real-time, reducing the risk of errors and minimizing the need for human intervention (Matyushok et al., 2021). The Internet of Things (IoT), artificial intelligence (AI), and machine learning (ML) are some of the technologies that Industry 4.0 leverages to automate production processes, optimize manufacturing operations, and reduce downtime (Rath et al., 2024). By incorporating these technologies, manufacturers can create automated production lines that quickly adapt to changing consumer demands, thereby reducing the time to market (Angelopoulos et al., 2019). Industry 4.0 also enables manufacturers to collect and analyze vast amounts of data, allowing for better decision-making and process optimization (Ghobakhloo, 2018). Overall, implementing Industry 4.0 is crucial for manufacturers to remain competitive in today's fast-paced market. By embracing this approach, manufacturers can create highly adaptable, efficient, and responsive production lines that can meet consumers' ever-changing demands (Abdelmajied, 2022).

In recent years, scholars have explored the challenges and solutions involved in incorporating Smart Manufacturing concepts into engineering curricula. One study focused on the integration of Industry 4.0 concepts within the industrial engineering department of King Saud University (Salah et al., 2020). They presented a case study, highlighting the benefits of Industry 4.0 and providing insight into the effective methods utilized to educate engineers. Five key recommendations were identified for universities seeking to implement smart technology effectively, which include the development of a skilled faculty development program, research collaboration, enhancement of research quality, increased funding for research, and promotion of research culture (Chelini & Richert, 2023). Another study focused on developing a methodology to incorporate Industry 4.0 concepts into the Turkish German University located in Istanbul (Coşkun et al., 2019). The process begins with an orientation program for students and concludes with an assessment of their ability to apply these concepts. Other researchers focused on cost-effective and sustainable manufacturing and highlighted the importance of integrating “Smart” principles into manufacturing processes (Ghahramani et al., 2020).

While previous studies have explored the integration of Smart Factory concepts into engineering education, our research has a hands-on approach to demonstrate the feasibility of integrating such technologies and provide concrete examples and lessons learned that can guide other institutions in similar endeavors. By providing hands-on experience, we aim to inspire other academic institutions to embrace innovation within engineering curricula. Our study emphasizes the importance of smart factory education in preparing engineers to tackle the challenges of future manufacturing. This, we hypothesize, will enhance students’ practical understanding of modern manufacturing systems, thus increasing their career prospects within industrial engineering.

2. Background

2.1. The Smart Factory

Smart factories represent a new generation of manufacturing facilities that rely on advanced technologies to enhance efficiency and productivity (Mohamed et al., 2019). These factories are designed to incorporate various technologies, such as Programmable Logic Controllers (PLCs), IoT, ML, Robots, and autonomous stations, responsible for assembling workpieces, ensuring quality control, and handling unforeseen issues (Hu et al., 2016). Smart Factories are equipped with data analytics and machine learning capabilities, which enable them to achieve adaptive production scheduling, predictive maintenance, and continuous quality improvement. Cyber-physical systems (CPS) form the backbone of these factories, integrating mechanical devices, software, and electronics into a cohesive system (Colombo et al., 2017). These interconnected systems support real-time communication and autonomous operation. IoT devices further facilitate data exchange between workstations and digital systems, enable data monitoring, and provide control over the Smart Factory system (Lin et al., 2019). PLCs are the key elements that orchestrate data flow and execute commands across the various components, which plays a valuable role in enabling optimal performance within the Smart Factory (Chen et al., 2017).

2.2. The Benefits of Smart Factories

One of the main advantages of Smart Factories is their ability to significantly reduce downtime and production costs. Smart Factories can minimize unexpected downtime and increase efficiency by predicting when maintenance is needed and scheduling repairs before a breakdown occurs (Chen et al., 2017). In addition, the use of autonomous stations and real-time communication between systems allows for more flexible production processes. In terms of quality control, smart factories have the potential to enhance product quality by using sensors and other control measures to ensure that products meet specific standards. By detecting and addressing quality issues early on, these factories can reduce waste and improve customer satisfaction (Büchi et al., 2020). Moreover, they can have a positive environmental impact by optimizing production processes and minimizing waste. As smart technologies continue to evolve, the potential for Smart Factories will continue to grow. The utilization of AI and ML can lead to more sophisticated automation and predictive capabilities, resulting in increased efficiency and productivity (Shi et al., 2020).

3. Research Methodology

This study employs a multiple-stage approach to integrate Smart Factory systems into the Industrial Engineering curriculum. The methodology focuses on identifying the primary skills, assessing smart technologies, mapping technologies into the curriculum, designing an integration strategy, and planning for future data collection. We hypothesize that the inclusion of smart factory technologies within the curriculum will enhance students' hands-on skills, improve their understanding of Industry 4.0 principles, and better prepare them for modern industrial challenges.

3.1. Skill Identification

The first stage in the research methodology focused on identifying the general skills associated with smart manufacturing and Industry 4.0. The literature suggests that skills such as data analysis, digital prototyping, robotics, and IoT will be highly valued skills for industrial engineers working with smart manufacturing (Deloitte, 2018). Additionally, skills such as automation and data-driven decision-making are vital to operational efficiency (Rath et al., 2024). We focused on four primary competencies: automation technology, data analytics, production control, and systems integration. These skills were selected based on their role in optimizing manufacturing processes, reducing waste and downtime, and improving product quality (Angelopoulos et al., 2019).

- Automation Technology: The focus of this area includes the ability to work with sensors, actuators, and robotic systems to control and monitor manufacturing processes. Understanding automated systems is critical to enhancing flexibility, efficiency, and reducing errors (Matyushok et al., 2021).
- Data analytics: The ability to collect, interpret, and utilize this sensor and process data. Smart factories rely on real-time data analytics to optimize production, predict maintenance needs, and improve decision-making (Rath et al., 2024). By developing data analysis skills, students will be prepared to analyze the large datasets that are vital to modern manufacturing.
- Production Control: Cyber-physical production systems allow for quick changes to production processes which must adapt to variations in market demands and system conditions. Thus, skills in managing production schedules, material flows, and process efficiency are important for graduates entering the workforce.
- Systems Integration: Competency in systems integration includes understanding how different subsystems, such as IoT, cloud computing, and robotics, communicate to optimize overall performance.

3.2. Smart Factory Components Assessment

In the second stage, the researchers identified the main components of the smart factory. Technologies such as the PLC, conveyor belt, robotic arm, and cloud-based data systems were analyzed and used by researchers to determine how each component could be used to enhance student learning in industrial engineering courses.

3.3. Curriculum Mapping

Next, the courses within the Industrial Engineering curriculum were evaluated to identify the classes that would benefit from integrating smart factory technology. Courses were organized based on their relevance to smart manufacturing principles and their potential for hands-on coursework. These courses included Systems Simulation, Manufacturing Systems & Facilities Design, and Production & Inventory Control Systems as the main choices for smart factory integration.

3.4. Designing the Integration Plan

The next stage focused on the development of an integration plan for the selected courses. This plan will outline specific learning objectives, assignments, and lab sessions that use the smart factory to reinforce theoretical and experimental understanding. In the Systems Simulation course, for example, students will use the smart factory to model industrial processes and run simulations to predict the outcomes of different production processes. In the Manufacturing Systems & Facilities Design course, students can use the assembly line and analyze process data to simulate manufacturing processes and improve system layouts. The integration plan will provide students with opportunities to engage with these technologies in a meaningful way, enhancing their hands-on knowledge of manufacturing systems.

3.5. Future Data Collection and Evaluation

Although no data has been collected at this stage, future research will focus on evaluating the effects of smart factory integration on improving student learning outcomes. The planned methods for data collection include:

- Student Assessments: Students’ knowledge can be measured before and after the course to determine students’ knowledge of automation, data analytics, and systems integration.
- Student feedback: Surveys can be given to students to gain qualitative data about the

perceived value of smart factory learning activities.

- Instructor Evaluations: Faculty members can provide feedback on the challenges or benefits that the smart factory provided.

This methodology provides a framework for integrating smart factory technologies into the Industrial Engineering curriculum. By focusing on smart factory skill identification, assessing the smart factory components, curriculum mapping, and developing an integration plan, this research aims to prepare students for the challenges of Industry 4.0. Future data collection and analysis will determine the effectiveness of these efforts in improving student outcomes.

3.6. Potential Challenges

While the integration of Smart Factory technology holds significant promise, it is not without its challenges. One of the main challenges is the financial investment required for acquiring and maintaining equipment, such as PLCs, robotic arms, and IoT devices. Additionally, faculty members may need specialized training to effectively teach the concepts of Industry 4.0 technologies, which could require additional time and resources. Addressing these challenges will involve a combination of securing external funding, offering professional development courses, and developing collaborations with industry partners to ensure the successful implementation of these technologies in education.

4. Results & Analysis: Smart Factory Lab Integration

4.1. Smart Factory Lab

The specific systems used for our research are the Lucas Neulle "CBP 44 VARIANT PRODUCTION WITH EJECTION" integrated with a Programmable PLC (model: Siemens Simatic S7-1500). It is meant for student experiments involving a conveyor belt or for integration into a more complex mechatronics system. The Siemens PLC system, mounted on the front of the belt module, is responsible for controlling the module. The conveyor belt is used for carrying pallets and their workpieces, connecting different processing stations. It can also be combined with other belts, curve segments, or transfer nodes to develop more complex processes. Processing stations connected to the belt can be controlled by the PLC system via the 25-pin D-Sub port. The workpiece is created on a pallet, which is pushed by a conveyor belt to specific selection, assembly, and processing stations. The user places an order with the cloud-based ordering system which initiates the workpiece to begin being built. The components of the Smart Factory are shown in Figure 1.

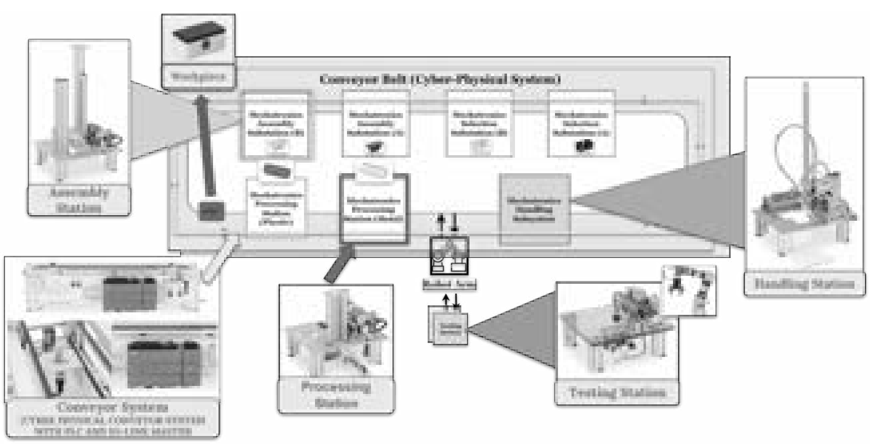

Figure 1. Smart Factory Lab Layout and Components

4.2. Integration within the Industrial Engineering Curriculum

To integrate smart factory technology, we mapped relevant courses in the Industrial and Systems engineering curriculum to smart manufacturing skills, identifying 15 classes that could benefit from this integration.

Based on our analysis, 'Introduction to Systems Simulation' was the most suitable course for incorporating Smart Factory concepts. It focuses on developing simulations to replicate real-life industrial scenarios, allowing students to understand manufacturing processes, examine the systems behavior, and collect data for analysis.

'Manufacturing Systems & Facilities Design' was the second-best fit. This course focuses on facility layouts, including workstations and machinery. Integrating Smart Factory technology would allow students to explore how PLCs monitor stations, analyze data, and manage quality control through systems like online ordering and cloud integration.

The 'Production & Inventory Control Systems' course was determined to be the third-best fit. This course examines topics such as demand forecasting, production planning, materials procurement, and the development of a production system to maximize profitability. This requires balancing factors like product quality, manufacturing costs, and process time through production control.

'Introduction to Industrial and Systems Engineering' came in fourth, providing students with a basic understanding of Industry 4.0 concepts and Smart Factory applications.

Finally, Introduction to Statistical Quality Control was selected for its potential to explore quality control within the Smart Factory, focusing on the communication between the conveyor system, PLCs, and other components. Figure 2 illustrates the most relevant courses.

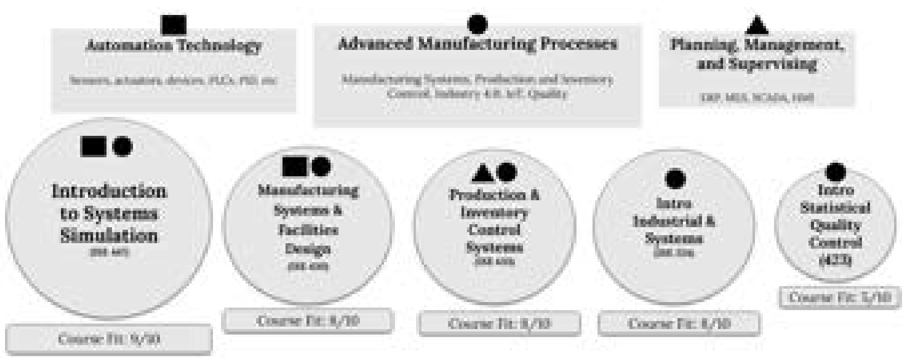

Figure 2. Industrial Engineering Courses that Could Benefit from Smart Factory Integration

In summary, the Smart Factory can be integrated into the Industrial and Systems Engineering curriculum to offer students hands-on experience through specialized labs in areas like simulation, robot operation, quality control, and lead time management using PLCs. These labs cover key aspects of smart factory operations and provide practical skills.

The first proposed lab focuses on simulation techniques, where students build models to test scenarios, using real data to predict and optimize processes. The second lab idea develops skills in programming and operating robots, with students conducting quality tests and writing instructions for automated factories. Lastly, the third lab could be centered around quality control, with students analyzing data, applying statistical techniques, and troubleshooting production issues.

5. Discussion

We hypothesize that integrating smart factory technology into the curriculum will equip students with essential skills that meet the future demands of the manufacturing industry. By providing students with skills in automation, data analytics, production control, and systems integration, they can be prepared for a technologically advanced work environment. While challenges such as resource allocation and faculty training exist, the benefits of equipping students with hands-on experience in smart technologies are significant.

The analysis shows courses like ‘Introduction to Systems Simulation’ and ‘Manufacturing Systems & Facilities Design’ are well-suited for this integration. Furthermore, the practical labs in simulation, robotics, and quality control can allow students direct experience with real-world manufacturing processes. These labs help students understand automation and real-time process optimization, enhancing students' understanding of key industrial engineering principles.

6. Conclusion

This research presents an exploration of the integration of a smart factory into the Industrial and Systems Engineering curriculum to prepare students for Industry 4.0. Through an examination of existing literature and case studies, we have obtained insights into the transformative potential of Smart Factory concepts in preparing students for the challenges of modern manufacturing. The literature suggests that by integrating Smart Factories into industrial engineering curricula, educational institutions can cultivate a workforce that is adaptable, innovative, and well-prepared for the demands of the modern manufacturing industry. This approach benefits student learning outcomes and contributes significantly to the advancement of industry practices and sustainability efforts. Specifically, the role of technologies such as PLCs, IoT, AI, and robotics cannot be overstated. These technologies are crucial for enabling automation, data analytics, and real-time decision-making in manufacturing processes.

The research shows that smart factory labs enhance students' understanding of modern manufacturing processes and help institutions stay relevant with advanced manufacturing practices. Challenges such as faculty training and resource investment are acknowledged, however, they can be addressed through potential industry partnerships and funding. Faculty development is also key to enhancing the teaching of these new technologies. Thus, future efforts could focus on developing faculty training programs and seeking industry collaborations to continue enhancing engineering education to meet the challenges of Industry 4.0. By doing so, institutions can ensure that their graduates are well-equipped to lead innovation in manufacturing and beyond. Through such efforts, we can ensure that future industrial engineers are adept at applying their skills to enhance efficiency, productivity, and sustainability in modern manufacturing.

7. Disclaimer Statements

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8. References

Abdelmajied, FathyElsayed Youssef (2022). Industry 4.0 and Its Implications: Concept, Opportunities, and Future Directions. Supply Chain - Recent Advances and New Perspectives in the Industry 4.0 Era. https://doi.org/10.5772/intechopen.102520

Angelopoulos, A., Michailidis, E. T., Nomikos, N., Trakadas, P., Hatziefremidis, A., Voliotis, S., & Zahariadis, T. (2019). Tackling faults in the industry 4.0 era- a survey of machine-learning solutions and key aspects.

Sensors, 20(1), 109. https://doi.org/10.3390/s20010109

Büchi, G., Cugno, M., & Castagnoli, R. (2020). Smart factory performance and Industry 4.0. Technological forecasting and social change, 150, 119790. https://doi.org/10.1016/j.techfore.2019.119790

Chelini, J., & Richert, D. (2023). Teaching Engineering Design for Industry 4.0 Using a Cyber-Physical Learning Factory. IFAC-PapersOnLine, 56(2), 4699-4704. https://doi.org/10.1016/j.ifacol.2023.10.994

Chen, J.-Y., Tai, K.-C., & Chen, G.-C. (2017). Application of Programmable Logic Controller to Build-up an Intelligent Industry 4.0 Platform. Procedia CIRP, 63, 150–155. https://doi.org/10.1016/j.procir.2017.03.116

Colombo, A. W., Karnouskos, S., Kaynak, O., Shi, Y., & Yin, S. (2017). Industrial Cyberphysical Systems: A Backbone of the Fourth Industrial Revolution. IEEE Industrial Electronics Magazine, 11(1), 6–16. https://doi.org/10.1109/mie.2017.2648857

Coşkun, S., Kayıkcı, Y., & Gençay, E. (2019). Adapting Engineering Education to Industry 4.0 Vision. Technologies, 7(1), 10. https://doi.org/10.3390/technologies7010010

Deloitte. (2018). The future of manufacturing: The jobs are here, but where are the people? Retrieved from: https://www2.deloitte.com/content/dam/insights/us/articles/4736_2018-Deloitte-skills-gap-FoW-manufacturing/DI_The-jobs-are-here-where-are-the-people.pdf

Ghahramani, M., Qiao, Y., Zhou, M. C., O'Hagan, A., & Sweeney, J. (2020). AI-based modeling and data-driven evaluation for smart manufacturing processes. IEEE/CAA Journal of Automatica Sinica, 7(4), 1026–1037. https://doi.org/10.1109/jas.2020.1003114

Ghobakhloo, M. (2018). The future of manufacturing industry: a strategic roadmap toward Industry 4.0. Journal of Manufacturing Technology Management, 29(6), 910–936. https://doi.org/10.1108/jmtm-02-2018-0057

Hozdić, E. (2015). Smart factory for industry 4.0: A review. International Journal of Modern Manufacturing Technologies, 7(1), 28-35. Retrieved from: (PDF) Smart factory for industry 4.0: A review (researchgate.net)

Hu, F., Lu, Y., Vasilakos, A. V., Hao, Q., Ma, R., Patil, Y., Zhang, T., Lu, J., Li, X., & Xiong, N. N. (2016). Robust Cyber–Physical Systems: Concept, models, and implementation. Future Generation Computer Systems, 56, 449–475. https://doi.org/10.1016/j.future.2015.06.006

Kosty, Amanda and McAtee, J. Craig. (2019). Defining Industry 4.0 for Community Colleges Creating Connections in Manufacturing Communities with Community Colleges initiative Capstone Report. Retrieved from: https://www.aacc.nche.edu/wp-content/uploads/2021/04/ArconicCapstoneReport_FINAL.pdf

Kumar, K., Zindani, D., & Davim, J. P. (2019). Industry 4.0: developments towards the fourth industrial revolution. Cham, Switzerland: Springer. https://doi.org/10.1007/978-981-13-8165-2

Lin, Y.-J., Wei, S.-H., & Huang, C.-Y. (2019). Intelligent Manufacturing Control Systems: The Core of Smart Factory. Procedia Manufacturing, 39, 389–397. https://doi.org/10.1016/j.promfg.2020.01.382

Matyushok, V., Krasavina, V., Berezin, A., & García, J. S. (2021). The global economy in technological transformation conditions: A review of modern trends. Economic Research-Ekonomska Istraživanja, 34(1), 1471–1497. https://doi.org/10.1080/1331677x.2020.1844030

Mohamed, N., Al-Jaroodi, J., & Lazarova-Molnar, S. (2019). Leveraging the Capabilities of Industry 4.0 for Improving Energy Efficiency in Smart Factories. IEEE Access, 7, 18008–18020. https://doi.org/10.1109/access.2019.2897045

Rath, K. C., Khang, A., & Roy, D. (2024). The Role of Internet of Things (IoT) Technology in Industry 4.0 Economy. Advanced IoT Technologies and Applications in the Industry 4.0 Digital Economy, 1–28. https://doi.org/10.1201/9781003434269-1

Salah, B., Khan, S., Ramadan, M., & Gjeldum, N. (2020). Integrating the Concept of Industry 4.0 by Teaching Methodology in Industrial Engineering Curriculum. Processes, 8(9), 1007. https://doi.org/10.3390/pr8091007

Shi, Z., Xie, Y., Xue, W., Chen, Y., Fu, L., & Xu, X. (2020). Smart factory in Industry 4.0. Systems Research and Behavioral Science, 37(4), 607–617. Portico. https://doi.org/10.1002/sres.2704

Xu, L. D., Xu, E. L., & Li, L. (2018). Industry 4.0: state of the art and future trends. International Journal of Production Research, 56(8), 2941–2962. https://doi.org/10.1080/00207543.2018.1444806

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ARTIFICIAL INTELLIGENCE & AVIATION: CONTENT ANALYSIS OF RESEARCH PUBLICATIONS FROM 2013-2023

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Abstract

The aviation industry has explored the integration of artificial intelligence (AI) into its unique aspects but has not yet actively incorporated AI into the cockpit. This study aimed to identify trends in peer reviewed research publications that discuss AI and aviation from 2013 to 2023. Content analysis was used to identify the trend in annual AI and aviation publication counts over time. The study collected publication data from the Advanced Technologies & Aerospace Database (ATAD) using specific search terms, "AI and aviation," "artificial intelligence and aviation," "AI and aircraft," and "AI and aircraft safety," to accurately obtain publications. The results showed a strong positive trend, indicating a growing trend in research and discussion concerning the applicability of AI in the aviation industry. These findings highlight AI's increasing importance and relevance in shaping the aviation industry.

Keywords: *AI and Aviation; Artificial Intelligence and Aviation; AI and Aircraft; AI and Aircraft Safety*

1. Introduction

Artificial Intelligence (AI) is a recent technological advancement that can streamline and assist tasks. AI and machine learning can be used as administrative assistants to complete tasks faster and more efficiently than humans. The aviation community has debated the applicability of this new technology to flight decks, traffic towers, and airport operations. However, increased automation has been on-going, and implementing AI in aviation would replace traditional autonomous tools such as autopilot and create single-pilot flight decks for large commercial flights.

The purpose of this study was to analyze the trends in peer reviewed publications discussing Artificial Intelligence (AI) in aviation from 2013 to 2023. The annual number of publications that discuss AI was defined as the number of publications that mention AI within the Advanced Technologies & Aerospace Database (ATAD) with the following specific search terms: "AI and aviation," "artificial intelligence and aviation," "AI and aircraft," OR "AI and aircraft safety."

The aviation industry needs to be aware of the research trend in AI and applications for aviation, and a content analysis of the literature accomplishes this. Understanding the trends in the discussion

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of AI helps professionals consider the feasibility of future research exploring the applicability of AI in aviation and potential avenues for future work. In the aviation industry, it takes time to implement new changes because of the high regulatory standards. Analyzing the trends in AI publication provides valuable information that can be applied to various aspects of the aviation industry in the United States.

2. Background

AI is the advancement of machines that are capable of human-like intelligence and machine learning. AI has both prior and active research on its applications in aviation. To provide background on the current state of AI in aviation, we reviewed research in this area, specifically, the current published uses of AI in aviation, proposed future uses of AI in aviation, and content analysis research methodologies that will be applied in this study.

There are many AI uses and applications in place within aviation and aerospace as evidenced by published research. Here, a few recent applications across the industry are highlighted. Neretin et al. (2022) studied AI algorithm models to determine which best predicted a 4-D aircraft trajectory model. Historical ADS-B flight data and real-time, synched weather data were used as inputs to test several types of models: linear regression, random forest, XGBoost, and deep neural network (DNN). After performing three scenarios, they found that the DNN model has great potential for predicting aircraft trajectories and improving the accuracy of aircraft trajectory prediction (Neretin et al., 2022, p. 88). This study confirmed the effective use of AI in predicting aircraft trajectories, a critical application in aviation, aerospace, and flight testing.

Zhang et al. (2021) evaluated AI adoption in air traffic, focusing on human-machine interaction. Four experienced pilots were interviewed: three test pilots and one former airline pilot of similar age and experience. The interviews focused on crew collaboration, prior exposure to AI in aviation, and positions on AI applications in the flight deck (Zhang et al., 2021, pp. 1-2). Zhang et al. (2021) found two main themes in the four interviews: the importance of the human element and the cautious view that the pilots held of AI in the cockpit (Zhang et al., 2021, p. 2). This research illustrates that typical caution towards new technology is applied to AI in aviation, in part because the human-machine interface is critical to safety.

AI fuzzy logic in aircraft onboard systems in military applications, specifically the air task efficiency of the onboard systems, was investigated by Grzesik (2016). Fuzzy logic functions were tested for accuracy and quality in modeling aircraft system information. Grzesik (2016) found that the functions with the least information and simplest methods worked best and did not interfere with the accuracy and quality of logic systems (Grzesik, 2016, p. 715). This study provides a method to improve aircraft onboard systems through AI. However, the applicability of these results beyond military aircraft to civil aircraft remains unclear.

Oktay et al. (2018) assessed the redesign of a UAV using an AI neural network to improve certain inflight functions. Using AI techniques, an object function was researched with an artificial neural network (ANN) to determine the best values of roll stability and Lift/Drag (L/D) ratio. An ANN was used to predict complex aerodynamic parameters for the UAV. Oktay et al. (2018) found that using an ANN and optimization algorithms is preferred for redesigning a morphing UAV. AI models as a way to improve the aerodynamic design of UAVs is a critical first step in the application of AI to aviation. Testing AI models to improve UAV designs shows possible future applications that could be applied to more advanced aircraft as well.

Saraf et al. (2020) developed a prototype to verify and validate AI, other algorithm-based safety-critical systems, and an operational explanation of algorithms' decisions to users (Saraf et al., 2020, p. 1). This research had three main objectives: to determine system and functionality requirements, develop analyzable enhancement techniques tailored to the chosen AI algorithm, and demonstrate proof-of-concept (Saraf et al., 2020, p. 2). Using the National Aeronautics and Space Administration's (NASA) AI algorithm, Multiple Kernel Anomaly Detection (MKAD), and variations in input and output were identified to determine flight anomaly scenarios with AI. The Interpretable Model-Agnostic Explanation (LIME) helped to test the function of the AI models. The generation of heat-score anomaly maps found by the MKAD algorithm in a scenario over John F. Kennedy International Airport (KJFK) was a key result of this study (Saraf et al., 2020, p. 6). They discovered a pattern in the heat-score anomaly maps that helped to identify various flight anomalies that took place over the simulated KJFK airport. According to Saraf et al. (2020), experts were asked to provide feedback to test the proof-of-concept portion of the experiment, which determined that the data was reliable, and a valid generation of anomalies would help benefit post-operations analysis personnel (Saraf et al., 2020, pp. 7-8). These findings further demonstrate the benefit of AI applications in aviation, this time on the airport side by identifying potential flight anomalies found around airports. This result also helps improve the safety-critical phase of flights, which can assist the aviation safety aspect of the industry. These studies demonstrate that there are already applications of AI currently in use in the industry from aerospace and flight trajectory modeling to airport and military applications.

Because of regulation and the primacy of safety, the adoption and incorporation of new technologies takes time in aviation. Thus, many of the most recent publications are either theoretical or proposed. Abubaker et al. (2022) broadly discussed the usefulness of AI applications in the aviation industry. AI has been proposed for aviation applications in management, air traffic control, airport security and processing, and aircraft improvements, with the aim of meeting the aviation industry's challenges and improving aviation. The market for AI applications in aviation is projected to grow (Abubaker et al., 2022, pp. 53-54), which is one of the rationales for this study, to determine the rate of research in the field. The possible applications of AI in automation systems of aircraft and other aviation systems have a potentially large impact. Abubaker et al. (2022) claimed that using AI to improve aviation will be impactful through a shift in how aviation integrates AI. However, implementing new technologies is expensive, and not every airline or manufacturing company can integrate them.

Researchers have generally investigated AI applications to the National Airspace System (NAS). Anderegg and Mulcare (2021) proposed the implementation of AI to capture critical safety information and provide results to improve the NAS; this focused on the automation side of aviation to help identify the safety principles to uphold those regulations within the NAS better. The results pointed to future applications of AI, particularly aviation systems, to improve safety (Anderegg & Mulcare, 2021). Given that the NAS is a massive component of the aviation industry, the integration of AI could pave the way for future safety applications. Stroup et al. (2019) also discussed future applications of AI in the NAS, specifically improving navigation and communication operations with AI. They explained how AI can solve problems such as traffic flow management, airspace integration with UAVs, access to diverse users, information exchange, interoperability of AI in air and ground operations, and other infrastructure issues. This emphasizes the value of AI research to the future of aviation.

The application of AI in UAV automation was discussed by Chen (2020), who focused on applying AI to the functions of quadcopter UAVs that can be automated without human input. AI could be integrated into UAVs' functions that are limited by human input. Such functions included manual control or autopilot, stability augmentation, attitude auto stability, and navigation (Chen, 2020, pp.

569-571). This work both demonstrated how models can assist in UAV control and proposed AI as further technology to improve UAV automation. Similarly, Garcia et al. (2021) discussed the integration of AI machine learning into aviation cyber security systems through autonomous and semi-autonomous cyber security functions in airworthiness and engineering. Different machine learning approaches were explored to teach AI, so AI can be implemented in different ways to have unique effects (Garcia et al., 2021, pp. 2-6). These studies demonstrate the variety of ways researchers are contemplating improving the aviation industry through AI applications.

Torens et al. (2022) explored the potential uses of AI in the nascent field of Urban Air Mobility (UAM). This would mean the use of AI in large-scale operations with UAVs and air taxis in urban settings, including the European Aviation Safety Agency's (EASA) future roadmaps for integrating AI into autonomous aviation (Torens et al., 2022, p. 2). In response to high demands for UAVs and AI integration into air travel, EASA provided several proposals to integrate new technologies, using concepts for design assurance neural networks and machine learning applications (Torens et al., 2022, pp. 2-6). Torens et al. (2022) reported that an international government agency is proposing the use of AI in UAM, which will likely incorporate AI for some applications.

Kulida and Lebedev (2020) focused on six main areas of interest for AI application in civil and military aviation: decision support systems for aircraft crew, intelligent crew interfaces, pilot training, efficiency of air traffic management, diagnostics of mechanical components and units, and automation of aircraft management (Kulida & Lebedev, 2020, pp. 1-5). The authors effectively provided unique future AI applications in aviation across all six different areas emphasizing the likelihood that AI will be applied across most sectors of aviation with time and research.

Assessing the trend in AI research publications in aviation over time allows for a direct analysis of the interest in AI in the industry. Content analysis is employed to achieve this. Content analyses have a specific purpose in research methodology: identifying trends. Prior content analyses demonstrated both the validity of the methodology and illustrated the process. Clarke et al. (2017) evaluated trends over time in the field of positive behavioral support using a content analysis that included all articles in the Journal of Positive Behavior Interventions (JPBI). Articles were categorized and coded by raters to examine trends over time in the entire field. Matson and LoVullo (2009) conducted a content analysis on trends in research on the autism spectrum. Scopus was used to search for articles using broad and then more specific terms, and the numbers of publications of each type were tallied (Matson & LoVullo, 2009, pp. 253-255). They then used regression to determine the trends in publications.

Content analysis has also recently been applied in aviation. Li et al. (2023) presented a content analysis on carbon emissions from the aviation industry. Li et al. (2023) also used Scopus to evaluate all articles pertaining to their topic of interest during a specific period, from 1992 to 2021. One of the main objectives was to determine the annual trends in publications. This bibliometric approach allowed them to effectively quantify annual publications and examine the trend over time (Li et al., 2023, pp. 4-6). Thus, the use of databases and content analyses, specifically to evaluate research trends over time, is a well-established and useful research methodology.

Research to date illustrates that AI has already been implemented in some areas of aviation. However, many other uses are in the proposal or exploratory stages of research, indicating that this is a growing area. Content analysis can be used to help researchers identify trends and track shifts both within a field and overall.

3. Methods

Content analysis is an established methodology to quantify published articles and examine trends over time. This study employs the process of counting annual publications in a selected database with specific search terms, following methodology as in Li et al. (2023) and Matson and LoVullo (2009). The data collection consisted of a census of all peer-reviewed publications in the Advanced Technologies & Aerospace Database (ATAD) that met the search term criteria: "AI and aviation," "artificial intelligence and aviation," "AI and aircraft," OR "AI and aircraft safety." The annual number of publications was recorded for each calendar year from 2013 to 2023; thus, the dataset represents the annual rate of peer-reviewed publications on AI and aviation. When querying the database, the resulting list of publications was checked for the following basic criteria: publication year, peer-reviewed articles, and topic of AI in aviation. The search terms, start and end dates, and Boolean operators were double-checked by a separate author to ensure they were entered correctly before searching the database. The publications for each year were entered into an Excel spreadsheet.

The mean, median, mode, minimum, maximum, and standard deviation of the annual publications were calculated for the descriptive statistics. For inferential statistics, linear regression was conducted in R-Studio Version 4.3.1 to examine the trend in publications over time.

4. Results

Using the Advanced Technologies & Aerospace Database (ATAD), the data comprised the annual number of publications from 2013 to 2023. Table 1 contains the annual publication counts, and Table 2 shows the descriptive statistics for AI and aviation publication counts. On average, 374 articles were published annually on AI in aviation. The number of annual publications ranged from 238 to 681. Figure 1 illustrates the trend in annual publications over time and the regression model. The linear regression model was statistically significant; both the slope (39.23) and intercept (-78786.27) were statistically significant ($p = .0004$). There were approximately 39 more AI-related publications in aviation each year during the study period. The R-squared value for the model was 0.77, indicating a good fit of the model to the data.

Table 1. Annual Peer-Reviewed Publications on AI and Aviation (2013-2023)

Year	AI Publications
2013	238
2014	280
2015	260
2016	251
2017	320
2018	297
2019	344
2020	378
2021	471
2022	681
2023	598

Table 2. Descriptive Statistics for Annual Peer-Reviewed Publications on AI and Aviation (2013-2023)

	Annual AI Publications
Mean	374.4
Median	320
Minimum	238
Maximum	681
Range	443
Standard Deviation	148

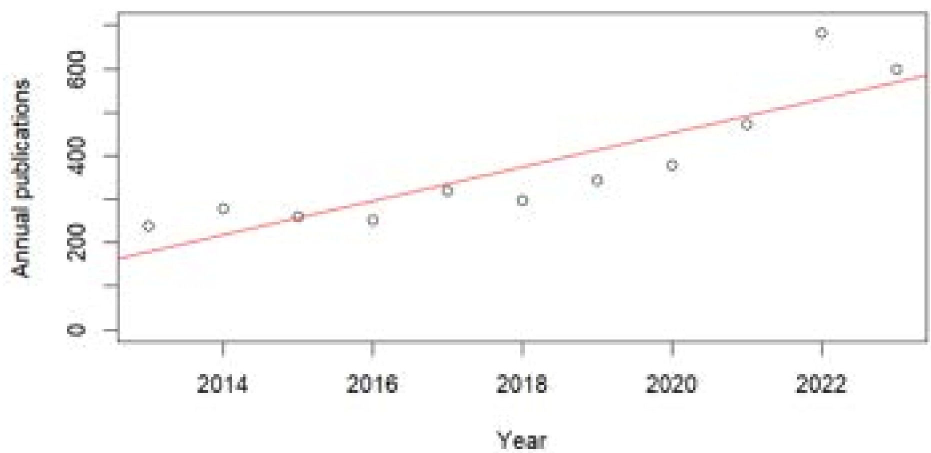

Figure 1. Peer Reviewed AI In Aviation Publications Per Year (2013-2023)

Note: The line of best fit was statistically significant (p < .001): y = -78786 - 39x, (R^2= .77).

5. Conclusions, Limitations, and Future Research

From 2013 to 2023, annual aviation AI peer-reviewed publications demonstrated an increasing trend. Figure 1 illustrates the positive relationship in the linear regression of aviation AI publications by year. The linear regression model was statistically significant (p = .0004), with an R2 value of .77. This is a good fit to the data as 77% of the variance in annual publications was explained by year. This indicated growth in publications confirmed the expectations and highlights the direction of both the current and proposed applications of AI in aviation.

This study only examined the ATAD, which may not include all publications on AI in aviation. Additionally, not all articles on this topic may have been identified if the authors used different terminology (e.g., machine learning). All peer reviewed articles in the selected database that met the specified search criteria were included. Therefore, this study accurately represents trends in peer-reviewed research in journals included in ATAD.

The rapidly increasing number of annual publications discussing AI and aviation indicates that AI is gaining more attention in the industry. AI research may change how the industry operates using new technology. Content analyses can clarify research and industry trends in aviation. Additionally, the results of this study help show that these publications are actively exploring the options and applicability of this new technology in the aviation industry. Further research on the considerations of governments, companies, and agencies to introduce any form of integrated AI in the aviation industry is an opportunity for future study. As AI is introduced into various applications in aviation, research on consumer and pilot perceptions is critical and should be tracked over time.

6. Disclaimer Statements

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7. References

Abubakar, O. EriOluwa, M. Teyei, & Al-Turjman, F. (2022). AI Application in the Aviation Sector. IEEE 2022 International Conference on Artificial Intelligence of Things and Crowdsensing (AIoTCs) (pp. 52-55), http://dx.doi.org/10.1109/AIoTCs58181.2022.00015

Anderegg, A. H. A., & Mulcare, S. P. (2021). Assuring Human and Artificial Intelligence are Appropriately Informed in Aviation Systems. IEEE/AIAA 40th Digital Avionics Systems Conference (DASC) (pp. 1-6). https://doi.org/10.1109/DASC52595.2021.9594325

Chen, B. (2020). Research on AI Application in the Field of Quadcopter UAVs. IEEE 2nd International Conference on Civil Aviation Safety and Information Technology (ICCASIT) (pp. 569-571). https://doi.org/10.1109/ICCASIT50869.2020.9368551

Clarke, S., Zakszeski, B. N., & Kern, L. (2017). Trends in JPBI Publications, 1999–2016. Journal of Positive Behavior Interventions, 20(1), 6-14. https://doi.org/10.1177/1098300717722359

Garcia, A. B., Babiceanu, R. F., & Seker, R. (2021). Artificial Intelligence and Machine Learning Approaches For Aviation Cybersecurity: An Overview. IEEE Integrated Communications Navigation and Surveillance Conference (ICNS) (pp. 1-8). https://doi.org/10.1109/ICNS52807.2021.9441594

Grzesik, N. (2016). Fuzzy sets in aircraft system efficiency evaluation. Aircraft Engineering and Aerospace Technology, 88(6), (pp. 707-716). https://doi.org/10.1108/aeat-03-2015-0084

Kulida, E., & Lebedev, V. (2020). About the Use of Artificial Intelligence Methods in Aviation. IEEE 13th International Conference Management of large-scale system development (MLSD) (pp. 1-5). https://doi.org/10.1109/MLSD49919.2020.9247822

Li, X., Tang, J., Li, W., Si, Q., Guo, X., & Niu, L. (2023). A Bibliometric Analysis and Visualization of Aviation Carbon Emissions Studies. Sustainability, 15(5), (pp. 4644). http://dx.doi.org/10.3390/su15054644

Matson, J. L., & LoVullo, S. V. (2009). Trends and topics in autism spectrum disorders research. Research in Autism Spectrum Disorders, 3(1), (pp. 252-257). https://doi.org/10.1016/j.rasd.2008.06.005

Neretin, E. S., Phuong, N. T. L., & Quan, N. N. H. (2022). An Analysis of Human Interaction and Weather Effects on Aircraft Trajectory Prediction via Artificial Intelligence. IEEE Technical Scientific Conference on Aviation Dedicated to the Memory of N.E. Zhukovsky (TSCZh) (pp. 85-89). https://doi.org/10.1109/TSCZh55469.2022.9802458

Oktay, T., Arik, S., Turkmen, I., Uzun, M., & Celik, H. (2018). Neural network based redesign of morphing UAV for simultaneous improvement of roll stability and maximum lift/drag ratio. Aircraft Engineering and Aerospace Technology, 90(8), (pp. 1203-1212). https://doi.org/10.1108/aeat-06-2017-0157

Saraf, A. P., Chan, K., Popish, M., Browder, J., & Schade, J. (2020). Explainable Artificial Intelligence for Aviation Safety Applications. AIAA Aviation 2020 Forum, (pp. 1-9). https://doi.org/10.2514/6.2020-2881

Stroup, R. L., Niewoehner, K. R., Apaza, R. D., Mielke, D., & Mäurer, N. (2019). Application of AI in the NAS – the Rationale for AI-Enhanced Airspace Management. IEEE/AIAA 38th Digital Avionics Systems Conference (DASC) (pp. 1-10). https://doi.org/10.1109/DASC43569.2019.9081768

Torens, C., Durak, U., & Dauer, J. C. (2022). Guidelines and Regulatory Framework for Machine Learning in Aviation. AIAA SCITECH 2022 Forum, (pp. 1-9). https://doi.org/10.2514/6.2022-1132

Zhang, Z. T., Liu, Y., & Hußmann, H. (2021). Pilot Attitudes Toward AI in the Cockpit: Implications for Design. IEEE 2nd International Conference on Human-Machine Systems (ICHMS) (pp. 1-6). https://doi.org/10.1109/ICHMS53169.2021.9582448

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INVESTIGATING BUSINESS TOXIC LEADERSHIP

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Abstract

This manuscript investigates toxic leadership in modern business. It focuses on the key role that poor ethics, and Machiavellianism, Narcissism, and Psychopathy (the three elements of toxic leadership (Nahavandi, 2016)) have played in the failures of a variety of modern major business enterprises. Toxic leadership is management that goes beyond corruption and results in irreparable damage to the organization and its stakeholders (e.g., Adolf Hitler). The emphasis is on toxic leadership that has contributed to the catastrophic failures of several major firms over the past quarter century. It uses a book by Stephen Arbogast entitled "Resisting Corporate Corruption (RCC): Practical Cases in Business Ethics from Enron. The manuscript complements this book with a New Leadership Model that enhances the analysis of a variety of recent toxic leadership case studies. The model is illustrated in failures such as the Madoff Ponzi Scheme and in major firms such as Theranos, Nikola, We Work and Volkswagen. It provides a useful tool and shows that the dark side of leadership can be examined in real-world cases. The model is recommended for firms to employ in finding toxic leaders and in evaluating the consequences of their nefarious actions.

Keywords: *Mismanagement; Ponzi Scheme; Digital Revolution; Corruption; Toxic Leadership*

1. Introduction

This manuscript introduces an innovative approach for business leaders. It focuses on the key role that poor leadership and ethics have played in the failures of a variety of modern businesses. It emphasizes that toxic leadership and poor management may have played a key role in the failures of these firms. A variety of companies that failed due to their poor leadership and management cover a wide spectrum. Several will be discussed in some detail in this study.

The Literature Review primarily covers major firms that failed in the latter part of the 20th century. Then moving into the early part of the 20th Century there are several major firms that will be discussed that appear to have failed partly due to the mismanagement and toxic leadership The main portion of the paper will cover a 'New Leadership Model' that greatly enhances the analysis of a variety of toxic leadership and poor management case studies over the past several years. This research structure is covered in the major section of the paper entitled 'The New Leadership Model in Course Design.' This model in the paper is the main contribution to research. This leadership model is also available for use in risk management techniques that can be used when firms are considering the potential hazards of risky decision-making.

Stephen Arbogast's book "Resisting Corporate Corruption (RCC): Practical Cases in Business Ethics from Enron Through SPACs, IV edition" provides a plethora of cases that can be analyzed using the leadership model e.g., Goldman Sachs, AIG, Fannie Mae, Bear Stearns. Lehman Brothers, WeWork, Nikola, Volkswagen and Theranos. The latter two are discussed in some detail in this paper.

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One individual that is singled out for his toxic leadership is Bernie Madoff. His $20 Billion Ponzi scheme was a particularly egregious example of how one individual defrauded thousands of investors of their hard-earned money fueled by his manipulation of technology.

2. Literature Review

In the years leading up to 2000, there were several company failures due to poor management. Several of the most significant were Lincoln Savings and Loan in1989 (Binstein & Bowden, 1993), Pan-Am's failure in 1991 (Conrad III, 2000), and Long-Term Capital Management in 1998 (Lowenstein, 2000) . The references specifically mention major management failures that led directly to the collapse of these firms. Some of the specific reasons cited were management's inability: (a) to recognize poorly designed products; (b) to determine that the technology being used was not mature enough "for prime time"; (c) to properly estimate the large costs that would be involved in the development, production and operations of new products; and lastly (d) to recognize that in their industry that there was a paradigm shift often where new technology was replacing their firm's older, established technology.

First there was the management's inability to recognize poorly designed products. Personal computers (PCs) and cell phones first began to appear on the market in the early 1980s. Focusing on PCs, this field at once experienced a good deal of competition, as firms were anxious to take the lead in this new market. The market quickly became flooded with devices such as the Altair, Commodore 64, Kaypro II, the Apple II, the Tandy TRS-80, the Texas Instrument TI 99/4, the Atari 400, and the IBM PC Jr. IBM was the leading computer maker in the world at this time. With mainframe dominance achieved in the 1960s, the computer industry was known at the time as "IBM and the seven dwarfs"- the dwarfs being UNIVAC, Burroughs. NCR, Control Data, Honeywell, General Electric and RCA. However, in 1982 IBM was not really committed to their PC Jr. Announced in November 1983, it sold only 270,000 units by 1985 and was dropped in 1985 (Cringely, 2014). There were several factors that were cited for its failure. The biggest was that it was not properly engineered and designed. IBM also did not market it properly and provided poor developer support. This weak backing of the PC Jr. by IBM management illustrates its mismanagement of the technology. The latter was a device that IBM produced without lofty expectations. To them the computer world was defined by massive mainframes. They considered the IBM PC Jr. to be no more than a toy, and the half-heartedness in which they fielded the PC Jr. was on full display in 1983 (Cortada, 2019). The most popular home computers in the USA up to 1985 were: the TRS-80, various models of the Apple II, the Atari 400/800 (1979) and its follow-up models, the VIC-20, and the Commodore 64. Other poorly designed PCs that also did not do as well due to poor management of technology were the Altair and TI- 99 (Ibid).

Another factor was management's inability to recognize when a technology was not mature enough. Management became so obsessed with the potential of a technology that it was willing to forge ahead with major strategic investments before a specific technology was ready. A good example of this was virtual reality. Research into the viability of virtual reality (VR) systems goes back five decades. (Lum, et al.,2020). Several small firms jumped readily into virtual reality in the 1980s and 1990s and incorporated it into their business models. These included such companies as VPL Research. The idea of putting on special goggles and gloves and immersing oneself fully in a 3-D game or training session appealed to many who thought the technology was ready. However, the consumer public was far from ready to engage in these exercises. VR never took off commercially, even though some useful niche applications, such as providing surgeons with a way to practice tricky medical procedures, still exist (Haskin, 2007).

A third factor was the inability to estimate the large costs associated with bringing on modern technologies is the next factor to be reviewed. Here we see several firms in the latter 1900s that failed due to this factor. Iridium's idea to launch sixty-six satellites that could be linked in a network to route calls all around the world seemed to be the future of world-wide instant communications. In Wired magazine's 1998 cover story heralded Iridium and said that "Iridium may well serve as a first model of the 21st-century corporation. However, Iridium's managers grossly mismanaged the cost of the technology to bring such a complex satellite system into fruition. Also, these managers failed in their market research to accurately determine what users were willing to pay for their service. Specifically, most users did not wish to pay their estimated dollars per minute of call time. Another factor that they missed was that users were unwilling to carry around a phone larger than a brick. Less than a year later, Wired News backtracked, saying, "After losing nearly US$1 billion in two disastrous quarters, the engineering marvel is in danger of becoming the Ford Edsel of the sky" (Ibid).

The Apple Newton was another product that used modern technology and was overpriced when it debuted in 1993. Pushing the state-of-the-art, the Newton promised many features that were too advanced for its time e.g., personal information management. However, the device was huge and expensive. It cost approximately $700 for its first model and $1,000 for later, more advanced models. Released in 1995 a smaller, cheaper PalmPilot became the device that the market much preferred When Steve Jobs returned to Apple in 1997, he quickly killed the Apple Newton (Issacson, 2011).

A last factor affecting mismanagement was industry paradigm shifts in technology. The 1980s and 1990s digital revolution is noteworthy. Kodak is a firm that completely missed the decline of analog technology with the rise of digital technology. A technology company that dominated the photographic film market during most of the 20th century, Kodak used analog photographic chemicals and film. Even though they developed the world's first digital camera, Kodak's management was so focused on the success of photography film that they missed the future major paradigm shift in technology. When the Digital Revolution hit in the latter the latter part of the 20th century, Kodak decided that its future was to stay with their venerable, analog processes (Kotter, 2012). Even though they developed the world's first digital camera, Kodak's management was so focused on the success of photography film that they missed the onslaught of the digital revolution. They failed to keep innovating and filed for bankruptcy in 2012 (Ho and Chen, 2018).

Fujifilm, a competitor of Kodak, pursued a completely different strategy in the management of their technology (Shibata et al., 2022). While Kodak had been enamored with their traditional analog technology, "silver halide" technology (named after the chemical compounds in Kodak's film), Fujifilm and other competitors took different paths. Fujifilm diversified away from the declining film market and moving into the digital mainstream (Ibid). Fujifilm, which was always the challenger in the shadow of Kodak, learned to be bold and innovative to close the gap with the historic leader. In addition to moving into digital, Fujifilm opened factories in the USA in the eighties, and it dared to challenge the Kodak marketing empire in its backyard when it won the rights to sponsor the 1984 Los Angeles Olympics. In addition, Industry outsiders—Hewlett-Packard, Canon, and Sony—did even a better job. They launched products based on home storage with home printing capabilities and, in the process, uncovered new demand for convenience, storage, and selectivity" explained the Harvard Business Review in 2002. Two years later, Facebook was born, and soon after that, prints became outdated. Most consumers were not going to print pictures anymore. Instead, they would share them online (Ibid).

Motorola was another American firm that did not consider the Digital Revolution. In the 1995-

time frame, Motorola was the best phone maker in America. AT&T went to Motorola and asked that they provide them with one million digital phones. Motorola responded that they would be happy to honor AT&T but insisted that they be analog phones (Nair et al., 2014). AT&T thanked Motorola but told them that they needed the phones to be done with the new digital technology. AT&T then turned to a little telephone manufacturer in Finland and asked if they could provide the requisite number of phones. Nokia recommended that they must scale up their operations to provide such many phones, but they would be willing to do so at the right price. AT&T complied, and the order would put Nokia on the map as a major digital telephone provider (Vecchiato, 2017).

3. Post 2000 Mismanagement and Toxic Leadership

The Literature Review covered primarily Pre-2000 Poor Management. The focus on this section will be on the trends that have occurred in the most recent twenty-four years. This includes continued poor management along with a major increase in ethical violations. Abuse and corruption in firms started to occur at an increased rate as the 21st Century approached. This was due in large measure to more cases involving bribery, commodities fraud, price fixing, tax evasion, and insider trading of stock (Ferguson, 2012). Ivan Boesky, Michael Millken, Charles Keating, and celebrities such as Martha Stewart went to jail for violations of these practices.

The early part of the 21st century saw a sudden and unexpected increase in toxic leadership. Corruption worsened and appeared to have morphed in too many cases into toxic leadership. Toxic leadership is both unethical and illegal but goes further by violating the basic interests of the organization and the well-being of its followers (Nahavandi, 2016). It normally has three dimensions: (1) Narcissism is manifested as an Inflated view of self, arrogance along with a sense of entitlement; (2) Machiavellianism involves being manipulative with the willingness to use and exploit others: and (3) Psychopathy shows up as being antisocial, vicious, ruthless along with a major lack of empathy and caring for others (Nahavandi, 2016). The demise of entire corporations in the 21st century appears to may have been affected by toxic leaders. The cases now to be discussed will mention leaders who had many of the attributes of toxic leadership.

The most famous case that occurred in 2003 was the ENRON Corporation. Enron is an oil and gas company that engaged in huge fraud transactions. CFO Fastow used accounting software to create a network of shell companies designed solely to do business with Enron, for the ostensible dual purposes of sending Enron money and hiding its increasing debts. He also used broadband technology illegally to trade commodities. Both initiatives failed, but Enron was able to record non-existent profits for these ventures (McLean & Ekland, 2013). Other such fraud centric initiatives by manipulating ENRON's accounting software result in the firm's Chapter 11 bankruptcy in 2001. Due to this massive fraud, many of its employees lost their pensions and life savings, while investors lost over $11 billion in shareholder value. CEO Ken Lay was sentenced to prison but died before entering jail. Both Andy Fastow and his wife also served sentences in jail. Bernie Ebbers, the CEO of WorldCom, followed ENRON as a toxic leader. His company collapsed in 2002 amid revelations of similar behavior and accounting irregularities. This was also one of the largest accounting scandals in the United States (Jeter, 2003). Ebbers was convicted of fraud and conspiracy. He is served 13 years of a 25-year sentence. Due to these and several other huge fraud cases (e.g., Tyco International and Adelphia), Congress enacted the Sarbanes-Oxley Act in 2002. This act was targeted at the management of public companies, as well as their Board of Directors. It added criminal penalties for management misconduct, and required the Securities and Exchange Commission to create regulations for defining how public corporations are to comply with the law (Arbetter et al., 2009).

The Financial Crisis of 2007- 2009 brought a new wave of unethical behavior and toxic leadership, primarily in the banking and financial sectors of the economy. The crisis was a systemic failure brought about by a variety of contributing factors. However, embedded in virtually all of the major factors were unprecedented greed and ethical lapses demonstrated by the poor management of: (a) the major US banks i.e. Goldman Sachs, Bear Stearns, Lehman Brothers, AIG, and Merrill Lynch; b) the quasi- governmental banks such as Fannie Mae and Freddy Mac; and (c) large mortgage firms that had grown rich with sub-prime mortgages such as Country-Wide and Ameriquest (Foster & Magdoff, 2009). Stephen Arbogast's RCC book documents in detail the specific poor management and toxic leadership that occurred in these firms (Arbogast, 2022). The results were catastrophic for many major financial institutions: (a) Bear Stearns and Lehman Brothers went bankrupt; (b) Merrill Lynch had to be rescued by Bank of America; (c) Fannie Mae and Freddy Mac went into conservatorship and remained there through 2022; (d) Country-wide and Ameriquest went bankrupt; and (e) AIG had to be bailed by the government with a huge loan (Ibid). Without major government interaction and capital infusions, the fallout might have been catastrophic and brought on a major depression in the United States. As many of the bad financial instruments had been sold all over the world, the global effect of the US fiscal crisis was also toxic to many other countries (Ibid).

Beside the fiscal crisis, toxic leadership also began to appear in many other business areas. The first of these was the largest Ponzi scheme in history by Bernie Madoff. Charles Ponzi had invented the original illegal "Ponzi Scheme" in 1920 when he launched a novel investment initiative that promised to double his investor's money in three months. It was a clever investment fraud that "robbed Peter to pay Paul." The fake investment swindle generated returns for earlier investors with money taken from later investors. When Ponzi's scheme was revealed as a major investment fraud, Ponzi was sentenced to five years in prison in the 1920s.

Madoff's Ponzi Scheme was worth about $64.8 billion. Madoff had gained prominence In the 1960s, when he founded Bernard L. Madoff Investment Securities LLC as a broker-dealer for penny stocks. His firm then began using innovative computer information technology to issue its quotes. Madoff continued to use this and other information technologies which then evolved in the 1970s into the National Association of Securities Dealers Automated Quotations Stock Market (NASQAQ). Later, Madoff would become its chair. With this platform and by also engaging in several humanitarian initiatives, Madoff became a highly acclaimed financier. He started his now famous Ponzi scheme in the 1990s. Essentially, Madoff promised his clients high returns on their monies, saying that he was investing their funds in lucrative investments. In fact, he was not doing so (Henriques, 2012). Finally, in 2009 it all came to a head when Madoff pled guilty to a variety of criminal charges including perjury, money laundering, mail fraud and false SEC filings. This was triggered by a criminal complaint filed earlier, which said that Madoff had defrauded his clients of almost $65 billion. Madoff was found guilty and subsequently received a maximum sentence of 150 years in federal prison Madoff later died while incarcerated. Over 24,000 investors of Ponzi were seriously injured by his scheme. They less than a quarter of their total investments (Jordanoska, 2017). However, the consequences of Ponzi's actions have gone well beyond his malfeasance. In the past few years there has been a surge in imitation Ponzi schemes. 57 Ponzi schemes were discovered in 2022 representing $5.3 billion in investor funds. This was a 70% increase over the prior year when thirty-four schemes were uncovered. The average size of a scheme in 2022 was $94 million (Ponzitracker,2023).

The last ten years saw toxic leadership and mismanagement in a variety of industries: construction, extraction (oil, gas, and mining), transportation and storage, and investments and finance (Beattie, 2022). In addition, news media has covered a variety of serious problems in such industries as sports (e.g., FIFA), crypto currency (e.g., Bankman-Fried an apparent toxic leader at Alameda Research/FTX Crypto), health technology and automotive. This paper will later focus on two of the recent egregious cases.

4. A New Leadership Model for Business Leaders

A primary contribution of this paper is the New Leadership Model that compliments the RCC Book. While the book provides ample poor leadership and toxic leadership cases in the last twenty-four years, it is the Leadership Model that takes the analysis of these cases to a new level. By employing this model, business leaders can secure a valuable analysis tool in the analysis of leadership.

The Five Step Model can be used to analyze the cases mentioned previously. In working with Executive MBA and MBA students at Jacksonville University the authors introduce these actual practitioners in business on how to properly employ the Five-Step Model in actual cases. Below is an outline of the five-step model:

- Step 1- Name the main protagonists and antagonists in the case and a clear statement of the Ethical Issue(s).
- Step 2- Define the Ethical Boundary Condition(s). These are the ethical and moral standards that were breached and put the firm into serious ethical trouble.
- Step 3 – What were the consequences to the firm and protagonists when the Boundary Conditions were exceeded?
- Step 4 – What were the feasible strategic alternatives (with pros and cons) that were available to the protagonists? Feasible alternatives are options that would have kept the firm from straying beyond the Boundary Conditions?
- Step 5- What is the group's recommended strategic alternative (with rationale) along with a Strategic Plan outline.

Five person groups prepare a 20-minute PowerPoint presentation on a case they have chosen . All groups then present their twenty-minute Power Point presentation later in the course. The presentation groups are encouraged to integrate classical ethical concepts taught earlier. Examples include: (a) Aristotle's and Confucius' "Golden Mean of Moderation" (Jamblyn & Legge, 2016); (b) Judeo-Christian "The Golden Rule" (Rae, Scott & Wang, 1996); and (c) Kant's "Categorical Imperative (Bowie, 2002)". Groups are provided an additional 25 minutes for group interaction. This involves: (a) conducting an interactive session with the class using discussion questions that they have previously developed; (b) informing the class of actual consequences that occurred to the firms and individuals involved; and lastly (c) discussing interactively the significant 'Lessons Learned' from the case. The professor then caps each exercise with a critique using an Exercise rubric (available on request).

The groups have performed admirably using the Five Step Model and conducting spirited interactive post-presentation sessions. Students have also responded well to the group's discussion questions and Lessons Learned. Concerning suggestions for additional teaching uses, the interaction session described above is a major plus to the exercise. Debates often occur as students often challenge the group on their best alternative chosen. Students are also held responsible in their final exam for questions on the cases. Class feedback on the RCC cases has been excellent.

5. Recent Toxic Leadership Cases

The Volkswagen (VW) Case- Two recent cases from the RCC book are now discussed in some detail. The first is the VW Emissions Scandal Case. VW is a German Engineering automobile company.

In 2007 they were struggling with diesel emissions standards. Their new diesel was producing emissions that would exceed EPA standards in the United States. For some time, VWs engineers were under pressure by VW management to solve this problem. Unable to find a fix, the engineers were forced by a toxic management to produce a work-around that would allow the diesels to pass the EPA standards. Under this pressure they produced a “Defeat Device” that could be installed in the diesel cars. This device had a binary switch so that: (a) When the diesel was being tested by EPA, the car would operate in the dyno mode, with less power, but complying with low NOx emissions; and (b) when on the road software would switch the car back into the normal operating mode with up to 35x the emissions from the dyno mode; in this mode the car would operate way over EPA minimum standards. This device was installed with the prompting and full knowledge of the new CEO (Martin Winterkorn) and his staff. The vehicle was produced and sold in the United States between 2008 and 2015 (Arbogast, 2022).

In 2015 Hemanth Kappanna was a junior engineer working in a small team for General Motors in West Virginia. Their job was automobile emissions testing. Kappanna was doing his emissions testing outside of the lab and concluded that the outside emissions from the Volkswagen diesel were dirtier than projected to the public. When asked to testify later in California at an emissions forum, he made his findings known to the EPA. The EPA quickly reacted upon realizing that their indoor testing had been duped. When VW was confronted with this, CEO Winterkorn blamed the problem on the separation of the C-level suite and middle management. Middle management blamed the engineers. VW had been previously caught manipulating emissions testing in the early 1970s, the EPA moved decisively. VW recalled eleven million cars at once and pledged $6.7 billion dollars for repairs. However, that was not enough to satisfy this gross mismanagement of VW’s technology. In January 2017 VW pled guilty to criminal charges of defrauding the U.S. government and obstructing a federal investigation. In addition to a $15.3 billion settlement with U.S. regulators, VW agreed to pay a $2.8 billion criminal fine and $1.5 billion in civil penalties. This was the largest settlement in the history of automobile-related consumer class action cases in the United States. The other fall-out that ensued was CEO Winterkorn was seen as unethical and a toxic leader. He was cited as being manipulative of his engineers, forcing them to produce and install for over seven years a device in VW’s diesels that several of the engineers from 2008 to 2015 knew to be a fraud; ; He also showed psychopathy in that major pollution was unleashed in the United States to the health detriment of millions on the highways. As a result, CEO Winterkorn He was fired along with a number of other keys of his close executives; (b) the company also lost 46% of its shareholders values, about 42.5 billion dollars; (c) investors suffered major losses as the stock price continued to decline; and worst of all; (d) the pollution in the US from 2008-2015 put people’s health at risk. An MBA presentation is available on request that will demonstrate the use of the New Leadership Model in the VW case.

The Theranos Case- the second case in the health industry- the Theranos fraud case. Elizabeth Holmes was a student at Stanford University in the early 2000s. For a summer internship, she traveled to Singapore and worked in the blood laboratories there. She became appalled at the amount of blood being drawn from patients to evaluate for diseases. She was drawn to nanotechnology at Stanford and set out to find a simpler way to evaluate diseases. She then dropped out of Stanford and directed her energies into forming Theranos, a private Health Technology company in the mid-2000s. She did this with the aid of a chemical-engineering professor at Stanford as her science and technical advisor. Holmes maintained that Theranos could use a single finger-prick of blood to accurately predict many diseases.

The Theranos device that they claimed could do this was named ‘Edison.’ It was a machine that had been developed in-house. Holmes was good at raising a considerable amount of capital to fund her firm. Many well-known industrialists and dignitaries invested in Theranos, to include several technology CEOs: two Secretaries of Defense General James Mattis and former Sec Def William Perry; and two former Secretaries of State Henry Kissinger and George Shultz. Theranos was able to raise more than $700 million from those cited as well as venture capitalists and private investors. This resulted in a $10 billion firm valuation by 2014. (Arbogast, 2022). Also included in investors was Walgreens, which invested heavily in Theranos. Theranos Wellness Centers in Walgreens started to appear around the country starting in 2014 (Ibid). The ethics issue was that Holmes was duping everyone by claiming that it was her Edison machine that was predicting the results being furnished to Walgreen's customers. In fact, the Edison machine was rendered ineffective and incapable of providing accurate results. The Edison test results were "erratic and different" compared to Siemens. Some results even erroneously showed patients having HIV and Hepatitis (Ibid).

This was known by Holmes and only a few others, including Theranos executives (e.g., COO Sunny Balwani). Instead of being transparent on this, Theranos lied to everyone including their users and investors. In fact, they were secretly diluting the finger-prick blood samples and using a German company's machines (Siemens) to help provide their results (Carreyrou, 2018). Also aware of this deception was Theranos' Lab Director Adam Rosendorff and several others employed in the lab (lab Assistants Adam Schulz and Erica Cheung. Rosendorff was appalled and went to Holmes on this breach of ethics. However, he was met with hostility and rejection. Unable to convince Holmes and Balwani to stop running HIV tests on a finger prick and covering up their results, Rosendorff retreated but knew something had to be done. However, he soon found out that getting past Theranos' strict policies and guidelines proved to be a huge challenge. Theranos was using the following tactics: (a) all employees were required to sign non-disclosure agreements (NDAs); (b) security cameras had been installed and security personnel (ex-military) roamed the halls; (c) with multiple laboratories, personnel could not go between labs; (d) the windows were tinted "to prevent spying"; (e) employee emails and calls were closely monitored; and (f) any employee who indicated any dissatisfaction was intimidated and threatened with huge lawsuits. Feeling totally stifled by these restrictions, Rosendorff decided to resign and quietly disappeared in 2014. However, after a few months he felt obliged to do something. He wrote to John Carreyrou at the Wall Street Journal about the situation at Theranos (Ibid). Carreyrou later testified that this was the first inkling of knowledge he had about the potential fraud going on at Theranos and put him on a trail of discovery (Carreyrou, 2020).

Two Lab workers were also sufficiently concerned and tried to alert higher-ups of the true nature of affairs. Tyler Schulz was the grandson of former Secretary of State George Schulz, who was sitting on the Theranos Board of Directors. He went to his grandfather and tried to inform him of his ethical concerns. The elder Schulz then called Holmes and was assured that Tyler was ignorant of the big picture and that everything at Theranos was ethically sound. Secretary Schulz had a large stake in Theranos and chose to believe Holmes. Tyler was threatened with lawsuits and elected to resign. A second lab worker who tried to be heard initially within the firm was Erika Chung. When she received similar harsh treatment (i.e., potential lawsuits), she was so frightened that she prepared to leave the country and travel to Hong Kong for safety. However, before she was able to leave, Erika contacted Carreyrou with more details of Theranos' nefarious operations and emailed the government lab inspector in the Center for Medicare and Medicaid Service (CMS). Then on Oct 16th, 2015, Carreyrou went to press with an article with circumstantial evidence that Theranos had defrauded their investors and the CMS, Theranos' accrediting agency. CMS reacted quickly and investigated the Theranos operation. They initially found that Theranos had unreliable devices, sloppy lab practices, had cheated on proficiency testing and misled inspectors during prior visits. A subsequent CMS lab investigation found forty-five deficiencies which Theranos proved unable to correct. Thereafter, the CMS permanently shut down the Theranos labs in 2016 (Arbogast, 2022).

In June 2018, Elizabeth Holmes, and "Sunny" Balwani (Theranos COO) were accused of sixteen charges of fraud and conspiracy to committed fraud. This included: (a) Holmes had incorrectly maintained that Theranos could use a single finger-prick of blood to accurately predict many diseases; (b) Elizabeth Holmes engaging in unethical actions against her employees to not reveal Theranos' malfeasance; (c) they lied to investors, Walgreens, and users by providing results from Siemens and presenting them as from their own Edison machine; and (c) they had been interfering with potential inspections and audits by government agencies. Based on the trial; Walgreens, Walmart and a host of prominent political figures filed a class-action lawsuit against Theranos (March 2020). The global pandemic caused delays in the trials. Both were finally found guilty on all counts of fraud. Balwani received a prison term of 12 years, 9 months while Holmes received 11 years. Pregnancy delayed her incarceration, but she was finally jailed in May 2023.

Lessons learned from these cases using the new Leadership Model included: (a) Don't fake it, until you make it; Silicon Valley firms have too often used this strategy to acquire capital for technology based initiatives, often failing to produce the promised outcome; (b) A failure is not a loss, but rather a lesson that you can grow from; Holmes willingness to accept failure early on may have prevented the monumental downfall of her company; (c) one should accept responsibility and avoid blaming others; taking responsibility enables both the leadership and employees to own their actions and the consequences.

6. Conclusions

This paper has documented the recent trend toward increased toxic leadership in modern Business. This included a review of many of the major business cases in corporate corruption. A main contribution to research in this paper is the New Leadership Model. Analysis of poorly managed firms by business leaders can be enhanced by using this model. It is also concluded that the study of leadership, and especially toxic leadership, requires the use of a book that has hard-hitting corporate corruption cases. Such a book is Resisting Corporate Corruption (RCC), 4th Edition cited in the References. Two major recent cases from RCC illustrated this in some detail The synergy gained by juxtaposing the New Leadership Model and this book provides many benefits in the study of leadership.

The New Leadership Model is also available and should be considered for use by major firms. This is true specifically when such firms are employing risk management techniques and considering the potential hazards of risky decision-making.

7. Recommendations

Future research needs to focus on educating business leaders on the hazards associated with supporting toxic leaders and themselves becoming toxic leaders. Considering the rapid advances in technology, it is becoming more difficult for managers to keep up with changes that are affecting their industries. Such new challenges are being posed on a variety of fronts to include stunning new advances in such technologies as Artificial Intelligence, Blockchain and Virtual Reality (Lum et al., 2020). In the past toxic corporate leaders could rely on subordinates to monitor such changes and often to escape poor ethical decisions by blaming others (see VW case). Sarbanes-Oxley, Dodd-Frank and other legislation have put top management on notice that toxic leaders can no longer lay the blame for failure on subordinates if poor ethical shortcuts are employed. Such leaders will now be held accountable and as such, need to be better educated in proper ethical standards that must be embraced. The New Leadership Model is recommended as one of the tools that can be employed by corporate leaders in avoiding the pitfalls of poor leadership and toxic leadership.

8. Disclaimer Statements

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9. References

Arbetter, Brian, et al. Complying with Sarbanes-Oxley's Whistleblower Provisions: Leading Lawyers on Understanding Whistleblower Provisions, Complying with Key Regulations, and Responding to Claims. Aspatore, 2009.

Arbogast, Stephen V., (2022), Resisting Corporate Corruption (RCC), 4th Edition, John Wiley & Sons.

Beattie, Andrew, (2022), Why these Industries are prone to corruption, Investopedia, https://www.investopedia.com/articles/investing/072115/why-these-industries-are-prone-corruption.asp.

Binstein, Michael and Bowden, Charles, (1993), Trust Me: Charles Keating and the Missing Billions, Random House Books.

Bowie, Norman E., (2002), A Kantian Perspective 2d Edition, Alibris Books, 9780631211730

Carreyrou, John, (2020), Bad Blood: Secrets and Lies in a Silicon Valley Startup, Knopf, NY.

Conrad III, Barnaby, (2000), Pan Am- An Aviation Legend, Council Oaks Books.

Cortada, James, (2019), IBM: The Rise and Fall and Reinvention of a Global Icon (History of Computing), The MIT Press.

Cringely, Robert X. (2014), The Decline and Fall of IBM, End of an American Icon, Published by NeRDTV, LLC.

Ferguson, Charles H., (2012), Predator Nation, Corporate Criminals, Political Corruption and the Hijacking of America, Crown Books, New York.

Foster, John B. and Magdoff, Fred, (2009), The Great Financial Crisis: Causes and Consequences, Monthly Review Press.

Haskin, David (2007), The 10 Biggest Technology Flops of the Past 40 Years, ComputerWorld July 9, 2007.

Henriques, Diana B., (2012), The Wizard of Lies: Bernie Madoff and the Death of Trust, St. Martin's Press, McMillan.

Ho, Jonathan, and Chen, Hongyi, (2018), Managing the Disruptive and Sustaining the Disruptive: The Case of Kodak and Fujifilm; Review of Public Policy; Volume 35, Issue 3, May 2018.

Issacson, Walter, (2011), Steve Jobs, Simon & Schuster, ISBN:1451648537

Jeter, Lynne W., (2003), Deceit and Betrayal at WorldCom, John Wiley & Sons.

Jordanoska, Alekdandra, (2017), Bernie Madoff and the Crisis: The Public Trial of Capitalism, Standford University Press.

Kotter, J. (2012). Barriers to change: The real reason behind the Kodak downfall. Forbes, May,2012. Lum. HC, Elliott, LJ, Aqlan, F. (2020), Virtual Reality: History, Applications and Challenges for Human Factors Research, Proceedings of the Human Factors and Ergonomics, Society, Sage Journals.

Lowenstein, Roger, (2000), When Genius failed: The Rise and Fall of Long-Term Capital, Random House.

McLean Bethany and Ekland, Peter, (2013), The Smartest Guys in the Room: The Amazing Rise and Scandalous Fall of ENRON, Penguin Books

Nahavandi, Afsaneh, (2016), The Art and Science of Leadership, 7th Edition, Pearson, 2015, ISBN-13: 978-0133546767; ISBN-10: 0133546764

Nair, Ramalu and Kumar, (2014), Impact of Innovation and Anticipating Competence on Organizational Health, https://www.researchgate.net/publication/264162759.

Ponzitracker, (2023), https://www.ponzitracker.com

Rae, Scott, and Wong, Kenman, Beyond Integrity: A Judeo-Christian Approach to Business Ethics, Zondervan, 1996.

Shibata, T., Baba, Y. and Suzuki, J. ((2022), Managing Exploration Persistency in Ambidextrous Organizations, R&D Management, Volume 52, January 2022.

Tamblyn, Nicholas and Legge, James; The Complete Confucius: The Analects, The Doctrine of The Mean, and The Great Learning, Golden Books, 2016.

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EMPOWERING CHANGE: A REVIEW OF EDUCATIONAL LEADERSHIP DYNAMICS IN JUVENILE DETENTION CENTERS

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Abstract

The purpose of this article is to provide a comprehensive overview of the current state of education in juvenile detention centers (JDCs) while providing valuable insights for educational leaders to enhance education. Understanding the key barriers, including the lack of administrative support and the challenge of limited resource availability, underlines the significant role of educational leaders in overcoming these challenges for better results for the detained teens. Therefore, the primary focus of this article is to highlight the lack of administrative support as a major barrier to providing quality education in JDCs and offer insights for building an effective leadership capacity. Educational administrators in juvenile justice settings face unique problems that call for innovative and functional strategies to avert being ineffective leaders. The article will also bring to the forefront evidence-based practices from two case studies representing successful educational programs in juvenile justice settings. This thorough review of the literature examines the critical levers that may enhance education in JDCs. Two fundamental questions guide this literature review: 1) What is the current state of education in juvenile facilities, and what challenges and best practices are evident? 2) How can educational leaders improve the academic and behavioral outcomes of the youth in JDCs?

Keywords: *Juvenile Detention Center; Educational Leadership; Barriers; Evidence-based Practices*

1. Introduction

The United States developed the juvenile justice system to manage cases of incarcerated youth under the age of eighteen. Therefore, the juvenile justice system operates independently from the adult criminal justice system and prioritizes rehabilitation over punishment (Puzzanchera et al., 2022). The establishment of the first juvenile court in Cook County, Illinois in 1899 marked the beginning of the juvenile justice system in the late 19th century. The legal principle of parens patriae, which allowed the state to intervene and act as guardian for those who cannot take care of themselves, including minors, established this court. The Office of Juvenile Justice and Delinquency Prevention reported in 2022 that they placed 27,587 youth in juvenile residential facilities nationwide (Hockenberry, 2024). This number showed a 10% increase in placement between 2020 and 2022.

JDCs are meant to be vitally important through design and intent in rehabilitating incarcerated juveniles for future success. The primary goal of the educational system in JDCs is to assist young offenders in their rehabilitation and successful reintegration into society. “Education is the most cost-effective means of reducing recidivism and ensuring successful community transitions for formerly incarcerated children and adults” (Leone & Gagnon, 2022, p. 389). Davis et al. (2013) emphasized that multi-dimensional educational opportunities offer detained adolescents the necessary competence and knowledge to find legal jobs, after which the likelihood of continued

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criminal activities or returning to illegal operations becomes considerably lower. Quality education provided by JDCs is designed to help detained minors rehabilitate by lowering recidivism rates, encouraging positive behavioral changes, and facilitating easy reintegration into society after release (Development Services Group, Inc., 2019). In 2014, the Departments of Education and Justice published a report, which included several best educational practices that may assist in ensuring that detained youth receive quality educational services. The report is titled “"Guiding Principles for Providing High-Quality Education in Juvenile Justice Secure Care Settings.” This introduction briefly highlights key advantages linked to the effective educational models' utilization in juvenile correctional centers.

Moreover, there is consistent evidence that providing education in JDCs prepares youths for successful community reintegration (Davis et al., 2013). Studies have proven that education is effective in providing the social, cognitive, and life-competent skills for these young people to successfully integrate with society post-release from correctional institutions (Christian, 2022). This will happen as education reduces the gap that separates incarceration from community life by offering the requisite tools for success outside JDCs. Educational programs within correctional facilities present youths with opportunities to earn high school diplomas or equivalency certificates, which have become basic prerequisites for employment (Blomberg et al., 2011). In essence, this then allows incarcerated youths to continue their educational pursuits upon completion of the incarceration period. Studies show that youths who participate in programs while in custody are more likely to become enrolled in schools post-release periods, showing gains in literacy and numeracy learning. Additionally, the sustained educational engagement facilitates the connection between detention environments and community living, thereby enhancing long-term outcomes (Christian, 2022). Leone and Gagnon (2022) confirmed that proper education while in detention helps the youths develop skills in reading and mathematics, thus accruing credits towards higher education or even receiving diplomas or certificates.

Finally, youth in custody often come from deprived backgrounds and have experienced significant dislocations in their school attendance (Blomberg et al., 2011; Underwood et al., 2006). For instance, Azalia et al. (2021) found that “Black children were 2.4 times more likely to be arrested and American Indian children were 1.5 times more likely to be arrested than white children” (p. 7). As a result, they might not have had the same level of opportunities as those experienced by youths in mainstream educational environments. Minority children have considerable challenges due to their overrepresentation in the juvenile justice system. Additionally, minorities, particularly African Americans, have a propensity for recidivism that is both more rapid and at elevated rates compared to non-minorities (Blomberg et al., 2011).

The provision of education within JDCs is crucial for minimizing recidivism rates, encouraging constructive behavioral transformations, pursuing higher education after incarceration, and supporting effective reintegration into society. Educating detained youth is challenging due to their transient nature and complex needs. However, those who receive quality education while in the juvenile justice system tend to have better outcomes in the community after their release (Development Services Group, Inc., 2019).

2. Barriers and Challenges

Providing quality education in JDCs is challenging due to various barriers. Inadequate training for teachers and administrators contributes to a lack of continuity and support, while security concerns and the need for a safe learning environment further complicate the delivery of quality education to juveniles. This section explores some common barriers while highlighting the lack of administrative support.

2.1. Common Barriers in JDCs

Education for youth in JDCs encounters challenges that may range from a lack of resources to high staff turnover and further to balancing concerns about security issues. Additional barriers may include difficulties with physical space, lack of funding, and constant changes in daily schedules (Development Services Group, Inc., 2019; Houchins et al., 2009). Insufficient or outdated technology is a clear example of a scarce educational resource in JDCs. Another example of the scarcity of educational resources is the lack of adequate supplies and funding for the purchase of academic materials. This barrier could potentially hinder the academic progress of juveniles. “Without adequate educational resources, young people in juvenile justice facilities are chronically behind in school and make no meaningful progress in academic achievement while incarcerated” (Azalia et al., 2021, p. 27).

Providing quality education in JDCs may be hindered by the significant issue of teachers' safety. US Departments of Education and Justice (2014) stated that “to establish conditions for learning where teachers can teach and students can learn content and build skills, the school and facility climate should be free of threats or instances of physical or emotional harm from adults or peers” (p. 9). Another barrier is “the lack of parental involvement in decisions related to students in the facility” (Houchins et al., 2009, p. 164). Hiring and promoting white staff over black in juvenile facilities is noted as a sign of racism that hinders providing incarcerated youth with quality education. According to Houchins et al. (2009), teachers in juvenile facilities have noted that “the practice of promoting unqualified White employees over Black employees should cease. In addition, teachers indicated that facilities should not employ White instructors who regard African American students as “animals” (p. 162). Besides, education systems in JDCs lack caring and nurturing schooling environment that supports the social and emotional well-being of such detained adolescents (Azalia et al., 2021, p. 31). “While incarcerated, children are often provided with inadequate education instruction, health care, and counseling services and they are at greater risk of maltreatment” (Azalia et al., 2021, p. 31). To enhance the educational systems in juvenile societies, we must address the barrier of hiring and retaining qualified staff, including administrators. “Recruiting, hiring, and retaining the right people are the most critical elements to operating an effective education program in a custody setting” (Underwood et al., 2006).

2.2. School Administrators in JDCs Pose a Significant Barrier

Houchins et al. (2009) surveyed seventy-eight teachers who worked for three state-operated juvenile facilities in Louisiana to determine the barriers to providing quality education to incarcerated youth. The study revealed several barriers, including lack of staff morale, lack of administrative support, and lack of staff support. The study raised a concern about hiring qualified administrators with a degree from accredited schools. Participating teachers emphasized that administrators should have degrees from accredited institutions and adhere to legal standards and the laws. The study results highlighted the lack of administrative support as a primary barrier to providing quality education in juvenile facilities. In this study, participating teachers pointed out that the school’s administration often hinders educational quality due to a lack of necessary support. Educators also recognized that school administrators lack sufficient training relevant to their roles in JDCs, asserting that more training for administrators will result in improved goal formulation, feedback, and adherence to applicable laws. Adequate training and abiding by the laws can help educational leaders to oversee the complex issues that come with working in a correctional facility, which may involve solving inconsistencies in priorities and policies between the education and corrections departments (Flores & Barahona-López, 2021).

3. School Administrators as Agents of Change

The work of educational leaders in JDCs is crucial for providing children with quality education and support for staff. Ensuring that students with special education needs receive the necessary accommodations and appropriate educational provision is a necessary step toward achieving this goal. This section offers practical insights that could assist educational leaders in JDCs in implementing positive changes that will lead to success for the incarcerated youth.

3.1. Support Staff and Provide Adequate Professional Development (PD) Opportunities

The US Departments of Education and Justice's (2014) report emphasized that recruiting highly effective teachers is an exceedingly difficult challenge in JDCs. The report urged education administrators to give priority attention to how to retain committed educators within JDCs. It stated that one of the major concerns for the educational leaders in JDCs is to "provide or otherwise facilitate access to professional development opportunities for education staff so they can develop the skills to address the unique needs of students in juvenile justice settings more effectively" (US Departments of Education and Justice, 2014, p. 5). Staff in state-level detention facilities often lack adequate training to address the developmental needs of juveniles and to ensure continuity of their education (Development Services Group, Inc., 2019; Underwood et al., 2006). Accordingly, educational leaders should be responsible for ensuring that continuous professional development opportunities are available to directly address the special challenges related to teaching in a correctional environment. Gagnon et al. (2012) indicated that professional development is an essential activity for teachers in juvenile correction schools to deliver research-based instructional practices in their classrooms. Research studies have shown that schools of juvenile correction facilities rarely implement effective strategies for students with disabilities, and teachers have identified professional development as crucial in implementing these strategies. National surveys have revealed that teachers commonly report being certain that specific effective practices are ineffective in meeting the needs of their students, which is an indication of a gap between research and practice. For example, teachers reported that peer-mediated instruction that would have been helpful for many students does not work. This indicates a need for professional development for teachers to understand and apply effective instructional methods, especially in mathematics and reading (Gagnon et al., 2012). For example, Underwood et al., 2006 urged JDCs to provide specialized training for educators who collaborate with juveniles with special needs.

Implementing a professional learning community (PLC) model can be a powerful strategy to help improve the learning outcomes for youth in correctional facilities, establish collaborative teams, and ensure educational equity for all inmates (Whalen et al., 2029). PLCs are collaborative groups of educators working through an ongoing process of learning and implementation to build their instructional practice and improve student learning. Working in PLCs could involve educators sharing best practices, discussing issues of varying nature, and designing new strategies that would help in meeting the unique needs of their students (Whalen et al., 2019).

3.2. Create a Caring Schooling Environment

A positive learning environment is vital for the success of a well-planned educational program, especially within JDCs. "Creating the right conditions for learning depends heavily on creating a facility-wide climate that promotes positive outcomes for all youths" (US Departments of Education and Justice, 2014, p. 8). The word "positive" implies an educational atmosphere that encourages learning and individual growth. For example, policies that promote respect, decrease the potential for bullying, and reinforce positive behaviors will likely have a greater positive impact on improving student engagement and academic performance (Roush, 1983). Additionally, it is crucial for school administrators to facilitate equipping classrooms efficiently and prioritize learning. The US Departments of Education and Justice (2014) developed five guiding principles to achieve quality education in JDCs. The guiding principles emphasized that a juvenile detention center shall be "a safe, healthy facility-wide climate that prioritizes education, provides the conditions for learning, and encourages the necessary behavioral and social support services that address the individual needs of all youths, including those with disabilities and English learners" (US Departments of Education and Justice, 2014, p. iv). Given the legal mandate for JDCs to provide detained youth with education on par with their public-school peers, educational leadership should prioritize fostering a positive, safe, supportive, and inclusive environment that adheres to legal standards and upholds the fundamental rights of these students (Christian, 2022).

3.3. Support Data-Driven Decision-Making

It is important that educational leaders use data to inform their decision-making and adopt a data-driven culture that guides educational improvement in JDCs. Data aggregation and analysis on students' performance, attendance, and behavioral trends can help school administrators understand where the deficiencies are and, therefore, enable them to focus on interventions. "To ensure that instructional methods are effective, and students are receiving the services they need to succeed, agencies and secure-care-facility schools should regularly collect and analyze data, consistent with FERPA or any other potentially applicable privacy laws" (US Departments of Education and Justice 2014, p. 19). Data-driven decision-making allows administrators to use data to allocate resources effectively, monitor the development of education programs, and make evidence-based adjustments as needed. Educational administrators may apply data-driven decision-making to assess teacher performance by implementing an "evaluation process that routinely evaluates teacher performance against identified state standards for exemplary teaching" (US Departments of Education and Justice, 2014, p. 5).

3.4. Address The Needs of Diverse Learners

Educational administrators at JDCs must address the needs of all students, including people with learning disabilities and those who suffer from mental health problems (US Departments of Education and Justice, 2014; Underwood et al., 2006). To put it another way, JDCs should provide excellent special education, Individualized Educational Plans (IEPs), and mental health services to students in special education. "Therefore, it is important for teachers providing correctional education instruction to special education students in secure care settings to be flexible in their approaches to teaching" (US Departments of Education and Justice 2014, p. 3). Leaders must carefully collaborate with special education teachers, counselors, and mental health specialists in designing and implementing coordinated support plans for the students (Miller, 2019). Houchins et al. (2009) reported that special education teachers felt misunderstood about their needs. They usually make significant efforts to manage the behavior and teaching methodologies for students with disabilities. Finally, the limited resources of JDCs hinder their ability to establish a traditional educational setting with grade-level classrooms and specialized subject teachers. Therefore, teachers often must instruct the same-class students, whose age and skills can vary within a single classroom setting. This underpins the assumption that the caregiver should offer support to the teachers in JDCs, who are more equipped to attend to students' academic and cognitive needs while enhancing their social-emotional development in a secure space. Underwood et al. (2006) stated that “the reality is that juveniles with serious mental illness are committed to youth corrections facilities, and these facilities must develop the capacity to provide effective mental health care” (p.

109).

4. Best Practices

This section provides two examples of best practices for the successful integration of educational programs within the juvenile correction setting. The first case study explores Avon Park Youth Academy's comprehensive approach, which includes vocational training. Similarly, the Maya Angelou Academy at DC Jail demonstrates strong educational leadership by providing specialized education and support services.

4.1. Case Study 1: Avon Park Youth Academy

The Avon Park Youth Academy (APYA) in Florida is a wonderful example of the effective management of an educational program within a juvenile correctional institution. APYA has initiated an elaborate educational program that involves individualized academic tuition, career-oriented skills training, and behavioral support. The program at APYA contributes to community support after the students have been reintegrated back into society. Customized learning strategies at APYA cater to the diverse learning needs and styles of the learners. The strategy has been tested to enhance class performance and involvement of students attending classes at the center (Steele et al., 2016).

Additionally, the institution offers diverse vocation programs, which include automobile mechanics and cooking. The above programs equip the students with applicable skills, hence making them more marketable once released (Steele et al., 2016). APYA ensures cognitive-behavioral treatment that resolves behavioral problems and builds social skills positively. Such a holistic approach provides students with improved life skills, hence a decrease in the recidivism rate, as stated by Steele et al. (2016). Interventions done at APYA have made notable improvements in academic progress, graduation, and job placement once released. The commitment to personalized education and job skills by the correction facility is also another factor that has caused less recidivism among the alumni of that facility.

4.2. Case Study 2: Maya Angelou Academy @ DC Jail

Maya Angelou Academy is an alternative school for detained youths. This is an example of strong educational leadership among the few juvenile detention centers. The school opened in October 2021 and serves male and female young adults ages 18–22 with IEPs. By the end of the 2021-2022 school year, the academy had enrolled seventy-two students, and its first class of fourteen students graduated in June 2022. Impressively, 90% earned credits toward a high school diploma while receiving special education services (Maya Angelou Academy @ DC jail, 2023).

The School Justice Project and the co-counselor reached a landmark settlement in September 2023, securing compensatory education services for special education students at DC Jail who had their educational rights denied during the pandemic (Charles H. v. District of Columbia, 2023). This settlement followed a class action lawsuit filed in April 2021, which highlighted the failure to provide Free Appropriate Public Education (FAPE) under the Individuals with Disabilities Education Act (IDEA). The academy's extensive support services and active community involvement have significantly contributed to positive behavioral changes and decreased recidivism rates among the students.

5. Actionable Insights to Improve Educational Programs in JDCs

The juvenile detention centers can initiate various programs to improve the educational, behavioral, and mental health outcomes of incarcerated youths. This section provides key insights into various programs that educational leaders can implement in juvenile detention centers (JDCs) to ensure that incarcerated youth receive high-quality education.

5.1. Personalized education interventions

Many youths in detention centers have experienced educational disruptions, including school exclusion, school dropout, truancy and absenteeism, grade repetition, and behavioral issues. For example, "out of 100,000 petitioned status offense cases in 2015, 55 percent were for truancy, with most resulting in probation as a disposition" (Development Services Group, Inc., 2019, p. 3). Therefore, flexible design or tailored interventions can enhance the effectiveness of educational programs. For instance, APYA in Florida has effectively utilized personal learning plans that meet the individual learning needs of each student. Therefore, the level of performance and engagement among the students became better (Steele, et al., 2016). The YouthBuild Offender program is another example of successful interventions. This is a full-time community-based intervention where incarcerated youths live and work in a family-like environment. This program had a positive impact on reducing recidivism and enhancing juvenile academic success. Results showed a rise in the attainment of high diplomas and training certificates for participating juveniles (Development Services Group, Inc., 2019). Tailoring educational interventions to meet the needs of youth in incarceration may improve the academic outcomes of the youths in JDCs. For detained youths who consistently have challenges in adapting to life in secure care and/or exhibit ongoing academic failure, a facility must provide specialized and intensive services, including mental therapy, specialist medical care, and targeted tailored behavioral interventions (US Departments of Education and Justice, 2014).

5.2. Vocational training integration

Vocational oriented programs have been helpful to youths behind bars in many ways specifically in discouraging future delinquency (Development Services Group, Inc., 2010b). These programs instill practical skills and professional competencies that can increase employability and reduce recidivism. "Vocational training and employment programs address several risk factors, including academic failure, alienation and rebelliousness, association with delinquent and violent peers, and low commitment to school" (Development Services Group, Inc., 2010b, p.1). For example, educational and vocational training forms the primary foundation of the APYA schooling system. APYA records show that there is a significant increase in completion rate, and excellent job prospects once detained youths are out of confinement. APYA participants' diploma completion rate "was about 27 percentage points higher than the rate for comparison youth" (Development Services Group, Inc., 2019, p.10). Davis et al. (2013) defined an educational program as a vocational or academic curriculum taught by an instructor that is aimed at a degree, license, or certification. The program might be part of a broader set of services for inmates or only a single-standing program, yet it must have within it a vocational or academic instructional component. More often, such well-designed programs do not only entail academic learning but also vocational and prevocational training specifically for smaller groups of youth (Gagnon & Barber, 2010). JDCs may establish place-based educational programs, which present vocational training in preparation for a job in the future and allow them to become familiar with relevant skills that will help them in the job market.

5.3. Psychological and mental health support

"Juveniles with mental health and other specialized needs are overrepresented in the juvenile justice system, and while juvenile corrections have not historically provided standardized and evidence-based mental health services for their incarcerated youth, the demand is evident" (Underwood et al., 2006, p. 107). Meeting the psychological and behavioral health needs of those students in JDCs is one of the key strategies that propel them into holistic and successful education

(Development Services Group, Inc., 2010). For instance, programs that have incorporated Cognitive Behavioral Therapy (CBT) along with other mental health approaches have been known to reduce behavioral issues and better mental health outcomes. CBT is "a problem-focused approach to helping people identify and change the dysfunctional beliefs, thoughts, and patterns of behavior that contribute to their problems (Development Services Group, Inc., 2010, p. 1). The implementation of CBT at Avon Park Youth Academy has resulted in a reduction in recidivism rates and enhanced coping mechanisms among students (Steele et al., 2016). However, Underwood et al., (2006) advocate for the use of Mode Deactivation Therapy (MDT) as an effective intervention for youths with reactive behavior disorder and post-traumatic stress disorder (PTSD). This approach integrates CBT and Dialectical Behavior Therapy (DBT) to successfully mitigate violence and suicidal ideations in adolescents with reactive conduct disorder, personality disorders, and PTSD symptoms. Leone and Gagon (2022) emphasized the effectiveness of behavioral and cognitive behavioral interventions in fostering a safe and healthy environment in juvenile correctional facilities. Miller (2019) suggests that "hiring individuals with backgrounds in special education for clerical roles … is also an effective start to establishing a reliable record retrieval and organization system" (p. 24).

6. Conclusion

In conclusion, effective educational leadership within juvenile detention centers is pivotal for fostering positive change and rehabilitation. By implementing dynamic leadership strategies, educators can create supportive learning environments that address the unique needs of detained youth. This review highlights the importance of tailored educational programs and the role of leadership in promoting academic and personal growth. Empowering educational leaders can significantly impact the prospects of these young individuals, paving the way for successful reintegration into society.

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8. References

Azalia, L., Campbell, S., Chinyavong, A., Dawson, B., Dixon Davis, M., Gardner, E., Hatch, T., King, K., Mehrabi, E., Olender, S., San Martin, B., Sowa, A., Sprow, S., & Tilly, Z. (2021). The state of America's children 2021. Children's Defense Fund. https://www.childrensdefense.org/wp-content/uploads/2023/08/The-State-of-Americas-Children-2021.pdf

Blomberg, T. G., Bales, W. D., Mann, K., Piquero, A. R., & Berk, R. A. (2011). Incarceration, education, and transition from delinquency. Journal of Criminal Justice, 39(4), 355-365. https://doi.org/10.1016/j.jcrimjus.2011.04.003

Charles H. v. District of Columbia (2023, November 14). Civil Rights Litigation Clearinghouse. Retrieved June 19, 2024, from https://clearinghouse.net/case/43556/

Christian, D. (2022, March 28). Education behind bars: A review of educational services in juvenile correctional facilities. College of Safety and Emergency Services Academic Journal. https://csesjournal.columbiasouthern.edu/education-behind-bars-a-review-of-educational-services-in-juvenile-correctional-facilities/

Davis, L. M., Bozick, R., Steele, J. L., Saunders, J., & Miles, J. N. V. (2013). Evaluating the effectiveness of correctional education: A meta-analysis of programs that provide education to incarcerated adults. RAND

Corporation
Development Services Group, Inc. (2010). Cognitive–behavioral treatment [Literature review]. Office of Juvenile Justice and Delinquency Prevention. https://ojjdp.ojp.gov/model-programs-guide/literature-reviews/cognitive_behavioral_treatment.pdf

Development Services Group, Inc. (2019). Education for youth under formal supervision of the juvenile justice system. Literature Review. Office of Juvenile Justice and Delinquency Prevention. https://ojjdp.ojp.gov/model-programs-guide/literaturereviews/education_for_youth_under_formal_supervision_of_the_juvenile_justice_system.pdf

Development Services Group, Inc. (2010b). Vocational/job Training. Office of Juvenile Justice and Delinquency Prevention.https://ojjdp.ojp.gov/model-programs-guide/literaturereviews/vocational_job_training.pdf

Flores, J., & Barahona-López, K. (2021). Correctional education and the impact on educators' lack of training. Curriculum Perspectives, 41(3), 237-244. https://doi.org/10.1007/s41297-021-00147-3

Gagnon, J. C., & Barber, B. (2010). Characteristics of and services provided to youth in secure care facilities. Behavioral Disorders, 36(1), 7-19. https://doi.org/10.1177/019874291003600102

Gagnon, J. C., Houchins, D. E., & Murphy, K. M. (2012). Current juvenile corrections professional development practices and future directions. Teacher Education and Special Education, 35(4), 333-344. https://doi.org/10.1177/0888406411434602

Hockenberry, S. (2024, July 1). Highlights from the 2020 juvenile residential facility census. Office of Juvenile Justice and Delinquency Prevention. https://ojjdp.ojp.gov/library/publications/highlights-2020-juvenile-residential-facility-census

Houchins, D. E., Puckett-Patterson, D., Crosby, S., Shippen, M. E., & Jolivette, K. (2009). Barriers and facilitators to providing incarcerated youth with a quality education. Preventing School Failure Alternative Education for Children and Youth, 53(3), 159–166. https://doi.org/10.3200/psfl.53.3.159-166

Leone, P. E., & Gagnon, J. C. (2022). The imperative of high-quality education in juvenile corrections: An introduction to the special section. American Journal of Orthopsychiatry, 92(4), 389-390. https://doi.org/10.1037/ort0000639

Maya Angelou academy @ DC jail (2023, August 7). Maya Angelou Public Charter Schools - See Forever Foundation. Retrieved June 19, 2024, from https://www.seeforever.org/maa-dc-jail/

Miller, A. A. (2019). Navigating barriers to special education in a juvenile detention center. Journal of Correctional Education, 70(2), 2-30. Retrieved from https://eric.ed.gov/?id=EJ1335464

Puzzanchera, C. M., Hockenberry, S., & Sickmund, M. (2022). Youth and the juvenile justice system: 2022 national report. National Center for Juvenile Justice. https://ojjdp.ojp.gov/publications/2022-national-report-ch7.pdf

Roush, D. W. (1983). Content and process of detention education. Journal of Offender Counseling, Services & Rehabilitation, 7(3-4), 21-36. https://doi.org/10.1300/J264v07n03_02

Steele, J. L., Bozick, R., & Davis, L. M. (2016). Education for incarcerated juveniles: A meta-analysis. Journal of Education for Students Placed at Risk (JESPAR), 21(2), 65-89. https://doi.org/10.1080/10824669.2015.1133308

Swank, J. M., & Gagnon, J. C. (2016). Mental health services in juvenile correctional facilities: A national survey of clinical staff. Journal of Child and Family Studies, 25(9), 2862-2872. https://doi.org/10.1007/s10826-016-0436-3

Underwood, L. A., Phillips, A., Von Dresner, K., & Knight, P. D. (2006). Critical factors in mental health programming for juveniles in corrections facilities. International Journal of Behavioral and Consultation Therapy, 2(1), 107-140. https://doi.org/10.1037/h0100771

US Departments of Education and Justice. (2014). Guiding principles for providing high-quality education in juvenile justice secure care settings. https://www2.ed.gov/policy/gen/guid/correctional-education/guiding-principles.pdf

Whalen, S., Swain, S., Fedele-McLeod, M., & Thacher, M. (2019). Professional learning communities in prisons. COABE Journal, 8(1), 94–98. https://eric.ed.gov/?id=EJ1253159

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