# Journal of Multidisciplinary Research

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## Mission Statement

The mission of the *Journal of Multidisciplinary Research* is to promote excellence by providing a venue for academics, students, and practitioners to publish current and significant empirical and conceptual research in the arts; humanities; applied, natural, and social sciences; and other areas that tests, extends, or builds theory.

Journal of Multidisciplinary Research

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# Editorial

Dear Colleagues,

The Spring 2026 issue of the *Journal of Multidisciplinary Research* explores how research, education, and perseverance can advance understanding and inspire meaningful progress. Across leadership, higher education, workforce development, sustainability, health innovation, and personal growth, our contributors demonstrate the value of examining complex challenges from multiple perspectives.

An article from the State College of Florida examines established leadership theories and the importance of adapting leadership approaches to organizational needs. A researcher from Florida Atlantic University explores the expectations and post-graduation realities of international graduates who secured employment-based green cards, highlighting the complex journeys connecting education and professional opportunity. An article from Appalachian State University investigates Generation Z first-year students and the implications for higher education, while research from Minnesota State University examines how the language used to describe agricultural careers shapes perceptions and influences career interest. Together, these articles challenge institutions and employers to reconsider how they lead, communicate, and create opportunities.

Our *Life Forward* feature presents the distinguished professor of marketing and management, international author, keynote speaker, and thought leader Marc Oliver Opresnik, whose work emphasizes purpose-driven leadership, innovation, and long-term value creation. This focus on purpose resonates with Jana A. Maynard's *Unfinished: Lessons in Failing Forward*, a moving reflection on perseverance, vulnerability, and the people who help us overcome obstacles. Both contributions remind us that meaningful success is measured not only by achievement but also by the value we create and the resilience we develop along the way.

The *Student Corner* showcases research addressing two pressing challenges. A Neumann University student examines the economic and environmental trade-offs of biodegradable packaging materials, while research from a University of South Florida student explores a prototype integrating posture optimization and respiratory measurement to support monitoring of chronic obstructive pulmonary disease. These studies illustrate how student scholarship can connect analytical thinking with practical problems and potential solutions.

Finally, the *Book Review* section includes a look at T. A. Severini's *Analytic Methods in Sports*, and invites readers to consider the impact various factors have on how people view sports.

These contributions affirm the value of multidisciplinary inquiry: Connecting ideas across fields, questioning familiar assumptions, and translating knowledge into purposeful action and action is key. As James Clear said, "Overnight success always takes a year or two."

May we always inspire you to continue collaboration and discovery.

Always forward,

Hagai Gringarten, Ph.D.
*Publisher & Editor-in-Chief*



"Golden Mato"

Photograph
10.08" x 13.44"
2026

Original Photograph by Caramia S. Frallicciardi

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# Leadership Styles: Flexibility for Success

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Abstract

This article explores how leadership styles affect individuals and organizations, discusses which characteristics promote organizational success, and analyzes four established leadership theories and their roles in achieving desired outcomes. Although research into leadership theories such as the path-goal, behavioral, servant, and transformational styles began several decades ago, there are still varied opinions on what defines an ideal leader and how that style translates to organizational success. The article discusses the shift from hierarchical structures toward collaborative team-based models that highlight emotional intelligence, adaptability, and shared decision-making. It suggests that no single leadership style is preferable, universally; instead, the most effective leaders will demonstrate flexibility in utilizing multiple approaches based on situational demands and follower needs. With the advancement of technology and changes in the generational workforce, future organizational success depends on a leader's ability to integrate diverse leadership styles, create inclusive environments, and balance objectives with genuine concern for the growth and well-being of others.

Keywords

leadership, leadership theories, organizational success, servant theory, path-goal theory, behavioral theory, transformational theory

## Introduction

In modern society, the way the world views individuals and organizations often determines their success. With the proliferation of digital technology and global innovation, it is increasingly essential to demonstrate the ability to lead amid potential turmoil. Measuring what makes a good leader, or how research defines leadership, poses a challenge. Many organizations aim to identify which leadership traits, qualities, and attributes comprise a great leader, with research suggesting that individual theories are more effective than others.

Although this research began attracting attention in the late 1800s, varied opinions remained about what defines an ideal leader and how that leadership translates into organizational success (Lindberg, n.d.). This article explores how leadership styles affect individuals and

organizations, discusses which characteristics promote organizational success, and analyzes four established leadership theories and their roles in achieving desired outcomes.

Developing a cohesive definition of leadership is analogous to trying to hit a moving target. Researchers over several decades have offered their own definitions of what defines a leader, with slight similarities. Most recently, Northouse (2022) defines leadership as "a process whereby an individual influences a group of individuals to achieve a common goal" (p. 7). More than four decades prior, Burns (1979) defined leadership as "leaders inducing followers to act for certain goals that represent the values and the motivations—the wants and needs, the aspirations and expectations—of both leaders and followers" (p. 381). When considering the emotional aspect of leadership, University of Notre Dame president, the Reverend Theodore M. Hesburgh (1971), believed that when leadership exists, "morale flourishes, people pull together towards common goals, spirits soar, order is maintained" and that "leadership always has a moral as well as an intellectual dimension; it requires courage as well as wisdom; it does not simply know, it cares" (p. 764). Researchers have provided many more definitions of leadership over the years, with similar descriptions and attributes, and continue to conduct studies to evaluate what styles produce the most effective results. However, hypothesizing the effects of productivity and follower morale based on a particular leadership style does not always yield accurate conclusions.

According to Johns and Moser (2001), when attempting to isolate leadership styles for effectiveness, researchers found that those deemed most beneficial were those that met the expectations of those being led. While there are common traits that fundamentally describe leadership characteristics, such as the ability to prioritize goals, being forward-thinking, being an effective communicator, being accountable and responsible, having a vision for the future, having the ability to foster creativity and team building, creating lasting relationships, and an openness to learning, these traits do not always translate to effective leadership (Patel, 2017).

Evidence shows that even though individuals in leadership positions, or those who aspire to be, possess these traits, it does not guarantee success. More recent findings suggest that things such as an organization's sociology, a leader's motivational techniques, lifestyle, social contributions, and willingness to assist in change and adaptability are more relevant to determining leader effectiveness in today's changing "complex and interdependent world" (Johns & Moser, 2001, pp. 121–122). Therefore, isolating specific traits and characteristics of a leader, or their perceived leadership style, and how they translate into organizational success becomes even more problematic.

As Jackson and Naziri (2020) state, organizational hierarchies are experiencing a shift from a top-down form of leadership to a more flattened structure that relies on teamwork dynamics, with "employees having a greater degree of involvement in decision-making" (p. 283). While still important, the traits that historically have been thought to be essential for an effective leader, such as vision, intelligence, and determination are no longer the determining factors that make them successful (Jackson & Naziri, 2020). Instead, today's leaders must possess a combination of skills that inspire others to be innovative within their organizations and through collaborative efforts externally and globally. Hill and others (2022) explain that, according to their research, there has been a profound shift in what defines excellent leadership within organizations. In today's world of continuous innovation, agility, digital technology, and increased competitiveness, leaders must shift from "getting others to follow them into the future" to "others to co-create the future with them" (Hill et al., 2022, n.p.).

As this organizational shift and leadership dynamic continues, it is even more critical that leaders are willing and able to collaborate with a more diverse environment and individuals. The most successful leaders of the future will have the emotional intelligence, patience, and courage to motivate others to think creatively, navigate through adversity, and find pathways to achieving their goals while respecting and protecting their team's well-being (Hill et al., 2022). Leaders who empower their teams in these ways will see people show a profound commitment, rather than simply comply with their roles in an organization. These are the characteristics Hill and others (2022) posit that leaders must possess to have the ability to "unleash the abundant talents and passions all around us and leverage them to create a better world" (n.p.). While this opinion outlines a path for leadership's future, it is necessary to understand the theories that have been researched and studied in the past. Researchers have developed several theories since they began studying leadership effectiveness, including path-goal, behavioral, transformational, and servant theories.

## Path-goal Theory

Researchers have been studying the path-goal leadership theory Evans developed initially in the 1970s. This theory explains how a leader's style motivates followers to achieve their goals in ways that align with their individual needs and expectations within the organizational setting. According to House and Mitchell (1975), the theory's name results from the primary concern of "how the leader influences the subordinates' perceptions of their work goals, personal goals, and paths to goal attainment" (p. 1). Furthermore, the theory's premise suggests that the leader's motivational behavior is satisfying to the degree that followers can attain their goals and have a defined path to do so (House & Mitchell, 1975). This perspective stems from the expectancy theory, a more general theory of motivation developed by Vroom, which assumes that followers who believe they will achieve their desired outcome will be more motivated to perform their work (Northouse, 2022). As House and Mitchell (1975) explained, "people are satisfied with their job if they think it leads to things that are highly valued, and they work hard if they believe effort leads to things that are highly valued" (p. 1). From this standpoint, a significant factor in follower behavior comes from a leader's behavioral style and management of situational tasks and organizational objectives (Fabac et al., 2022).

Four primary leadership behavioral styles have been identified in the path-goal theory: supportive, participative, directive, and achievement-oriented. These behaviors are essential for understanding the mechanisms of the path-goal theory and frequently appear in use in research on this approach (Northouse, 2022).

*Supportive leadership* behavior shows concern for followers' well-being and strives to foster a friendly environment by meeting their needs and preferences (Fabac et al., 2022). The leader also ensures a pleasant workplace and ensures that followers feel confident and respected as equals (Northouse, 2022). This behavioral style is best suited for followers who need to feel a sense of belonging (Fabac et al., 2022).

*Participative leadership* behavior allows followers to influence leadership decisions. Leaders actively encourage followers to make suggestions and share in the decision-making process. They also seek their opinions and incorporate their ideas into decision-making (Northouse, 2022). This behavior style benefits followers who need control because it provides them with the satisfaction of having decision-making authority (Fabac et al., 2022).

*Directive leadership* behavior reflects leaders who provide followers with clear directions, expectations, and required standards for an assigned task or project (Northouse, 2022). This leadership style removes ambiguity and confusion, allows followers to focus on their jobs and anticipated goals, and is most appropriate when a task is challenging, complex, or unclear (Fabac et al., 2022).

*Achievement-oriented leadership* behavior assumes that followers will achieve higher goals and produce high-quality results (Fabac et al., 2022). Leaders who use this style challenge followers to set higher standards, perform at the highest levels, and continuously seek ways to improve (Northouse, 2022). Like the directive style, achievement-oriented behavior supports followers when faced with challenging or complex tasks (Fabac et al., 2022).

Evans first asserted that influential leaders would make follower rewards contingent upon the successful completion of assigned goals and that it is the leader's responsibility to determine the specific behaviors they must exhibit to lead and motivate followers toward those goals (House & Mitchell, 1975). As Northouse (2022) explains, the path-goal theory does not mandate that leaders adhere to a single type of leadership but rather that they adapt their styles to specific follower and task characteristics. House and Mitchell (1975) provide further insight by stating that this theory "not only suggests what type of style may be most effective in a given situation—it also attempts to explain why it is most effective" (p. 14). Leaders who utilize this approach advance this assertion because it allows them to select the style that will benefit followers with their work according to their individual needs and the task being performed.

Leaders proficient at adapting to these situations will have satisfied followers who perform better. Some additional strengths this theory offers include integrating expectancy theory and emphasizing a leader's responsibility to coach and guide followers toward their goals (Northouse, 2022). While these are viable attributes, there are also weaknesses in the path-goal approach, including ambiguous study results, a complex and broad method of leadership, not considering gender, not explaining how a behavioral leadership style affects follower motivation, and finally, placing focus on the leader more than on the follower (Northouse, 2022).

## Behavioral Theory

The behavioral theory of leadership follows earlier approaches, such as the "Great man" and "Trait," which held that leaders were born, rather than made. The behavioral theory is based on the opposite: Individuals can become great leaders through teaching and observation and by focusing less on internal or mental qualities (Cherry, 2022). Northouse (2022) explains that this approach "emphasizes the behavior of the leader" and "focuses exclusively on what leaders do and how they act" (p. 84). Researchers believe that the inherent characteristics of a leader are set aside and instead focus on the behaviors they undertake to solve problems, increase effectiveness, and improve follower performance (Lindberg, n.d.). They also determined that leadership comprises two kinds of behavior: task behaviors, which facilitate achieving goals and objectives, and relationship behaviors, which help make followers feel comfortable and satisfied. Leaders who utilize both behaviors are the most effective (Northouse, 2022).

Four significant studies were conducted between the 1930s and 1970s that provided a profound understanding of behavioral leadership theory. The first study discussed is Kurt Lewin's leadership experiment, which postulated that every leader possesses one of three distinct behaviors: an authoritarian or autocratic style, a laissez-faire style, or a democratic style (Lindberg, n.d.). Next, the Ohio State University studies during the mid-1940s found that leaders exhibit two

general types of behavior: initiating structure, which is task-oriented, and consideration, which is centered on cultivating relationships through respect and trust (Northouse, 2022). Researchers further divide these behaviors into four outcomes or quadrants, ranging from high initiating and high consideration to low initiating and low consideration. This study was the first to assume that leaders can utilize two behavioral styles simultaneously (Lindberg, n.d.). Another study by the University of Michigan in the 1950s found that leaders fall into two categories of behaviors: job-oriented, which focused on tasks or employee-oriented leadership, which focused on the employee. While researchers found that both styles could produce excellent follower performance, a single leader cannot demonstrate individual styles simultaneously (Lindberg, n.d.). Finally, Blake and Mouton developed the Managerial, or Leadership, Grid in the 1960s and is now one of the most recognized leadership models (Northouse, 2022). The grid demonstrates five distinct management styles, which provide leaders with an assessment tool to determine which type they use, based on two factors: concern for people versus concern for production (Lindberg, n.d.). Two intersecting axes join the two styles, with the horizontal axis representing concern for production and the vertical axis representing concern for people; the most extreme positions are team management (9,9) and impoverished management (1,1) in the grid (Northouse, 2022). The remaining styles include authority compliance (9,1), country club (1,9), and middle of the road (5,5).

The behavioral leadership style offers a significant perspective on the assertion that individuals learn and develop leadership skills, rather than stemming solely from inherent traits. According to Northouse (2022), one of the most positive attributes of this style is that it "broadened the scope of leadership research to include the behaviors of leaders and what they do in various situations" (p. 93). Second, the many studies that have investigated this style provide continued validation and credibility to the theory's tenets and importance to the study of leadership (Northouse, 2022). Additionally, research on this style provides evidence that leaders can use both a job-oriented and an employee-oriented style, being attentive to production and people while fostering follower satisfaction and increased performance (Lindberg, n.d.). Finally, this style allows leaders to gain a better understanding of themselves and learn how to modify their behaviors and how those behaviors affect their organization and followers (Northouse, 2022).

There are also disadvantages and criticisms regarding the behavioral leadership theory. For example, researchers have not established a definitive link between job or employee relationship behavioral styles and increased productivity or follower satisfaction (Northouse, 2022). Furthermore, inadequate leadership can occur when leaders dismiss situational factors in high-paced environments, as leaders follow a specific behavioral leadership style (Lindberg, n.d.). Last, some leaders believe that behavioral styles are like personality traits, which reduces their willingness to change behaviors or attitudes toward personal growth and development (Lindberg, n.d.).

## Transformational Theory

James MacGregor Burns first conceptualized transformational leadership theory in 1978 in his book *Leadership* (Northouse, 2022). Burns determined that individuals should be capable of becoming transformational leaders who care for their followers and help them meet their needs and potential (Aydin et al., 2013). As Burns (1979) explains, "Such leadership occurs when one or more persons *engage* with others in such a way that leaders and followers raise one another to higher levels of motivation and morality" (p. 382). While the purposes of everyone differ, as is the case with transactional leadership, they become fused in a moral relationship when the ethical

aspirations of both a follower and a leader are affected through the transformational process (Burns, 1979). Therefore, the primary goal of transformational leadership is to help followers develop to their full potential and improve performance (Northouse, 2022). The model of transformational and transactional leadership comprises seven factors: idealized influence or charisma, inspirational motivation, intellectual stimulation, individualized consideration, contingent reward, management by exception, and laissez-faire (Northouse, 2022). This full-range leadership model provides leaders with an outline for understanding their leadership styles and techniques that are best suited to ensuring follower satisfaction and commitment to organizational goals (Aydin, Sarier, & Uysal, 2013).

Researchers have studied transformational leadership theory widely, providing significant documentation and descriptions of its defining characteristics and qualities, which support its many strengths. Some of this theory's attributes include leaders' ability to advocate for others, the incorporation of leader and follower needs, and attention to their growth, morals, and values (Northouse, 2022). Nevertheless, there are also criticisms regarding this theory. These weaknesses include a lack of defined parameters or conceptualization, difficulty validating measurement tools, an inability to determine whether transformational leaders are successful in an actual transformative process, and the potential for abuse or perception as elitist or anti-democratic (Northouse, 2022). Last, there is the potential for transformational leaders to be less effective in developed economies or among millennials, as they are less inclined to collaborate toward common goals (Northouse, 2022).

## Servant Theory

Servant leadership is one of the oldest styles, dating back to ancient monarchies, which acknowledged "leadership was for the service of people and country" thousands of years ago (Gandolfi & Stone, 2018, p. 261). Historically, leaders such as Confucius, the Zhou Dynasty, tribal Bedouin Arab culture, and even Jesus have demonstrated servant leadership (Gandolfi & Stone, 2018). Robert K. Greenleaf reinvigorated this theory, when, in an essay first published in 1970, he stated, "The servant-leader is servant first… It begins with the natural feeling that one wants to serve, to serve first. Then conscious choice brings one to aspire to lead" (Robert K. Greenleaf Center for Servant Leadership, 2026, n.p.). Greenleaf outlined 10 prominent characteristics that encompass servant leadership: "listening, empathy, healing, awareness, persuasion, conceptualization, foresight, stewardship, commitment to the growth of people, and building community" (Gandolfi & Stone, 2018, p. 265). Servant leaders who display these characteristics are viewed as having moral and ethical values and as leading in ways that serve their organization, community, and society (Northouse, 2022).

Interestingly, although in use throughout history, there is little research on the servant leadership style, with some limited studies describing it as a trait phenomenon or a behavioral process and providing little agreement on its primary attributes (Northouse, 2022). Researchers have agreed that three main components – including antecedent conditions, servant leader behaviors, and outcomes – provide a framework for understanding the style. Understanding the influence of "context and culture, the leader's attributes, and the follower's receptivity to this kind of leadership" on these components further defines this model (Northouse, 2022, pp. 259). Observers often misinterpret servant leaders as disengaged, but they are as proactive and ambitious as leaders in other styles. This style differs in its focus on putting the follower first to help them

achieve their goals and succeed in their roles, thereby benefiting the organization (Gandolfi & Stone, 2018).

As Northouse (2022) explains, one of the most insightful strengths of the servant leadership style is that it is the only approach that provides a process grounded in caring for others and makes altruism central to the leadership role. Additionally, it effectively predicts follower attitudes and performance, provides a viable method for leaders to share control and influence, and includes other important key stakeholders in the leadership process. Consequently, this style also has limitations. Researchers have a theoretical framework but have not reached a consensus on a definition for scholars or leaders to follow, nor does it provide an understanding of how the style affects an organization or leads to change (Northouse, 2022). Moreover, people can view the "put others first" style of leadership as too "altruistic" and conflicting with more traditional principles of leadership focused on production, vision, goal setting, and direction (Northouse, 2022).

## Analysis

Since the 1930s, researchers have studied how various leadership styles, theories, and approaches have affected individuals and organizations and have sought to determine which skills and characteristics lead to the most beneficial outcomes. This article focuses on four leadership theories: path-goal, behavioral, transformational, and servant. Understanding the basic components of each approach is essential for analyzing similarities and contrasts and understanding how they will benefit leaders, followers, and organizations.

One of the most defining characteristics of the path-goal theory is that leaders motivate followers by providing clear direction and opportunities to achieve a desired goal or reward (House & Mitchell, 1975). Similarly, while other styles will give followers motivational techniques designed to increase performance and achieve their desired outcomes, the path-goal focuses on ensuring that followers believe their efforts will result in the expected rewards (Northouse, 2022). Unfortunately, not every follower has the same motivation, nor will every task lend itself to this approach; therefore, leaders must recognize and adjust to these differences.

Additionally, the path-goal theory aligns with the behavioral leadership style when evaluating task-oriented behaviors against predefined standards in autocratic or commanding-style organizations (Lindberg, n.d.). However, when considering the strengths of this approach, acknowledging that different leadership styles can affect followers and their motivation and how leaders help in that role, a correlation exists with the servant leadership approach (Northouse, 2022).

Moreover, a behavioral leadership style is similar to servant leadership in terms of relational-oriented behaviors. When using this behavioral style, leaders focus more on followers, relationships, motivation, and teamwork. They will encourage their input and treat them as equals to build trust and respect to benefit them (Lindberg, n.d.). These characteristics are a few of the critical tenets of servant leadership. One makes a comparison between behavioral and transformational leadership when one considers leaders who adopt change-oriented behaviors, develop a vision for change, encourage innovation, and motivate followers to continuously improve or take risks (Lindberg, n.d.).

Researchers have shown consistently that the transformational style is one of the more effective approaches to leadership, with a strong correlation with follower commitment, job performance, and satisfaction (Jackson & Naziri, 2020). Leaders using this approach work to develop an organization's vision, inspire followers, determine and implement necessary changes,

and gain follower commitment to those changes. Study results have further shown that these leaders demonstrate significant emotional intelligence attributes, including empathy, self-awareness, and motivation (Jackson & Naziri, 2020).

Consequently, the transformational style is comparable to servant leadership in that, as Gandolfi and Stone (2018) explain, "both approaches encourage leaders and followers to raise one another to higher levels of motivation and morality" (p. 266). However, the stark contrast between the two styles lies in the transformational approach, which consolidates power in a select few, with followers expected to comply. In comparison, servant leadership provides greater interaction between followers and leaders to attain organizational goals through service to followers (Gandolfi & Stone, 2018).

As the oldest leadership style, the servant leader's approach, when applied with pure and authentic intentions, produces a relationship between follower and leader that is mutually beneficial and productive (Gandolfi & Stone, 2018). According to Gandolfi and Stone (2018), research analysis has shown that, while significant differences exist among the approaches discussed, their basic frameworks align with the principles of servant leadership. Although other leadership styles call for leaders to show compassion, empathy, and morality, servant leadership is the only style that requires humility. This characteristic makes the servant leadership approach one of the most desirable types of leadership, at least in theory (Gandolfi & Stone, 2018). Furthermore, research has shown that even the most effective leadership styles must adjust to individual followers and situations, indicating that leaders should be flexible and adaptable. Leaders proficient at combining multiple leadership styles while maintaining emotional intelligence and compassion are most beneficial to followers and organizations.

To be effective and successful in an organization today, leaders need to cultivate a dedicated, capable, and flexible workforce and retain them. The proliferation of artificial intelligence technology in the workplace creates additional challenges to organizations. Bock and von der Oelsnitz (2025) found that leaders who effectively preserve the human aspect of leadership represent the future of management. As technology and AI systems continue to evolve, further research is necessary to identify the leadership competencies that will remain relevant as more organizations utilize automated systems. Leaders must adapt to these changes through developing communication skills and collaborating synergistically with humans and technology (Bock & von der Oelsnitz (2025). Furthermore, if leaders can cultivate a more engaging leadership style, they are more likely to establish a positive, diverse, and inclusive work environment. Leadership requires more than simply directing followers or assigning tasks to complete. It requires individuals to build relationships with those they lead, the organization, and the community. The most successful leaders will be proficient at adapting the most appropriate leadership style to the situation, the organizational need, and action for the benefit of the follower.

## Summary

The characteristics and traits that shape individuals to demonstrate exceptional leadership have received scholars' and researchers' attention for decades. The four leadership styles the present article discusses represent only a small subset of the many approaches possible in organizational settings. While it is essential to understand the complexities of these leadership styles, their applications, strengths, and criticisms, they all rely on the leader's intrinsic personality and emotional intelligence to be the most effective. Leaders who fail to recognize when they must

adapt their leadership approach cannot provide their organization or followers with the tools and support they need to achieve expected goals.

Researchers have studied leadership approaches and their effects on follower satisfaction and organizational performance for more than 90 years. These studies have helped define leadership and how leaders can achieve the most successful outcomes for followers, the organization, and themselves. The four leadership theories this article discusses – path-goal, behavioral, transformational, and servant – each have specific characteristics and attributes that set them apart. However, with close analysis, they also share similarities, such as fostering follower motivation, goal setting, concern for others, and improving organizational performance.

Leaders using the path-goal theory provide followers with a clear direction for accomplishing their work through either a directive or a supportive style of leadership. They also display a participative or achievement-oriented leadership style. Behavioral theory shares the hallmarks of the path-goal approach in that leaders behave in certain ways based on the situation to be addressed. Leaders who use this approach provide guidance through a task- or behavior-based leadership style. The transformational theory is one of the most complex leadership approaches concerned with motivating and inspiring followers to achieve desired goals. Leaders using this approach display strong values as practical motivators, seeking to benefit others, rather than themselves. Last, the servant leadership theory emphasizes attentiveness to the needs of followers, the organization, and the community. This approach produces a set of behaviors that empower leaders to empower followers and allows them to reach their full potential (Northouse, 2022).

An essential aspect of effective leadership, which theories consistently demonstrate, is the need for leaders to be adaptable and flexible to manage an increasingly diverse workplace and global workforce effectively. Every leader must develop the skills to apply multiple leadership styles effectively as they support and guide today's highly diverse teams and evolving technological needs. Conversely, followers have varied preferences for their leaders, which shape their motivations, desires, goals, and requirements, and are essential factors for employee satisfaction and retention.

## Leaders in the Present and the Future

Leaders open to continuous growth and learning to improve their leadership skills have tools like the DiSC personality assessment to help them use their inherent skills effectively and provide insights into potential weaknesses. The DiSC assessment styles are similar to leadership theories, allowing individuals to exhibit more than one personality style. Everyone possesses a piece of each leadership theory and DiSC style innately within their personality (Personality Profile Solutions, n.d.). The most effective leaders have demonstrated the ability to use multiple leadership styles and understand how their personality types are best suited to achieve the most desirable outcomes for the situation or problem at hand.

As organizations evolve to compete in the twenty-first century, so must their leadership. The role of a leader in the future will not just involve leading others toward a goal; instead, it will require leaders and followers to achieve goals together through processes that involve diverse, collaborative effort (Hill et al., 2022). The style and personality of an effective leader will require diversity of thought, courage, emotional resilience, and the capacity to foster innovation and creativity by allowing opposing ideas.

Moreover, future leaders will have more followers and subordinates representing Millennials and Generation Z, a population segment with vastly different motivations and goals from previous generations. In the coming years, leadership will become less hierarchical and more collaborative, necessitating that leaders shift from requiring followers to comply to a more inclusive approach in which they choose to become committed. Organizations risk employees taking less initiative to pursue risks that generate innovative ideas that improve performance when they feel disengaged or segregated from a leader or the organization. As the sociology of an organization and the perceived social contributions of leaders become more apparent today, those in leadership positions must recognize their roles as mentors, motivators, visionaries, transformers, and servants.

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## Discussion Questions

1. Why does effective leadership require flexibility rather than reliance on a single leadership style? Provide examples from the four theories discussed.

2. What are the potential benefits and risks of each leadership style discussed? How could each style impact modern organizations?

3. What competencies are the most important for leaders in the next decade and how should organizations prepare leaders for the changes that can arise?

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"The Flower, Vase, and the Drape"

Acrylic on Canvas
16" x 20"
2026

Original Painting by Caramia S. Frallicciardi

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# Before Beginning their U.S. Studies: Expectations and Post-Graduation Realities of International Graduates Who Secured Employment-Based Green Cards

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Abstract

International students in U.S. higher education face numerous challenges, including cultural adjustment, academic demands, financial pressures, and navigating immigration pathways. Those who seek long-term employment in the United States encounter additional barriers, such as securing full-time employment, obtaining H-1B sponsorship, and achieving permanent residency. This qualitative case study contributes to the literature on international students' pathways to permanent residency by examining the expectations international graduates held before beginning their studies in the United States.

The case study explored participants' expectations regarding attending college in the United States, career opportunities after graduation, and post-graduation plans, including whether they anticipated remaining in the United States or returning to their home countries. The sample included 15 former international students who earned at least a bachelor's degree from a U.S. institution between 2000 and 2017 and obtained employment-based permanent residency within five to ten years of graduation. Data were collected through semi-structured virtual interviews, documents, and physical artifacts.

Findings revealed that participants entered their U.S. studies with diverse expectations about their educational experiences, career prospects, and long-term residency plans. The study highlights the complexity of international students' pathways from higher education to permanent residency and offers implications for future research and practice.

Keywords

international students, international education, immigration, green card, higher education, expectations

## Introduction

International students account for approximately 6% of all students enrolled in U.S. higher education and contributed nearly $55 billion to the U.S. economy during the 2024-25 academic year (Institute of International Education [IIE], 2025). As foreign nationals studying in the United States on F-1 visas, international students navigate a complex educational and immigration process that extends beyond degree completion (U.S. Citizenship and Immigration Services [USCIS], 2025).

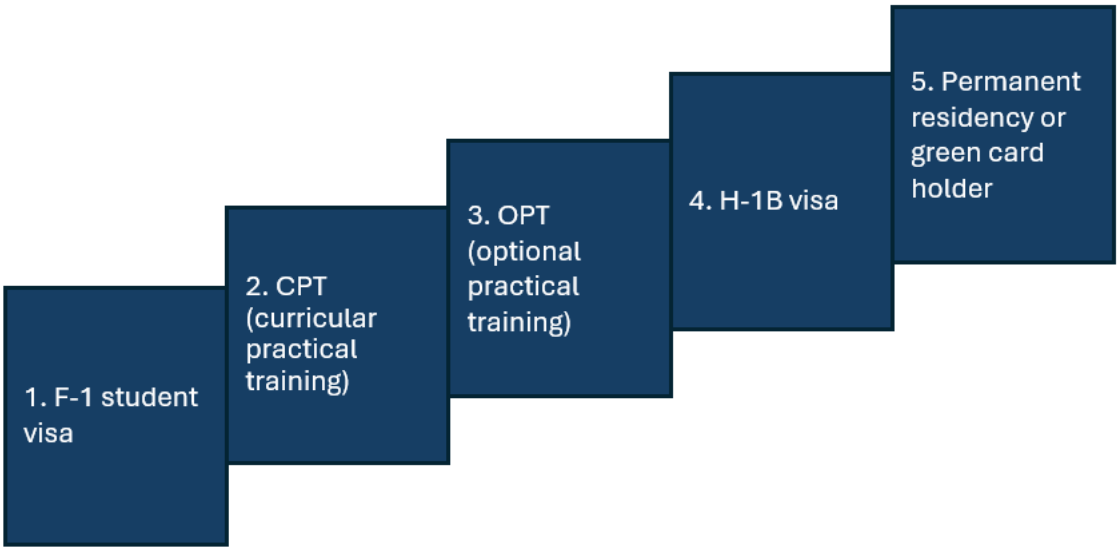
While enrolled, students may participate in internships and Curricular Practical Training (CPT) opportunities related to their fields of study. After graduation, many pursue Optional Practical Training (OPT), which provides temporary work authorization in the United States. During the 2024–2025 academic year, approximately 294,000 international students participated in OPT, and more than half of all international students were enrolled in STEM fields, making them eligible for extended work authorization (IIE, 2025).

For graduates seeking to remain in the United States long term, the pathway typically progresses from OPT to an H-1B visa and, eventually, employment-based permanent residency. The H-1B program annually issues approximately 85,000 visas for specialty occupations requiring specialized knowledge and at least a bachelor's degree (USCIS, 2025). Through employer sponsorship, H-1B holders may subsequently obtain permanent resident status, commonly known as a green card (USCIS, 2025).

Although considerable research has examined international students' academic and adjustment experiences, less is known about the expectations they held before beginning their studies in the United States regarding higher education, career opportunities, and long-term residency plans. This study explored those pre-enrollment expectations among international college graduates who ultimately secured employment-based permanent residency in the United States. Figure 1 illustrates the most common steps international students must take to become a permanent resident of the United States.

**Figure 1**

*Most Common Steps for International Students to Achieve Permanent Residency*



## Problem Statement

International students at U.S. higher education institutions often face significant adjustment challenges, including adapting to new social and cultural environments, academic expectations, and daily living conditions (Rivas et al., 2019; Mori, 2000). Common difficulties include language and communication barriers, limited knowledge of American culture, and challenges developing friendships and a sense of belonging on campus (Johnson & Sandhu, 2007; Bentley, 2008). In addition, many international students experience financial pressures, as they frequently pay substantially higher tuition rates than domestic students (Collier & Rosch, 2015). Challenges related to cultural adaptation, including differences in values, food, and climate, can further complicate their transition to life in the United States (Li & Gasser, 2005).

## Purpose of the Study

The purpose of this case study was to examine the expectations international college graduates held before enrolling in U.S. higher education institutions concerning their educational experiences, career prospects, and long-term residency plans, including their intentions to remain in the United States or return to their countries of origin.

## Literature

This section reviewed the literature on international students' pre-enrollment expectations of studying in the United States, focusing on their anticipated academic experiences, career prospects, and post-graduation plans, including whether they expected to remain in the U.S. or return to their home countries.

### International Students' Expectations about their Academic Experiences in the U.S.

International students' academic expectations are shaped by their prior educational experiences and preparation (Fletcher, 2013). Before arriving in the United States, many believe they are well prepared for academic success and understand U.S. classroom norms (Atebe, 2011; Fletcher, 2013; McLean & Ransom, 2005). Upon enrollment, however, many encounter challenges adapting to expectations related to English-language participation, collaborative learning, independent work, academic integrity, and critical thinking (Atebe, 2011; Fletcher, 2013; McLean & Ransom, 2005).

### International Students' Expectations about their Career Prospects

Before beginning their studies in the United States, many international students expect to secure internships and employment after graduation (Law, 2015). However, visa restrictions often limit access to work experience opportunities, creating challenges in competing for internships and jobs and making career expectations difficult to achieve (Law, 2015). Although many employers hire international students, others are reluctant to do so because of the complexities associated with

H-1B sponsorship and long-term work authorization beyond Optional Practical Training (OPT) (Mehrotra, 2014).

A survey of 1,087 international students studying at more than 125 U.S. institutions found that 23% chose to study in the United States primarily to pursue employment after graduation (Esaki-Smith, 2022). However, many expressed disappointments with the difficulty of securing internships and jobs, and 34% reported feeling unprepared to navigate the U.S. job market, citing limited knowledge of CPT, OPT, and work visa processes (Esaki-Smith, 2022). The study also found that students often relied on personal networks and self-directed efforts rather than university career services when exploring career opportunities (Esaki-Smith, 2022).

### International Students' Expectations about their Post-Graduate Plans

Research on international students' intentions to return to their home countries or remain in the United States after graduation remains limited (Alejandrini, 2013; Lu et al., 2009; Takeuchi, 2008), particularly for female students (Bamber, 2014; Jeyabalasingam, 2011; Kelly et al., 2018; Matsui, 1995; Qin & Lykes, 2006; Takeuchi, 2008) and male students (Lu et al., 2009). Existing studies suggest that post-graduation plans are shaped by cultural, familial, and social expectations, with these influences often differing by gender (Kelly et al., 2018).

Female international students are frequently influenced by family obligations, emotional connectedness, and parental expectations when deciding whether to return home (Bamber, 2014; Jeyabalasingam, 2011; Lu et al., 2009; Qin & Lykes, 2006; Takeuchi, 2008). Among Chinese women, family responsibilities, the legacy of the one-child policy, and expectations to bring prestige to the family often encourage a return home after graduation (Bamber, 2014; Jeyabalasingam, 2011; Kelly et al., 2018; Lu et al., 2009; Matsui, 1995; Qin & Lykes, 2006). In contrast, Japanese women tend to prioritize career opportunities and personal independence, making them more willing to remain abroad or relocate for professional advancement (Creamer, 2004; Heberle, 2009; Hines, 1994; Takeuchi, 2008). Similarly, some female students from Kazakhstan view returning home as an opportunity to contribute to their country's development (Holloway et al., 2012).

For male international students, the primary motivation for returning home is often family responsibility and caregiving obligations (King & Sondhi, 2016; Lu et al., 2009). Academic performance and parental educational attainment have also been identified as predictors of return intentions (Lu et al., 2009). In some cultural contexts, such as India, male students may experience a heightened sense of obligation to return home and support their families after completing their studies (King & Sondhi, 2016).

## Methodology, Data, and Sample

To understand the experiences of international college graduates on the pathway to permanent residency, this study employed a qualitative case study approach. Qualitative research is appropriate for exploring contextualized experiences and understanding what people know, think, and feel through interviews, observations, and document analysis (Merriam, 2009; Patton, 1990; Stake, 1995; Yin, 2018). In qualitative research, the researcher serves as the primary instrument for data collection and interpretation (Creswell, 2007).

Consistent with case study methodology, data were collected from three sources: semi-structured interviews, participant documents, and physical artifacts (Yin, 2018). Interviews

explored participants' perceptions and experiences, while documents included résumés and LinkedIn profiles when available. Participants also shared artifacts representing their journey from enrollment in a U.S. institution to obtaining employment-based permanent residency.

The study included 15 former international students who graduated from a U.S. higher education institution between 2000 and 2017 with at least a bachelor's degree and obtained permanent residency through employer sponsorship within five to ten years of graduation. Participants represented diverse countries, regions, languages, and academic disciplines, providing varied perspectives on the phenomenon under investigation. Table 1 summarizes participant demographics and educational backgrounds. Participants are listed in the order in which they were interviewed.

**Table 1**
*Participant Profiles*

| Number | Pseudonym | Gender | Country of Origin | Continent of Origin | Spoken Language | U.S. Degree(s), Major or Area of Concentration, and (Graduation Year) |
|---|---|---|---|---|---|---|
| 1 | Teddy | Male | France | Europe | English<br>French<br>Spanish | B.B.A., Accounting (2016)<br>MAcc (2017) |
| 2 | Jason | Male | Nigeria | Africa | English<br>Mandarin | B.A., Psychology (2011)<br>M.S., Counseling/College Student Development (2014)<br>M.B.A. (2020) |
| 3 | Miguel | Male | Spain | Europe | English<br>Spanish | M.B.A. (2005) |
| 4 | Keith | Male | Israel | Asia | English<br>Hebrew | B.B.A., International Business, concentration Marketing (2011) |
| 5 | Gabby | Female | Trinidad and Tobago | South America | English | B.S., Industrial Organizational Psychology (2006)<br>M.S., Human Resources Development (2008)<br>Ed.D., Organizational |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | Learning and Leadership (2024) |
| 6 | Maria | Female | Colombia | South America | English Spanish | M.B.A., General Management (2005) |
| 7 | Sierra | Female | Turkey | Europe Asia | English Spanish Turkish | M.A., Counselor Education in Career Counseling (2013) |
| 8 | Ferran | Male | Peru | South America | English Spanish Portuguese | B.S., Computer Information Systems (2000) B.S., Sociology (2000) M.S., e-Commerce (2004) M.B.A., Marketing (2008) |
| 9 | Karan | Male | India | Asia | English Hindi | B.S., Computer Science (2003) M.B.A. (2007) |
| 10 | Lima | Female | Peru | South America | English Spanish | M.S., Spanish Journalism (2002) |
| 11 | Ricardo | Male | Venezuela | South America | English Spanish | M.B.A. (2013) |
| 12 | Eduardo | Male | Spain | Europe | English Spanish | B.B.A., International Business (2001) |
| 13 | Fembu | Male | Bangladesh | Asia | English Spanish Portuguese Bengali Hindi | B.B.A., International Business (2004) M.B.A. (2010) |
| 14 | Kevin | Male | Spain | Europe | English Spanish | B.S., Business Administration, Marketing Management (2000) |
| 15 | Kumar | Male | Nepal | Asia | English Hindi | B.S., Management (2006) |

*Note*. The degree acronyms used include Bachelor of Arts (B.A.), Bachelor of Business Administration (B.B.A.), Bachelor of Science (B.S.), Master of Accounting (MAcc), Master of Arts (M.A.), Master of Business Administration (M.B.A.), Master of Communication, Master of Science (M.S.), Doctor of Education (Ed.D.). The major or area of concentration is included only if provided by the participant.

## Main Finding: Varied Expectations before Enrollment in U.S. Higher Education

Participants entered U.S. higher education with diverse expectations about their academic experiences, career opportunities, and post-graduation futures. Some arrived with clearly defined educational and professional goals, while others had few preconceived expectations. As participants progressed through their educational and professional journeys, many of these expectations evolved. Three themes emerged: expectations about studying in the United States, anticipated career paths, and post-graduation plans.

### Theme 1: Expectations about Attending College in the U.S.

The first theme, expectations about attending college in the U.S., has two sub-themes: (1) international college graduates came for a specific degree, and (2) international college graduates had no expectations.

#### *International College Graduates Came for a Specific Degree*

Nearly half of the participants (7 of 15) arrived in the United States with a specific degree in mind. Four participants, Miguel, Maria, Sierra, and Lima, pursued graduate degrees, while Gaby, Ferran, and Karan enrolled in undergraduate programs.

Miguel moved from Honduras to Miami to earn an M.B.A., which he viewed as a comprehensive and employer-valued credential that would serve as a "good stepping point" in his career. Similarly, Maria came to the United States after completing a bachelor's degree in microbiology in Colombia to pursue an M.B.A. in General Management, intending to combine scientific and business expertise.

An international upbringing shaped Ferran's educational path. Born in Peru and later living in Mozambique before relocating to Miami, he pursued a double major in sociology and computer information systems, allowing him to merge his interests in critical thinking, technology, and human interaction.

Overall, these participants viewed U.S. higher education as a pathway to a clearly defined academic goal and future career opportunities.

#### *International College Graduates had No Expectations*

Three participants, Ricardo, Teddy, and Jason, reported having few or no expectations before beginning their studies in the United States, although their reasons differed. Jason attributed his lack of expectations to his age, explaining, "I came fairly young at 16, so I really didn't know much." Because his family highly valued education, attending college was "sort of automatic," and he expected little beyond earning a degree.

The political and economic crisis in Venezuela shaped Ricardo's decision. He explained, "So, coming to the U.S. was more a way how to leave Venezuela and figure it out." When we asked about his expectations, he stated, "I did not have expectations at all. The main reason was to leave Venezuela and the political climate there."

Similarly, Teddy arrived from France as a scholarship student-athlete and had few expectations about college life in the U.S. due in part to language barriers. As he explained, "I had no expectations. I didn't speak English." His parents were equally uncertain about his future in the United States, telling him, "Teddy, you probably gonna come back home in six months."

**Theme 2: Expectations about Career**

Three sub-themes emerged regarding participants' career expectations: (1) career plans evolved, (2) career plans aligned with the participants' expectations, and (3) unknown career plans.

***Career Plans Evolved***

Seven participants' career plans evolved and were partially (Eduardo, Fembu, Kumar, and Kevin) or completely different (Teddy, Jason, and Maria) from their original expectations before coming to the U.S. to study.

**Partially Different Career Plans from Expectations.** Four participants (Eduardo, Fembu, Kumar, and Kevin) described career paths that generally aligned with their original expectations but evolved over time. Eduardo planned to build a career in banking and eventually return to Spain to join his family's businesses. Although he successfully established a banking career, he remained in the United States. Similarly, Fembu expected to return to Bangladesh after graduation, noting, "I was under the impression that as soon as I finish my degree, I'm going to go back to Bangladesh." Although he briefly returned home, he relocated back to the United States after three months and ultimately built a successful sales career in Florida.

**Career Plans Completely Different from Expectations.** Three participants (Teddy, Jason, and Maria) reported career outcomes that differed substantially from their original expectations. Teddy initially envisioned a career in law or real estate, explaining, "My father is a lawyer, and I either wanted to be a lawyer or real estate investor... I didn't expect to be an accountant." Instead, he earned a master's degree in accounting, became a Certified Public Accountant, and joined Deloitte.

Jason originally planned to return to Nigeria after earning a degree, noting, "The original expectation was that you go to get the degree, and then you can come back [to Nigeria] and use that to your advantage." After changing his major from pre-med to psychology, however, he chose to remain in the United States and pursue a career in higher education.

Similarly, Maria expected to build a career in management but ultimately combined her M.B.A. and microbiology background in the science industry. As she reflected, "I did not expect to get [a job] in my original degree. I am a microbiologist.

***Career Plans Aligned with their Expectations***

Five participants, Sierra, Ferran, Karan, Lima, and Ricardo, reported that their careers aligned closely with the plans they had before coming to the United States for college. Sierra

intentionally chose a degree that would support her long-term goal of working and remaining in the U.S.:

> I knew that if I got a specific degree as an international student, it would be much easier for me to gain employment versus like going for mental health, counseling and looking for a career counselor job, because I knew I wanted to stay.

Her goals of working in career counseling and staying in the United States were achieved.

Similarly, Ferran pursued an international marketing and sales career that combined his communication, technology, and cross-cultural strengths. Karan also followed his planned path in technology, sharing: "My plan was to do computer science and then maybe work if I can, and then do my master's degree."

### *Unknown Career Plans*

Three participants, Miguel, Keith, and Gabby, reported having little or no clear career plan before coming to the United States. As Miguel explained, "I didn't know exactly what I wanted to do." Despite that uncertainty, he earned an M.B.A. in finance and launched a successful career in auditing.

Similarly, Keith shared, "I didn't even know the profession that I'm doing now exists at the time." An internship led to a full-time role, opening opportunities that advanced his career across several states.

Gabby was certain she wanted to earn her degree but was unsure of her long-term career path. Reflecting on her transition, she explained:

> I think what really helped is that I went to a private Catholic high school in Trinidad, and University E was a private Catholic University. So, a lot of the things that were familiar to me with education, and Miami being so diverse.

Her smooth adjustment to life in Miami influenced her decision to remain in the United States, where she built a successful career in higher education.

## Theme 3: Post-Graduate Plans

The third theme, former international students' post-graduate plans to stay or leave the United States, included three subthemes: (1) participants who initially planned to return home but ultimately remained in the U.S.; (2) participants who intended to stay in the U.S. and did so; and (3) participants whose post-graduation plans were uncertain.

### *Expected to Return to their Home Countries, but their Plans Changed, and They Stayed in the U.S.*

Nine participants, Jason, Gabby, Karan, Eduardo, Fembu, Kumar, Maria, Kevin, and Lima, initially expected to return to their home countries after graduation but ultimately remained in the United States. Their decisions to stay were shaped by a variety of factors, including expanded

career opportunities, personal relationships, and other life circumstances that emerged during their time in the U.S.

**Discovering Better Career Opportunities in the U.S.** Six participants, Jason, Gabby, Karan, Eduardo, Fembu, and Kumar**,** initially planned to return to their home countries after graduation but chose to remain in the United States because they found stronger career opportunities and greater potential for professional growth.

Jason originally intended to return to Nigeria but reconsidered after changing his major: "But after switching to psychology, I realized that in Nigeria, especially at that time, using or marketing a psychology degree would be difficult." Jason shared how he changed his mind halfway through the process of switching his major.

Similarly, Gabby expected to follow her parents' path by earning a degree in the U.S. and returning to Trinidad:

> Both my parents have bachelors and master's from schools in the U.S., so I knew for sure that I was going to the U.S. for school, and I think because both my parents came back to Trinidad I thought for sure that's the path. You go [to the United States], and you get your degree, and then you come back home.

Instead, she chose to build her career in the United States.

Fembu and Kumar also altered their plans. Fembu briefly returned to Bangladesh before deciding to come back to the U.S.: "So, the plan was to go back to Bangladesh, which I did. Yeah. After I completed my undergrad, I went back [to Bangladesh], and then, I came back [to the United States]. Within three months, I returned." Likewise, Kumar originally intended to return to Nepal after gaining experience in the United States: "I think I wanted to go back to Nepal … That was my idea. That's the reason I came was to get my management training, get some experience and then go back to Nepal and serve my country." However, both ultimately remained in the United States and developed successful careers.

**Falling in Love.** Three participants, Maria, Kevin, and Lima**,** initially planned to return to their home countries after graduation but remained in the United States because they fell in love and built their lives there. Maria explained: "Before coming [to the United States], my purpose was only to study. So, I never thought about staying in the U.S. Yeah, going back and working in Colombia somewhere." Instead, she established a successful career in Miami and started a family.

Similarly, Kevin planned to complete his degree, gain work experience, and return to Spain. However, after meeting Lima, the couple married, raised two children, and remained in the United States more than 25 years later.

> Well, my expectation always was, I mean, to come back to Spain, you know, come back home … But at the end of the day, look at me right now, and more than 24–25 years here, and you know, Lima, I met my wife.

Although Kevin did not originally plan to stay in the United States, he is happy with the decision he ultimately made. Similarly, Lima expected to earn her bachelor's degree, gain experience, and return to Peru. She explained: "My first intention was to come here and stay for a period, just to get some experience. But for personal reasons, I stayed here because I got married."

Lima met Kevin and their plans changed. Currently, they are successful in their professional careers and content in their personal lives.

### *International College Graduates Expected to Stay in the U.S. and Stayed*

Four participants, Miguel, Sierra, Ferran, and Ricardo**,** planned to stay in the United States after graduation and successfully did so.

Miguel was certain of his intentions from the beginning, stating, "I always expected to stay in the U.S." Likewise, Sierra shared, "I knew I wanted to stay in the United States…With that degree, I can get a job," reflecting her belief that a specialized degree would help her secure employment.

Ferran also intended to remain in the United States, although he envisioned eventually relocating to Europe: "My expectations were to stay in the United States and work there until I was 40 years old, and then I was gonna move to Europe." He ultimately moved to Spain at age 40.

Similarly, Ricardo arrived in the United States with a clear professional goal: "Oh, by the time that I moved to the U.S., I had already been working with EY, with Ernst and Young, in Venezuela for five years." He successfully continued his career with EY in the United States.

### *International College Graduates' Post-Graduate Expectations were Uncertain*

Only two participants, Teddy and Keith, entered the United States with uncertain post-graduation plans. As student-athletes, their primary focus was pursuing their sports and succeeding academically. Teddy explained: "We didn't make any plan past the first year when I was back home, they were like, okay, let's try to make it the first six months, first year." His immediate priority became adapting to college, maintaining his scholarship, and overcoming language challenges.

Similarly, Keith arrived with an open mind and no definite plan to stay or return home: "I came to do what I like to do, which is playing football, soccer, at the time, study, and you know, make new friends. Get a global experience in another country."

For both participants, post-graduation expectations developed over time rather than being established before arrival.

## Conclusions

Two conclusions emerged from this finding. First, international college graduates began their studies in the United States with diverse expectations shaped by personal, cultural, and contextual factors. While some arrived with clear academic and career goals, others had limited expectations due to youth, lack of information, or external circumstances. Second, as they adapted to life in the U.S., their expectations often evolved. Many who initially planned to return home chose to stay because of greater career opportunities or personal relationships, demonstrating how their experiences reshaped their educational goals, career paths, and long-term life plans.

## Future Studies

This section presents recommendations for future research based on the study's findings. Key recommendations for future research are the following:

### Conduct a Quantitative Research Study

Conduct a quantitative study at U.S. universities with large international student populations, such as New York University, Arizona State University, Boston University, University of Illinois, and University of Southern California, to identify the factors that impact international college graduates' success stories in obtaining permanent residency.

### Expand the Scope of Research

Collect data from multiple institutions and regions across the United States to enrich the study. Furthermore, subsequent studies could be conducted to compare the success stories of international college graduates by degree (for example, comparing accounting to STEM fields) and by university type (for example, public versus private institutions). Other subgroups may include international students with English language proficiency versus those with English language deficiencies, as well as international students with family in the U.S. versus those without any family members in the country.

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## About the Author

A native of Madrid, Spain, Dr. Cristina C. López Vergara (clopezvergar2016@fau.edu) is a higher education administration professional with more than 20 years of experience in academia, non-profit, for-profit, and corporate sectors. Currently, she is Director of Experiential Learning & Internships at Florida Atlantic University (FAU) in Boca Raton, Florida. She holds a Master of Arts in Communication Arts, a Master of Business Administration, and a Graduate Certificate in Human Resource Management from St. Thomas University, as well as a Master of Arts in Higher Education Leadership and a Ph.D. in Higher Education Leadership from Florida Atlantic University. Dr. López Vergara is passionate about traveling and languages, and is fluent in English, Spanish, and French.

## Discussion Questions

1. Prior to beginning their studies in the United States, what expectations did international graduates have about attending college in the U.S.?

2. Prior to beginning their studies in the United States, what expectations did international graduates have about their career prospects upon completion of their degree?

3. Prior to beginning their studies in the United States, what expectations did international graduates have about their post-graduate plans (specifically whether they expected to stay in the U.S. or return to their home country after completing their degree)?

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# An Analysis of Gen Z First-year Students and Implications at a Research II Institution

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Abstract

This article examines the demographics, beliefs, and aspirations of Generation Z (Gen Z) first-year students at a Research II institution. Utilizing a survey of 166 students, the research explores how this digitally native cohort navigates academic, societal, and career environments. Results indicate significant mental health challenges, with 52.3% of participants reporting disorders, predominantly anxiety. Politically, the cohort leans progressive, heavily favoring left-of-center ideologies and overwhelmingly desiring younger elected leadership (95%). While Gen Z relies on social media, they view it as a double-edged sword prone to echo chambers and disinformation, ultimately placing a high value on in-person social connectivity. In future career planning, 57.2% prioritize corporate alignment with their core values over raw financial gain, emphasizing psychological fulfillment and work-life balance. These findings offer critical insights for higher education, corporations, and policymakers, who must adapt structural frameworks, support networks, and retention strategies to successfully address Gen Z's distinct expectations, digital vulnerabilities, and financial anxieties.

Keywords

Generation Z, higher education, research 2 institution, mental health, workplace expectations, disinformation, political progressivism

## Introduction

The purpose of this study is to examine the demographics, beliefs, and aspirations of Generation Z (individuals born between 1997 and 2013; Gen Z) first-year students at Research II institution. In the 20th and 21st centuries, sociologists, historians, educators, and others felt the need to categorize generations. This partially results from the need to be able to identify commonalities among different generational groups. These commonalities, or stereotypical generational characteristics, often focus on a generation's outlook on life, how they see themselves, their concerns or fears, and their hopes. Often researchers analyze generations by demographic information such as gender, race, ethnicity, and socio-economic status (Twenge, 2023).

As a predominantly traditional institution with a student population of 18–23 years old, most Research II institution students fall into the Generation Z category. By identifying the demographics, beliefs, and aspirations, the respective institution where the researchers conducted the study, its Carnegie Peer Institutions, corporations, government individuals, and Gen Z individuals can gain a perspective of who Gen Z individuals are and, thus, help meet their needs.

## Literature Review

The world-wide pandemic, COVID-19 affected Generation Z's developmental stages and emergence as a societal group. This global event caused all but essential services to shut down, minimizing Gen Z's exposure to society. For the first time, students were going to school virtually, thus being isolated from their peers. In-person interaction was extremely limited. This resulted in a significant increase of screen time for this generation. Gen Z individuals do not remember a time without social media or iPhones. They are the first group to grow up with almost instant access to the internet, and a smart phone as their first cell phone probably – not the Pre-K access of Gen Alpha, but incredibly early. They were too young to remember the switch from analog to digital. These children were 15 and younger when Google Drive took over and laptops stopped coming with built-in CD/DVD players (Dimock, 2019).

Researchers have found that it is much more difficult to put this generation into a demographic box because many Gen Z think of themselves in terms of individuals, more than categories. To state that all of Generation Z feels a certain way would be an overreach and would make studying Generation Z an impossible task. This study could end right here if that were the case (Katz, 2022). Generation Z individuals reject traditional labels of society, refusing to identify demographically as previous generations did, for example, in gender and sexual orientation. Generation Z also has reduced the stigma of mental health, possibly due to the outbreak of COVID during their formative years.

According to Liu-Lastres and Wen (2023), in corporate circles, a mass exodus of this generation has occurred in search of a better job. Gen Z individuals seek a job in which respect is a priority. They are looking for jobs above minimum wage pay, without a toxic work environment, and without additional work hours. However, the lack of research and supporting literature on this phenomenon has led many universities and corporations to ask what their current Generation Z students want, need, and expect. Many individuals are making decisions in a vacuum, based upon old anecdotal evidence of the Millennial generation.

According to Pocztowski, Buchelt, and Pauli (2015), this generation would like to achieve a spectacular professional career right after college graduation, without any effort. It is difficult for them to understand that an extended professional career occurs in incremental steps. This generation searches for a job all over the world, as their characteristic features are mobility and knowledge of foreign languages. Change in the workplace is a threat for older generations, but it is an object of fascination and experimentation for Generation Z individuals. They do not care about stability at work; they easily change their workplace, looking for versatility and to escape from routine. Some consider them to be the most educated and sophisticated generation ever. Young people consider self-employment as a professional activity, especially because they consider it as better paid and as having greater independence.

According to the Pew Research Center (2021), a characteristic of Generation Z individuals is desiring greater feedback than previous generations on work performance; 72% of the participants in this study indicated they wanted increased feedback from supervisors in the

workplace. It is clear that young people using the Internet, especially social media, have gotten used to "liking" different things, commenting on reality, evaluating what they buy and use, where they spend time, etc. They are comfortable expressing themselves publicly in a virtual world. Due to their social media habits, they give feedback, but they also expect feedback and perceive the communication process as bidirectional. Expectation of feedback is of great value to this generation. Thus, Gen Z individuals want and need feedback from faculty in the classroom as well.

Gen Z individuals can switch easily between the virtual and real world, as they perceive them as complementary to one another (Żarczyńska-Dobiesz & Chomątowska, 2014). The consequence is that Gen Z individuals can easily source the information they need. They also quickly share information with others. Communication is continuous and fluid among them, as they use a wide variety of communication devices and social medias. "The active social media users have many contacts, and they mainly live their everyday relations through these channels (personal meetings are also important to them; however, keeping the online contacts have an equally important role)" (Csobanka, 2016, p. 68). Gen Z individuals use different mobile devices, and they comment on reality, the environment, and the surroundings they live in; much of Gen Z's opinion and attitudes form by them watching videos on social media and reading their feeds, which are often echo chambers, which reinforce their beliefs. "Generation Z not only uses the Internet, but controls the content of it" (Król & Zdonek, 2021, p. 750). It is more difficult for Gen Z to multitask and memorize information long term due to their habitual use of social media and video games (Tari, 2011, after: Csobanka, 2016, p. 69).

According to McQuade (2025), one major threat for this generation is the daily barrage of disinformation and misinformation. In a world in which information is literally at one's fingertips, this generation is exposed to more information than any in history, with disinformation as stories or hoaxes created to deliberately misinform or deceive readers.

Gherguț-Babii and others (2025) note that perpetrators spread this disinformation to influence people's views, push a political agenda, or cause confusion. Disinformation is one of the biggest threats to democracy because there is so much disinformation that young citizens become discouraged and often do not participate in civic engagement. McQuade (2025) describes discernment of what is accurate and what is misinformation or disinformation as a constant struggle. Gherguț-Babii and others (2025) emphasizes that Gen Z individuals must have strong critical thinking skills to discern what is disinformation and misinformation, and what is fact. Without these critical thinking skills, disinformation campaigns often lead to Gen Z's apathy toward civic engagement because they have difficulty concerning what is or is not true. This leads to apathy with regard to, but not limited to, voting.

Substance abuse and digital addiction are also another major threat to Gen Z individuals due to the severe physical, cognitive, and emotional consequences of substance abuse. The ease of access to substance abuse and digital addiction, in many cases socially acceptable and algorithmic reinforcement, often leads to compulsive behavior, psychological dependency, and in some cases, significant relational and spiritual damage (Szasz, 2025). These addictions lead to many mental health issues among this generation.

According to Twenge (2023), Gen Z individuals are vocal about their mental health. It is also a negative indicator that many Gen Z individuals suffer from mental health issues, with more than 60% reporting significant mental health challenges, primarily consisting of anxiety and depression.

According to Hoffman (2024), Gen Z individuals have a genuine mistrust of government. This mistrust is rooted in three main areas: party identification, Congress, and the economy. Despite these mistrusts, they prefer a nationalist approach to governance, in which the country's leaders make governmental decisions with the primary purpose of pursuing what is best for The United States of America, rather than a globalist approach – decisions made in concert with other global leaders with emphasis on what is best for the world, not just the nation. Gen Z individuals prefer a nationalist approach by large margins (Twenge, 2023).

According to Nwoke (2025), despite Gen Z individuals being the most educated and digitally connected cohort in history, these young adults face unprecedented obstacles to wealth accumulation, retirement readiness, and financial independence. The widening generational wealth gap has emerged as a critical challenge in contemporary financial planning. Economic disruptions, housing unaffordability, student loan debt of this generation being more than 1.7 trillion, and shifting labor dynamics put Gen Z individuals at a structural disadvantage, compared to previous generations.

Nearly half of Gen Z individuals believe society should distribute rewards and benefits based on people's needs, rather than their productivity. Moreover, the poll showed that more of these young adults had a positive view of socialism (51 %) than capitalism (45 %). Approximately half of Gen Z individuals believe that the government should set wages for jobs; in addition, 50% believe that the government should provide a job to anyone who wants one; approximately 25% are neutral on the matters, and only 25% disagree (Whaples, 2025).

## Methods

The purpose of this study is to examine the demographics, beliefs, and aspirations of Generation Z first-year students at Appalachian State University, in North Carolina. The study gives a better understanding to educators, future employers, and other constituencies of Generation Z.

To accomplish the purpose of this study, the researcher asked first-year students the following questions in a survey:

**Research Question 1:** What is your gender?
**Research Question 2:** What is your age?
**Research Question 3:** How do you identify?

- Straight
- Bisexual
- Gay
- Pansexual
- Other.

**Research Question 4:** What race/ethnicity are you? (Mark all that apply.)

- Caucasian
- African-American
- Asian-American
- Hispanic
- Latino
- Native American
- Pacific Islander

- Other.

**Research Question 5:** What is your family household income?

- Under $27,000
- Under $50,000
- Under $75,000
- Under $100,000
- Under $200,000
- Over $250,000.

**Research Question 6:** Do you have mental health issues? (Yes or No) If so, please identify.

- Anxiety
- Depression
- PTSD
- Other (Please explain).

**Research Question 7:** Do you see a mental health professional? (Yes/No)

**Research Question 8:** Do you consider yourself to be politically

- Conservative
- Moderate
- Liberal
- Other (Please explain).

**Research Question 9:** What five political/social issues are most important to you? Please rank in order of 1-5, with 1 being the most important to you and 5 being the least important to you.

- Climate Change
- Gender Equity
- Racial Equity
- Democracy
- Military
- Immigration
- Strong Labor Unions
- Student Loan Debt
- Political Polarization of the U.S.
- Importance of Diversity
- Environmental Sustainability
- World Hunger
- Homelessness
- Crime/Safety
- Health Care
- LQBTQ+ Rights
- Gun Violence
- Other.

**Research Question 10:** Would you like to see younger elected leadership? (Yes/No)

**Research Question 11:** Do you consider yourself religious? (Yes/No/Somewhat)

**Research Question 12:** What are the three biggest challenges for your generation?

**Research Question 13:** What is important to you in a job/career?

**Research Question 14:** Are you more interested in pay or an employer's core beliefs/values?

- Pay
- Employer Core Values.

**Research Question 15:** Do you want more or less government control?

- More
- Same
- Less.

**Research Question 16:** What social media platforms do you use?

**Research Question 17:** Do you feel connected to your peers? Other generations? What forms these connections?

- Social media
- In-person
- Virtual
- etc.

**Research Question 18:** What is your major?

**Research Question 19:** How important is your physical health?

- Very
- Somewhat
- A little
- Not at all.

**Sample Population**

The sample for this study consisted of 166 first-year students enrolled in a First Year Seminar in the Spring Semester 2023, Fall Semester 2023, and Fall 2025. This study did not occur during the Fall of 2024 due to Hurricane Helene, which devastated much of the geographic region where the Research II institution resides. All students in this survey were at least 18 years old but did not exceed 25 years of age. The age limitation of 25 years was to ensure responses by Generation Z individuals only.

**Research Instrument**

The researcher created a custom research instrument for this study, incorporating the questions above. Some questions generated more responses than participants because individuals could select multiple answers for a single question. The University Institutional Review Board (IRB) reviewed and approved the survey.

The first eight open-ended and multiple-choice questions collect the participants' demographic information.

Questions 9 through 19 gauged students' opinions on the issues important to them.

The researcher gave the Generation Z participants instructions prior to completing the survey. The researcher explained the instructions that the IRB had approved the survey, the purpose of the study, and that participation in the study was voluntary. The researcher gave individuals the opportunity to ask questions before deciding whether to participate in the survey or not.

The researcher administered the survey in a quiet, secure, and safe environment. The researcher left the room during the survey, so participants did not feel any conscious or subconscious pressure to answer the survey accordingly. Identity of the participants remained anonymous throughout the data collection process.

The researcher assessed the mean scores of demographic variables, political, cultural, and self-reflection questions.

## Data Analysis

Different motivations, learning styles, characteristics, skill sets, and social concerns drive Gen Z Research II institution students, compared to the previous Millennial generation. For universities and colleges, it is imperative to learn to adapt their courses, programs, processes, environment, and initiatives to meet the needs of these students. Generation Z is the "We" generation, as opposed to the Millennial generation, who often is the "Me" generation (Seemiller & Grace, 2016). Parents raised Generation Z individuals in a digitally centric world; technology defines their identity. Although this generation has entered or will soon enter the workforce, employers and researchers still know little about them, their needs, attributes, or work styles. Without understanding Generation Z individuals, it will be difficult to hire and retain them for sustainable growth for the workforce (Singh & Dangmei, 2016).

The researcher divided the following data analysis into categories. Depending on the survey question, the researcher presents the results in both narrative and table form.

**Table 1**
*Gender of Participants*

| Gender of Participants | |
|---|---|
| Female | 50.6% |
| Male | 42.7% |
| Non-binary | 6.7% |

**Table 2**
*Race/Ethnicity of Participants*

| Race/Ethnicity of Participants | |
|---|---|
| Caucasian | 82.5% |
| African-American | 7.8% |
| Asian-American | 3.0% |
| Latino | 6.5% |
| Other | 0.2% |

**Table 3**
*Sexuality of Participants*

| Sexuality of Participants | |
|---|---|
| Straight | 78.3% |
| Bisexual | 9.6% |
| Gay | 9.7% |
| Pansexual | 2.4% |

**Familial Income**

The financial background of the surveyed students reflects a polarized trend, though it skews heavily toward wealthier households. A combined majority of the students come from homes with incomes of $100,000 or more. Specifically, 26.1% come from families making above $250,000, and 6.0% come from families in the $200,000 to $249,999 range—meaning more than 31% of the 166 students come from households making at least $200,000. Conversely, a substantial 37.6% segment of the student population comes from homes with a familial income of less than $100,000.

**Table 4**
*Family Income of Participants*

| Family Income of Participants | |
|---|---|
| Above $250,000 | 26.1% |
| $249,999 - $200,000 | 6.0% |
| $199,999 - $100,000 | 30.7% |
| $99,999 - $75000 | 13.2% |
| $74,999 - $50,000 | 11.4% |
| $49,999 - $27,000 | 8.4% |
| Under $27,000 | 4.2% |

**Mental Health**

Mental health emerged as a critical focal point of the study, with a majority (52.3%) of the Appalachian State University Gen Z students reporting that they have mental health disorders. When asked to identify their specific struggles, anxiety was the most prevalent issue at 47.6%, followed by eating disorders at 31.8%, depression at 29.9%, and PTSD at 5.2%. Interestingly, while 77.3% of those experiencing issues do see a mental health professional, a notable 25% of the overall survey respondents do not seek professional help, despite the university offering these services entirely free of charge.

**Table 5**
*Mental Health of Participants*

| Mental Health of Participants | |
|---|---|
| Yes | 52.3% |
| No | 47.7% |
| Do you see a Mental Health Professional? Yes: | 77.3% |
| **Top Mental Health Issues of Participants** | |
| Anxiety | 47.6% |
| Eating Disorders | 31.8% |
| Depression | 29.9% |
| PTSD | 5.2% |

**Political Ideology and Social Issues**

Politically, the surveyed cohort heavily favors left-of-center ideologies. Liberals make up the largest group at 37.2%, with Moderates following closely as a strong second at 33.5%. Only 18.9% of the participants identify as Conservative, while 10.4% chose "Other," indicating that traditional political labels do not accurately describe them.

This progressive lean aligns with an expressed interest in democratic socialism and a welfare state, largely fueled by student fears regarding the cost of healthcare, heavy college loan debt, and the belief by some that "the American Dream is dead." When the researcher asked them to rank their top five political and social concerns, students prioritized the concerns in the following order:

1. Racial Equity
2. Climate Change
3. Democracy
4. Gender Equity
5. Gun Violence.

Additionally, an overwhelming 95% of participants stated they want to see younger elected leadership. When it comes to the size of government, opinion is perfectly split: 43.5% want the government to remain the same size, 43.5% want less government, and only 13.0% desire more government control.

**Table 6**
*Politics of Participants*

| Politics of Participants (open-ended) | |
|---|---|
| Moderates | 33.5% |
| Liberals | 37.2% |
| Conservatives | 18.9% |
| Other | 10.4% |

**Table 7**
*Leadership Opinions of Participants*

| Leadership Opinions of Participants | |
|---|---|
| Would you like to see younger elected leadership? Yes: | 95% |
| Do you want to see more/less government? | |
| Same | 43.5% |
| Less | 43.5% |
| More | 13.0% |

**Generational Challenges: The Top Three Threats**

When students were asked to identify the three biggest challenges facing Generation Z, their open-ended responses highlighted the following systemic issues:

1. Mental Health: Citing a "mental health epidemic," students frequently noted severe struggles with anxiety, depression, and isolation, alongside a frustrating lack of open discussion or proper help.
2. Social Media and Technology: A significant majority pointed to digital culture as a primary root of their issues. They identified phone addiction (which shrinks attention spans), self-image issues, and digital "echo chambers" that replace genuine socialization and weaken critical soft skills. They also expressed feelings that a constant stream of online disinformation barraged as well as the rising influence of AI.
3. Financial and Economic Stability: Students voiced immense anxiety regarding inflation, the general cost of living, and skyrocketing student loan debt. This manifests as a deep-seated fear of never being able to afford a home, buy property, find a stable career, or secure a livable wage after college.

**Workplace Expectations and Values**

- When looking toward their future careers, Gen Z individuals value corporate ethics and personal fulfillment over raw financial gain. A majority of 57.2% stated that working for a company that aligns with their core values is more important than money.
- The narrative responses heavily emphasized psychological and emotional fulfillment, with students frequently citing terms like "happiness," "satisfaction," "passion," and "doing what I love." Furthermore, achieving a healthy work-life balance through scheduling flexibility and having a "life outside work" emerged as a vital theme.

**Table 8**
*Workplace Importance of Participants*

| Workplace Importance of Participants | |
|---|---|
| Companies' values important | 57.2% |
| Money important | 41.8% |

**Table 9**
*Physical Health Importance of Participants*

| Physical Health Importance of Participants | |
|---|---|
| Very | 68.6% |
| Somewhat | 30.3% |
| A Little | 0.7% |
| Not at All | 0% |

**Social Connectivity and Relationships**

Despite being a digitally native generation, Gen Z individuals highly value physical presence. The consensus among respondents is that they can achieve "real" connection through in-person interactions, pointing to environments like school, work, church, and sports as the places where they can make meaningful relationships.

Some view social media as a "double-edged sword." While students view it as a functional tool to maintain long-distance friendships and track cultural trends, they acknowledge that it simultaneously causes them to feel isolated, creates a generational divide, and has left some peers "socially inept" and struggling to converse in person.

In terms of bridging the generational gap, feelings vary. Many feel fundamentally disconnected from older generations due to elders' lack of social media usage or their fixed, polarized beliefs. However, when people make connections, they build them on shared tastes in music, personal style, or core beliefs they discover through dialogue. Strikingly, Gen Z individuals note that their largest feeling of disconnection is actually with Millennials; they find it much easier to connect with Gen X and Baby Boomers.

## Future Implications

Based on the provided study, the future implications involve three major sectors: higher education, corporations, and government leadership.

**1. Higher Education**

- **Adapting Courses and Initiatives:** Colleges and universities will need to adapt their courses, programs, environments, and initiatives to fit the specific motivations, learning styles, and skills sets of Generation Z.
- **Increasing In-Person Engagement:** Because peer-to-faculty and peer-to-peer interactions are crucial to reducing feelings of disconnectivity, higher education institutions must focus on fostering strong in-person relationships.
- **Expanding Support Services:** Universities should leverage these insights to better advertise and offer enhanced student services, particularly in mental health counseling.

**2. Corporations and Future Employers**

- **Shifting Recruitment and Retention Strategies:** To successfully hire and retain Gen Z individuals for sustainable growth, companies must understand their specific workplace needs. Recruiters should place a heavy emphasis on core corporate values, such as a focus on diversity, equity, and driving positive social change.
- **Enhancing Workplace Culture:** Employers will need to actively address employee satisfaction by offering more flexible work schedules and emphasizing community engagement.
- **Providing Comprehensive Benefits:** Companies need to proactively provide services that address mental health challenges and consider implementing competitive incentives, such as paying off student loan debt as a reward for long-term employee loyalty.

**3. Government and Policy Leaders**

- **Addressing Top Generational Fears:** Policymakers must open an active dialogue and formulate strategies to address Gen Z individuals' primary anxieties: the mental health crisis, systemic disinformation, and financial instability.
- **Expanding Mental Health and Education Infrastructure:** Government leaders will need to increase mental health services across society. Additionally, due to growing alignments with democratic socialism, there will be increasing pressure to provide programs like universal healthcare, free college, free childcare, and paid maternity/paternity leave to address financial barriers.
- **Implementing Disinformation Literacy:** To protect civic engagement and combat democratic apathy, educational or civic frameworks must teach disinformation literacy to help Gen Z individuals build stronger critical thinking skills.
- **Evolving Political Representation:** With the vast majority of Gen Z voters identifying as liberal or moderate—and showing little alignment with conservatism—future political systems likely will need to adjust to a strong demand for younger elected leadership and progressive social reform.

**4. Areas for Further Research**

- **Sociopolitical Problem Solving:** The present study explicitly notes that researchers must conduct further investigations to deeply explore the roots and potential remedies for the political and social issues most critical to this generation, including racial equity, climate change, democracy, gender equity, gun violence, and extreme political polarization.

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In his free time, he loves to travel with his wife, Dr. Rebecca Coats; he also, loves to read, and hike with their dog in the High Country. ORCID 0009-0006-7784-9952.

## Discussion Questions

1. Given that 57.2% of Gen Z students prioritize corporate core values over raw financial gain, how should modern corporations shift their recruitment, workplace culture, and community engagement strategies to attract and retain this generation?

2. With 52.3% of respondents reporting mental health disorders—yet 25% failing to seek professional help despite free university services, what specific institutional barriers prevent Gen Z from utilizing campus mental health care, and how can higher education overcome them?

3. The study highlights a tension between Gen Z's desire for less government control (43.5%) and their strong preference for progressive policies normally associated with a welfare state (e.g., universal healthcare, free college tuition). How can political and policy leaders reconcile these seemingly contradictory ideological perspectives?

4. How does the constant threat of online disinformation shape Gen Z's approach to civic engagement, and what frameworks can educational institutions implement to bolster critical thinking without inducing political apathy?

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"Home Grown and Store Bought"

Acrylic on Canvas
12" x 12"
2026

Original Painting by Caramia S. Frallicciardi
Series: Titi's Garden

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# The Naming Problem: How Category Vocabulary Shapes Career Perception (Evidence from Agriculture)

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Abstract

Agriculture faces a persistent naming problem: the word itself may activate a narrow, farm-centered mental picture that excludes the professional, technical, and business careers the industry increasingly needs to fill. This study tests that thesis using survey data from 578 respondents across three groups spanning the career-development lifespan: high school students, college students, and a combined adult group. Fewer than 1 in 10 respondents spontaneously associated the word "agriculture" with professional or technical vocabulary. Moreover, 42% did not recognize that a list of professional careers could exist within agriculture, even after seeing that list. These patterns held uniformly across group, rural/urban background, and gender. Respondents perceived an F5 acronym (Food, Fuel, Fiber, Finance, Fabrication), which follows the STEM model, as moderately-to-highly effective. Average ratings did not differ significantly across groups ($p$ = .481), but the distribution of ratings did ($p$ = .002): adult respondents were markedly more polarized than younger respondents. Open-ended responses further revealed that career identity, not industry identity, was the most common spontaneous messaging theme. Thus, agriculture's naming problem appears structural and industry-wide, while its messaging solutions require audience-specific calibration.

Keywords

employer branding, career perception, category naming, message framing, agricultural careers

## Introduction

Agriculture has a naming problem, one that sits upstream of both marketing and education. This distinction matters because how the diagnosis shapes where the industry directs its resources. If the issue were simply a lack of information, the appropriate response would be curriculum development: more classroom exposure, more career fairs, more counselor training. If the issue instead lies in the industry's public vocabulary itself, then no amount of downstream messaging or curriculum can fully succeed until the industry addresses the label doing the framing. This article argues, and tests empirically, that the latter diagnosis better fits the available evidence, and that the industry's own category label, "agriculture," may be quietly working against the very recruitment goals its marketing and educational efforts aim to serve.

The industry's occupational reality no longer matches its public vocabulary. Modern agricultural and food-system careers span data science, biotechnology, supply chain finance, mechanical and software engineering, marketing, and international trade, alongside the production-agriculture roles the term "agriculture" has traditionally evoked. Yet if the word itself creates a narrow, farm-centered mental picture before anyone explains the broader range of work, employer branding, recruitment marketing, and career-awareness campaigns have an uphill battle against the label itself. That remains true, even when their content is accurate and their design is strong. Category labels are not neutral containers for information. A substantial body of consumer and cognitive research shows that the first label a person hears shapes their subsequent expectations, evaluations, and judgments of fit (Moreau et al., 2001). If "agriculture" functions this way, the industry's talent pipeline challenge begins before anyone reads a single job description.

At its root, this is a branding and market-positioning problem. It calls for the tools other industries use to solve exactly this kind of problem: audience research, message testing, and segmentation-aware communication strategy. This does not mean education is irrelevant. As the evidence below suggests, the most effective interventions often work by translating a broad reframe into concrete, specific career awareness, which blurs the line between marketing and education in productive ways. Employer branding research shows that job seekers evaluate the clarity, credibility, and consistency of the signals available to them well before any direct interaction with an employer or sector occurs (Wilden et al., 2010). When a narrow or outdated label anchors those signals, even strong opportunities may fail to register with the audience most capable of filling them.

The present study offers a direct empirical test of this thesis using survey data from 578 respondents spanning the developmental range of career decision-making. The sample includes high school students ($n$ = 83), four-year college students ($n$ = 283), and a combined group of working adults, community college students, and graduate students ($n$ = 212). Three questions anchor the analysis. First, what vocabulary do respondents spontaneously associate with the word "agriculture," and does that vocabulary skew toward traditional farm production or toward the industry's actual professional and technical breadth? Second, can a reframing device that follows the STEM acronym's model and centers on the categories Food, Fuel, Fiber, Finance, and Fabrication (F5) shift perceived career relevance? Does its effectiveness hold uniformly across audiences? Third, what messaging themes do respondents generate unprompted when the survey asks how the industry might better communicate its career opportunities, and how do those spontaneous themes align with, or diverge from, the vocabulary the F5 framework supplies?

Addressing these questions contributes to a growing, cross-disciplinary literature on how language and category naming shape perceptions of industries and careers. The author draws together evidence from marketing and employer branding (Wilden et al., 2010), cognitive and consumer psychology (Moreau et al., 2001), career development (Stoeger et al., 2025), and agricultural education (Manning et al., 2024). Because this problem sits at the intersection of communication, marketing, and workforce development, the author frames the discussion in terms accessible to marketers, communicators, and industry stakeholders outside agricultural education. The author's goal is to offer findings that are both empirically grounded and immediately actionable across disciplinary lines.

## Literature Review

### Language as a Framing Device

Words do more than transmit information. The specific vocabulary people use to describe a concept can shape how people think about it, feel toward it, and ultimately act on it. Flusberg and others (2024) provide a comprehensive account of this dynamic, arguing that framing effects operate across domains as varied as politics, health, and business, and that these effects follow predictable cognitive and social-pragmatic mechanisms rather than random noise. Career guidance research echoes this point directly. Sultana (2022) argues that terms career counselors use, such as "employability" or "activation," are never neutral descriptions; they carry embedded assumptions about responsibility and disadvantage that shape how both counselors and job seekers understand the problem they are solving. Thus, the vocabulary surrounding a career field is not incidental to how people perceive that field. It is part of the perception itself.

### Naming, Branding, and Sector-Level Attraction

The business and marketing literature offers a more targeted lens. Wilden and others (2010) apply signaling theory to employer branding, showing that job seekers evaluate potential employers based on the clarity, credibility, and consistency of brand signals available to them. An unclear or outdated signal does real work in discouraging otherwise qualified candidates before either party exchanges any substantive information about the job.

This dynamic plays out at the sector level as well as the company level. Jakobsen and Homberg (2024) ran an experimental recruitment study comparing public-sector and private-sector job ads and found that job seekers expressed less interest in continuing with a public-sector ad, largely due to stereotype-driven assumptions about that sector broadly. Critically, this penalty shrank substantially once the ad named a specific profession. The finding maps closely onto the present study's core thesis: broad, unspecified sector labels invite narrow assumptions, while naming concrete roles counteracts that narrowing.

Consumer researchers have studied this pattern for a long time. Moreau and others (2001) demonstrated that the first category label a person hears shapes their subsequent expectations, evaluations, and preferences, even when that label is only one of several plausible ways to categorize the same object. Applied to career perception, this suggests that the word "agriculture" itself may function as a category label that pre-loads a narrow way of thinking (farming, crops, livestock) before anyone presents any information about the field's professional or technical breadth.

## Agriculture as a Documented Case of the Naming Problem

Agriculture offers a well-documented, if underutilized, case study of a similar dynamic. Manning and others (2024) surveyed primary and secondary students and found that agriculture is overwhelmingly associated with traditional farming and animal production rather than the modern, technical, and business-oriented careers the sector increasingly requires. This finding independently reiterates the present study's own word-association data (roughly 89% farm-only vocabulary, 7% professional or technical vocabulary; the Results section reports the full figures) using a separate sample and separate methodology, lending convergent support to the claim that this is a durable, real pattern rather than an artifact of a single survey instrument.

The prestige this old image carries makes the problem worse. Two other studies found that young people frequently perceive agricultural work as physically demanding, low-status, and low in opportunities for self-realization, regardless of the sector's occupational diversity (Girdžiūtė et al., 2022; Consentino et al., 2023). A narrow perception is not a neutral misunderstanding. It actively discourages talented candidates who might otherwise consider the field.

Educator-facing research points toward a solution, and it is not the one the industry has generally pursued. McDonald and others (2025) surveyed secondary educators and found that the strongest predictor of successfully steering students toward agricultural careers was not exposure to modernized branding or slogans, but rather educators' own awareness of the sector's diverse job roles and their confidence in connecting those roles to individual students' existing interests. Being specific does the real work of changing how people see it.

## Precedent for Testing a Reframing Device

This article's empirical approach, testing whether a deliberate reframing scheme changes perception and stated interest, draws on precedent from within agriculture and beyond. Hershberger and others (2024) conducted a field experiment promoting small-scale maple syrup production on social media, testing multiple message frames (community, self-sufficiency, lifestyle, nature) against a Wisconsin audience. Effectiveness varied by age group, with older adults responding most strongly to a self-sufficiency frame while other groups favored different framings entirely. This is, to the author's knowledge, one of few published examples of a message-framing intervention within agriculture itself demonstrating the kind of age-based divergence in effectiveness that the present study's F5 results reveal.

The sales profession offers a familiar illustration of the same dynamic: the "used car salesman" stereotype is cultural shorthand for the same occupational stigma documented here, and it is more than folk wisdom. Assigning alternative job titles measurably raised how the public perceived sales occupations (Adkins & Swan, 1980), and shifting terminology from performance-focused to customer-need-focused language increased candidate interest in otherwise identical sales roles (Kim & Talbott, 2018).

The most instructive precedent for the F5 approach is the STEM acronym itself, which NSF director Judith Ramaley coined in 2001 when she reordered the agency's existing SMET label into the more pronounceable STEM (Sanders, 2009). The underlying disciplines did not change; only the label did. STEM has since grown from an internal shorthand into a self-concept ("a STEM person"), a curriculum, and a global recruitment engine, demonstrating this study's central premise: A single, well-chosen label can reshape how people perceive a domain and who enters it. F5 attempts precisely this move for agriculture and food.

Recent research confirms that the STEM label does measurable perceptual work rather than merely describing pre-existing categories. Stoeger and others (2025) investigated whether students were familiar with the STEM acronym, which subject areas they associated with it, and whether those associations predicted actual academic choices. They found that students were broadly familiar with the term (72%), that the specific subject areas they associated with it shaped real elective decisions, and that value beliefs mediated these effects, which varied by gender (Stoeger et al., 2025). This provides a close, recent precedent for the present study's test of F5: both ask whether a reframing acronym changes perception and choice, and both find that the answer is yes, but unevenly across the audience.

Agriculture is not alone in facing this kind of naming challenge. Several other industries have adopted umbrella labels for the same reason. Industry and trade commentary widely observes these parallels, but controlled studies have not established them, and the author offers them here as illustrative precedent. Pharmaceutical, biotechnology, and medical-device sectors now present themselves collectively as "life sciences"; the industry rebrands "factory work" as "advanced manufacturing" and the "skilled trades"; and agriculture now markets its own "mechanic" work as "mechatronics," reflecting equipment that integrates hydraulics, sensors, and computer control well beyond traditional repair. These interventions share a common feature with STEM, "food systems" (Brock, 2023; von Braun et al., 2021), and F5 itself: they bring multiple fields together under one label. Figure 1 shows this pattern, which is also central to this study's findings.

### Synthesis

Taken together, this literature supports a specific, testable position: naming and branding carry real, measurable weight in shaping how people perceive an industry's career opportunities, particularly at the earliest stages of attention and interest formation. Agriculture presents an unusually clear case, since a single word continues to activate a narrow, farm-centered representation even as the sector's occupational profile has diversified well beyond it. The precedent STEM set, and by parallel reframing efforts elsewhere, supports treating F5 as a reasonable, evidence-aligned intervention to test.

## Methods

### Participants and Procedure

The author collected data through an anonymous Qualtrics survey, primarily at the Minnesota State Fair Research Booth, and supplemented those responses with additional outreach channels, including business students at a Midwest university. The author segmented respondents into three groups based on self-reported status: high school students ($n$ = 83), four-year college students ($n$ = 283), and a combined group of working adults, community college students, and graduate students, hereafter the "Other" group ($n$ = 212). Of 643 total survey starts, 638 respondents provided informed consent to participate. Sixty of these provided no answer to any subsequent item, so the author excluded them from all analyses, yielding an analytic sample of 578.

This segmentation reflects the survey's original design intent rather than a post hoc analytic choice, and it allows for comparison across a developmental range spanning early career exploration (HS) through active career decision-making (College) to established or transitioning careers (Other).

## Measures

*Word association with "agriculture."* The author asked respondents an open-ended question: "When you hear/see the word 'agriculture,' what do you think? List 2–4 words or concepts that come to mind." The author coded responses ($n$ = 573 with usable text) into three mutually exclusive categories using a keyword-based classification scheme. The categories were farm-only vocabulary (e.g., farming, crops, livestock, dairy, tractor), professional/business/technical vocabulary (e.g., business, marketing, technology, engineering, science, career, industry), and other/ambiguous responses that did not clearly fit either category. The author classified responses containing any professional/technical term as professional/business/tech, regardless of co-occurring farm terminology. This reflects the author's interest in whether respondents reach for professional vocabulary at all, not whether farm vocabulary is also present.

*F5 acronym effectiveness*. Respondents rated the effectiveness of "F5" (Food, Fuel, Fiber, Finance, Fabrication) as a reframing device for agricultural careers that follow the STEM acronym's model, using a five-point scale ranging from Not effective at all to Extremely effective ($n$ = 575 with valid responses).

*Post-exposure awareness.* The survey first presented respondents with a list of career fields (e.g., engineering, finance, marketing, data analytics, communications) and asked which interested them. Immediately afterward, it asked a single yes/no item: "Did you realize ALL those careers can be in agriculture?" ($n$ = 577 with valid responses). Because this item followed the concrete career list, it provides a direct behavioral measure of the naming problem. It captures whether the connection between those professional roles and agriculture registered even when the survey placed the roles directly in front of the respondent.

*Open-ended messaging ideas.* The author asked respondents, "What ideas/words might you have that could positively show and encourage career exploration in agriculture and food?" The author coded the responses ($n$ = 405 with usable text) for four themes that prior analysis identified. These were career identity (mentions of specific careers, career diversity, or career exploration), innovation (mentions of technology, science, or research), salary/job security (mentions of pay, financial stability, or job security), and sustainability/values (mentions of environmental impact, feeding the world, or making a difference). The author coded themes as present or absent per response using a keyword-matching approach; themes are not mutually exclusive, as a single response could reference multiple categories.

## Coding Validation

Because both the word-association and open-ended theme coding relied on automated keyword matching rather than manual qualitative coding, the author validated the scheme against manual coding of a random subsample ($n$ = 60 for word association, $n$ = 40 for open-ended themes), refining the keyword lists to correct initial coverage gaps. Agreement between manual and automated coding was substantial to excellent across all categories: $\kappa$ = .844 for word

association, and κ = .838, 1.000, .787, and .867 for the career identity, innovation, salary/security, and sustainability/values themes, respectively (Landis & Koch, 1977). All results below reflect the corrected coding scheme.

### Analytic Approach

The author reviewed all usable responses for each item. Because the open-ended and rating questions came later in the survey and were optional, the number of usable responses differed by measure, as the Measures section shows. The author based percentages on the number of valid responses for each item, not the full sample of 578.

For each measure, the author calculated percentages and means by group (HS, College, Other) to see whether the patterns looked similar across the sample. The author then used chi-square tests to check whether the response categories, awareness, and F5 ratings differed by group, reporting Cramér's V to show how strong any differences were. Because F5 ratings were ordinal, the author also used a Kruskal-Wallis test to see whether the groups differed in their typical ratings. Because ratings can differ in spread as well as in level, the author additionally applied a Brown-Forsythe test to compare how divided the groups were; this version handles ordinal, non-normal data better than the mean-based original. Furthermore, the author looked at rural versus urban upbringing and respondent gender as possible influences, and ran all analyses in Python.

## Results

### The Naming Problem: Word Association with "Agriculture"

Consistent with the study's central hypothesis, respondents overwhelmingly reached for farm-centered vocabulary when asked to describe the word "agriculture," and this pattern held across all three groups (Table 1).

**Table 1**
*Word Association with "Agriculture" by Group*

| Group | n | Farm-only | Professional/Business/Tech | Other/Ambiguous |
|---|---|---|---|---|
| High School | 81 | 91.4% | 4.9% | 3.7% |
| College | 282 | 91.1% | 6.0% | 2.8% |
| Other (adult) | 210 | 86.2% | 9.0% | 4.8% |
| Overall | 573 | 89.4% | 7.0% | 3.7% |

Fewer than 1 in 10 respondents reached for professional, business, or technical vocabulary when prompted with the word "agriculture," despite the industry's actual occupational breadth. This coding rule was deliberately generous toward the professional category: the author classified any response containing even a single professional or technical term as professional, regardless of how much farm vocabulary accompanied it. The 7% figure is therefore an upper bound; the proportion of respondents whose associations were purely professional is lower still. A chi-square test of independence confirmed this pattern did not differ significantly by group, $\chi^2(4, N = 573) = 3.72$, $p = .445$, Cramer's $V = .057$, indicating that the term "agriculture" evokes the same narrow,

farm-centered representation across high school, college, and adult respondents alike, rather than at any single developmental stage.

A parallel pattern emerged for the word "food." Among word-association responses that mentioned "food," 91% paired it with production or consumption imagery (farming, crops, animals, eating), rather than professional or technical vocabulary. Thus, "food" activates a similarly narrow pattern, a point the Discussion develops further.

**The Naming Problem in Action: Post-Exposure Awareness**

The word-association data show what comes to mind when respondents encounter the term "agriculture" in the abstract. A subsequent survey item tested whether this narrow frame persisted even after respondents saw the industry's actual career breadth directly. After viewing a concrete list of career fields, including engineering, finance, marketing, data analytics, and communications, and indicating which interested them, the survey asked respondents whether they had realized that all of those careers can exist within agriculture. Notably, 41.9% (242 of 577) answered "No."

This finding is arguably a more direct demonstration of the naming problem than the word-association data alone. More than four in ten respondents did not connect these professional roles to agriculture, even when the survey placed the roles in front of them, indicating that the narrow frame the term activates is robust enough to survive direct exposure to contradicting information. As with word association, this pattern held across groups, with no significant difference between high school, college, and adult respondents, $\chi^2(2, N = 577) = 1.03$, $p = .597$, Cramer's $V = .042$, reinforcing that the naming problem is structural and industry-wide, rather than a feature of any single audience.

**The Reframing Device: F5 Acronym Perceived Effectiveness**

Respondents rated the F5 acronym (Food, Fuel, Fiber, Finance, Fabrication) as a moderately-to-highly effective reframing device overall ($M = 3.44$ on a 5-point scale; 50.4% rated it "Very" or "Extremely" effective). This item captured perceptions of the acronym's likely effectiveness, not a measured behavioral response, and works best as an indicator of receptiveness to the reframe (see Limitations). The distribution of ratings differed across groups in an informative way (Table 2).

**Table 2**
*F5 Acronym Effectiveness by Group*

| Group | n | Mean (1–5) | Top-2-Box (Very + Extremely Effective) |
|---|---|---|---|
| High School | 83 | 3.53 | 55.4% |
| College | 282 | 3.41 | 47.3% |
| Other (adult) | 210 | 3.45 | 52.4% |
| Overall | 575 | 3.44 | 50.4% |

Two tests clarify the nature of the group difference. A Kruskal-Wallis test, which respects the ordinal structure of the rating scale, found no significant difference in the central tendency of F5 ratings across groups, $H(2) = 1.46$, $p = .481$. In other words, the three groups did not differ in

how effective they rated F5 on average; all three means clustered tightly between 3.41 and 3.53. The groups did, however, differ in how divided they were. A Brown-Forsythe test, which suits ordinal, non-normal data, confirmed that the groups differed significantly in the spread of their F5 ratings, $F(2, 572) = 3.52$, $p = .030$. This shows up clearly in the raw numbers: 29.0% of Other/adult respondents gave an extreme rating (Not effective at all or Extremely effective), compared with 18.1% of high school and 16.0% of college respondents, $\chi^2(2, N = 575) = 12.93$, $p = .002$.

Read together, these results indicate that the groups differed not in average effectiveness but in the degree of consensus around it. The Other/adult group showed the most polarized response pattern, recording both the highest proportion of "Extremely effective" ratings and the highest proportion of "Not effective at all" ratings of the three groups. This suggests that adult respondents, who bring more accumulated real-world context to the acronym, may evaluate it more critically and divide into distinct camps of believers and skeptics, whereas younger respondents receive the reframing device more uniformly.

**Student-Generated Messaging Themes**

Analysis of open-ended responses regarding ideas for encouraging career exploration in agriculture and food ($n = 405$) revealed four recurring themes, which the author coded for presence, rather than mutual exclusivity (Table 3).

**Table 3**
*Prevalence of Messaging Themes by Group*

| Theme | HS (n=68) | College (n=192) | Other (n=145) | Overall (n=405) |
|---|---|---|---|---|
| Career identity | 17.6% | 31.2% | 29.7% | 28.4% |
| Sustainability/values | 8.8% | 10.9% | 15.2% | 12.1% |
| Innovation | 1.5% | 8.9% | 4.8% | 6.2% |
| Salary/job security | 1.5% | 4.7% | 4.8% | 4.2% |

Career identity, leading with the specific job or career rather than the industry label, was the most common spontaneous theme, and its prevalence scaled sharply with respondent age and career stage: less than a fifth of high schoolers referenced it, compared to roughly three in ten College and Other respondents. Sustainability and values-based language followed a different pattern, peaking among the Other/adult group rather than younger respondents. Innovation and salary/security were comparatively rare as spontaneous themes overall, each appearing in fewer than 10% of open-ended responses. This is notable given that just over half the sample rated F5, an acronym that explicitly centers finance and technical framing, as moderately-to-highly effective. The Discussion addresses this gap further.

More than half of open-ended responses (56.5%) did not clearly map onto any of the four themes, largely reflecting brief non-substantive answers (e.g., "idk") or statements too general to categorize (e.g., "Agriculture is essential").

### Robustness: Rural/Urban Background and Gender

Because the naming problem could plausibly reflect nothing more than differing levels of prior exposure to agriculture, the author examined two obvious alternative explanations. One might expect respondents who grew up in rural communities to hold a broader, less farm-bound conception of agriculture than urban-raised respondents. They did not. Rural-raised respondents produced farm-only associations at essentially the same rate as urban-raised respondents (87.3% vs. 90.3%), a difference that was not statistically significant, $\chi^2(2, N = 574) = 2.76$, $p = .252$. Second, given that the STEM literature in the Literature Review frequently reports gender-moderated effects, the author compared F5 effectiveness ratings by gender; these too showed no significant difference (51.3% vs. 49.1% top-two-box for female and male respondents respectively), $\chi^2(4, N = 572) = 1.64$, $p = .801$. That the core patterns hold across both rural/urban background and gender further supports the interpretation that the naming problem is a broad, structural feature of how people perceive the term "agriculture," rather than an artifact of any particular subgroup's exposure or demographics.

## Discussion

### The Naming Problem is Structural, Not Developmental

The central empirical finding of this study, that fewer than 1 in 10 respondents associate the word "agriculture" with professional, business, or technical vocabulary, held consistently across all three groups. The absence of a significant group difference ($\chi^2 = 3.72$, $p = .445$) is itself important. It indicates that the narrow schema the word "agriculture" activates is not a symptom of insufficient exposure among the young, nor a stereotype that fades with career maturity. It is a stable, industry-wide perception that the term itself carries, consistent with schema theory's account of how category labels pre-load expectations before anyone exchanges any substantive information (Moreau et al., 2001). This reframes the practical challenge. The problem is not a knowledge gap that will close naturally as people age or enter the labor market. It is a linguistic and branding problem that requires deliberate intervention at every stage of the talent pipeline, not just at the point of initial career exploration.

This finding also converges with Manning and others' (2024) independent survey of primary and secondary students, reinforcing that the pattern is durable and not an artifact of this study's sample or wording.

The post-exposure awareness measure offers the strongest evidence for this schema's durability: 41.9% still did not recognize these careers as agricultural even after seeing them listed directly. Incidental exposure or a single career fair will not dislodge a schema robust enough to survive direct contradiction.

### F5 as a Tested Intervention: Uneven, but Real

Against this uniform backdrop, respondents perceived the F5 acronym as moderately-to-highly effective. The key finding, however, concerns consensus rather than favorability. The groups did not differ in how effective they rated F5 on average ($p = .481$); what differed was how divided they were. The Other/adult group drove this pattern, recording both the highest rate of "Extremely effective" and the highest rate of "Not effective at all" ratings, while younger

respondents clustered more uniformly in the middle-to-high range. The distinction matters for interpretation. F5 is not less effective for older audiences; older audiences are simply more divided about it. This divided-versus-uniform contrast is not just a descriptive impression; the dispersion test in the Results section confirms it statistically. As a result, adult respondents were nearly twice as likely to give an extreme rating (29.0%) as high schoolers (18.1%) or college students (16.0%).

This pattern is consistent with, and extends, prior evidence on the STEM acronym. Stoeger and others (2025) found that students' familiarity with and specific associations to the STEM acronym predicted real academic choices, with effects that varied by subject area and gender. The present findings suggest a parallel dynamic with F5: the acronym works, but the audience's prior context shapes its reception. A plausible explanation is that adult respondents bring more accumulated real-world knowledge of the agricultural sector against which to evaluate an unfamiliar acronym, producing sharper, more polarized reactions, whereas younger respondents, with less prior context to contradict or confirm the reframing, receive it more uniformly. This interpretation is consistent with Hershberger and others' (2024) field experiment on agricultural message framing, which similarly found that effectiveness varied by age group depending on which frame the researchers tested.

The practical implication is straightforward: a single, one-size-fits-all F5 campaign is unlikely to perform equally well across audiences. Industry communicators targeting younger audiences (high school and early college) can likely deploy F5 with confidence in broad, uniform reception. Campaigns targeting working adults, however, should anticipate a more divided response and may benefit from pairing the acronym with more concrete, individualized evidence, consistent with McDonald and others' (2025) finding that specific job awareness, not abstract reframing alone, was the strongest predictor of successfully shifting perceptions among a similarly experienced audience (secondary educators).

**The Gap Between Spontaneous Vocabulary and Structured Reframing**

A subtler but theoretically interesting pattern emerged when comparing the open-ended messaging theme data to the F5 results. Innovation and salary/job security, the two themes most closely aligned with F5's own finance- and technology-oriented framing, were the rarest spontaneous themes in respondents' own words, appearing in only 6.2% and 4.2% of open-ended responses respectively. Just over half the sample rated F5 as moderately-to-highly effective.

This gap is not a contradiction; it is arguably the entire point of a reframing intervention. Respondents do not spontaneously reach for "finance" or "innovation" when thinking about agriculture, precisely because the industry's naming convention has not cued them to. Yet, a framework that someone else supplies can still land as effective. This suggests that people are not rejecting the professional and technical side of agricultural careers. The problem is that the current wording does not bring that side to mind. That is an optimistic finding for industry communicators: the audience is not resistant to a broader conception of agricultural careers, only unprompted toward one.

By contrast, career identity was both the most common spontaneous theme and consistent with the study's applied recommendation to lead with specific career identity rather than industry identity. This convergence between what respondents generate unprompted and what the data recommends strategically lends additional confidence to that recommendation.

## The Limits of a Better Word

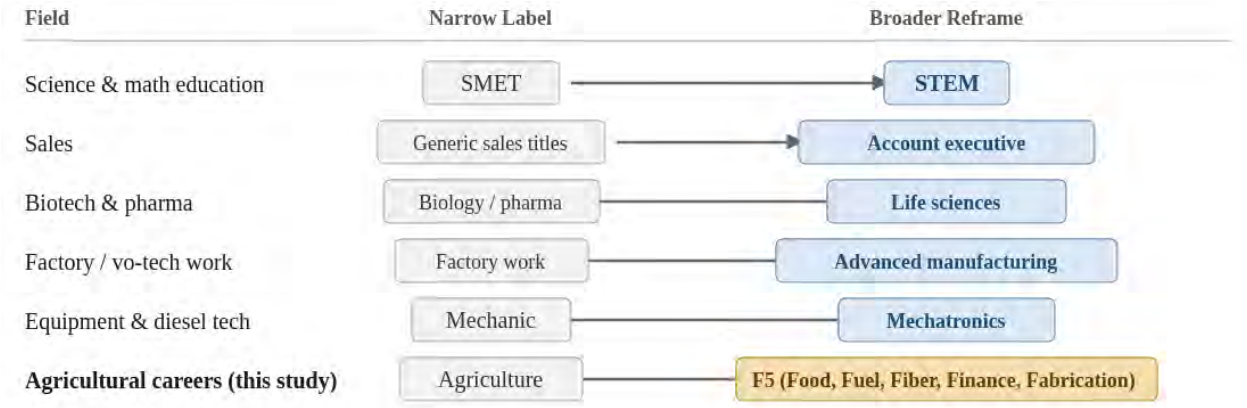
If the word "agriculture" itself causes the naming problem, an obvious question follows: would a different word solve it? Several respondents suggested one unprompted. When the survey asked how the industry might better communicate its opportunities, a number of respondents reached for "food," with one advising directly that if "you want to get people interested in the non-farm aspects, maybe use a different word like food industry," and another arguing that "focusing more on the word food is better than focusing on the word agriculture." The intuition is understandable. Everyone eats, while comparatively few farm, so "food" carries a broader personal relevance that may lower the initial barrier to engagement.

The data, however, suggest that "food" reproduces the naming problem, rather than resolving it. As the Results show, these "food" associations paired overwhelmingly with production or consumption imagery rather than any professional or technical vocabulary. In other words, "food" activates its own narrow mental frame, one that centers on the plate and the farm, rather than the profession, just as "agriculture" does. Substituting one single word for another appears to trade one narrow frame for a different narrow frame, not to widen the category.

This pattern points toward a more fundamental conclusion. The obstacle is not the particular word "agriculture," but the reliance on any single-word category label to represent a field whose actual breadth spans production, science, finance, engineering, and communication. As Figure 1 summarizes, the interventions that show the most promise multiply the frame rather than replace the word. The most common spontaneous messaging theme in this study, leading with career identity rather than industry identity, follows the same logic: it replaces the umbrella term with a concrete, plural set of professional roles. The path forward is not a better noun but an escape from single-noun framing altogether.

**Figure 1**

*A Recurring Pattern: Rewording an Industry to Widen Its Perceived Scope*




## Limitations

Several limitations warrant mention. First, both the word-association and open-ended theme measures relied on a keyword-based automated coding scheme rather than full manual qualitative coding. While validation against a hand-coded subsample showed substantial to near-perfect agreement after correcting initial scheme errors ($\kappa$ = .79–1.00 across categories), some residual misclassification at the margins is likely, particularly for responses using metaphorical or

highly idiosyncratic language that keyword matching cannot capture. Second, the F5 effectiveness measure captured stated perceptions of the acronym's effectiveness rather than measured changes in actual career interest or behavior following exposure to it; future work using a pre/post experimental design would strengthen causal claims about F5's persuasive impact. Third, the "Other" group combines working adults, community college students, and graduate students into a single category; while this grouping reflects the survey's original design, it may obscure meaningful heterogeneity within that population that a finer-grained segmentation could reveal.

As a check, the author tested whether removing community/technical college students from this group changed the reported polarization pattern. It did not; the dispersion finding held, and if anything, strengthened slightly, suggesting the pattern reflects genuine variation among working adults, rather than an artifact of how the author classified community college students.

## Conclusion

Agriculture faces a naming problem that is remarkably consistent across the developmental spectrum from high school through adulthood, a finding that shifts the burden of solution away from age-targeted education campaigns and toward deliberate, sustained rebranding efforts that target the industry's public-facing vocabulary itself. The F5 framework offers a promising starting point for that rebranding, one this study has tested empirically, though its uneven reception across age groups indicates that no single messaging campaign will suffice for all audiences. Industry communicators, educators, and marketers seeking to close agriculture's talent gap would do well to treat naming and framing not as a cosmetic afterthought, but as a central lever, one that both this study's data and a growing, cross-disciplinary body of literature support on how language shapes career perception long before anyone reads any job description.

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## Discussion Questions

1. If this naming problem is structural, rather than developmental, where should industry resources go: schools, adult-facing recruitment, or the industry's vocabulary itself?

2. Given F5's more polarized reception among adults, what would a segmented messaging strategy look like, and what would it cost organizations with limited budgets?

3. Career identity emerged as both a spontaneous theme and a recommended strategy. How might other industries facing similar naming challenges apply it?

4. This study measured stated perceptions, not behavior. What would a follow-up study need to show that F5 produces durable shifts in career pursuit, not just short-term interest?

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# Life Forward

## Marc Oliver Opresnik:
## Educator, Author, Speaker, Thought Leader



## Background

Professor Dr. Marc Oliver Opresnik is a distinguished professor of marketing and management, international author, keynote speaker and thought leader. He is the creator of the PIVOTAL Infinity Marketing Canvas® and founder of PIVOTAL Thinking, a purpose-driven approach to strategy, innovation, and long-term value creation. He has co-authored books with Philip Kotler, one of the most influential marketing thinkers of our time, and works internationally with universities, business schools, executives, and institutions. Prof. Opresnik is Honorary Professor at the New Delhi Institute of Management, Honorary Lead Professor of Marketing & Strategic Management at PIMR in India, a member of the LSE Academic Speakers Bureau, TEDx speaker, and United Nations World Food Programme mentor. His personal mission is "Building a Better World through Education," reflecting his belief that education is one of the most powerful instruments to unlock human potential and create positive societal impact.

## Interview
## by Hagai Gringarten
*Editor-in-Chief*
*Journal of Multidisciplinary Research*

### (1) Life is about stories. Do you have a favorite story you use as an icebreaker?

Yes. One of my favorite stories is the old parable of the three stonemasons.

A traveller once passed a large construction site and asked the first stonemason:

– "What are you doing?"

The man sighed and answered:

– "I am cutting stones. It is hard, repetitive work, and I am waiting for the day to be over."

The traveller then asked a second stonemason the same question. He replied:

– "I am earning a living. I work hard to provide for my family. It is honest work, even if it is sometimes difficult."

Finally, the traveller asked a third stonemason:

– "What are you doing?"

The third man smiled, looked at the building, and said with pride:

– "I am building a cathedral."

For me, this story captures one of the most important truths about life and leadership. The task may be the same, but the meaning we attach to it can be completely different.

Some people see only the task. Others see the income. Leaders see the purpose.

This is also how I understand my own work. I am not only writing books, teaching classes, building educational programmes, or developing frameworks. At a deeper level, I am trying to contribute to something larger: Building a Better World through Education.

That is why I like this story so much. It reminds us that success is not only about what we do. It is about why we do it — and what larger contribution we believe our work can make.

## (2) What are the top three characteristics that contributed to your success?

The first characteristic is purpose. I have always believed that success becomes more meaningful when it is connected to something larger than personal ambition. My purpose is "Building a Better World through Education."

The second is persistence. In academic, entrepreneurial, and international work, things rarely happen immediately. You need patience, discipline, and the ability to continue – even when progress is slow.

The third is relationship orientation. Almost every important step in my life was connected to people: mentors, colleagues, students, co-authors, partners, and friends. Long-term success is rarely built alone. It is built through trust, credibility, and shared value creation.

## (3) What life-changing events or decisions have guided your career?

One of the most important turning points in my life was discovering how much joy and meaning I found in teaching.

Interestingly, this began during my time at Shell International. Even in a corporate environment, I realized that what truly inspired me was not only managing business challenges, but helping people grow, understand complex issues, and develop their potential.

This experience shaped my entire career. It awakened in me a deep passion for education and for empowering young people, students, executives, and future leaders. Over time, I understood that teaching is not simply the transfer of knowledge. At its best, teaching unlocks confidence, perspective, and human potential.

Another life-changing decision was to pursue a more international path. I always wanted my work to reach beyond national boundaries and connect people, institutions, and ideas across cultures.

In this context, my work with my dear friend and mentor Philip Kotler has been one of the defining influences of my professional life. I deeply admire him, not only for his intellectual contribution to marketing but also for his generosity, humanity, and global vision. Much of my own international orientation, visibility, and confidence to think globally has been shaped by his encouragement and support.

Looking back, my career was guided by one overarching purpose: to use education as a force for empowerment, leadership, and positive transformation. The joy of teaching, the desire to develop human potential, and the inspiration to think internationally all ultimately come together in my personal mission: Building a Better World through Education.

## (4) Tell us of any expressions your parents often repeated with you.

One message I learned early was that nothing valuable comes without effort. My parents taught me, directly and indirectly, that discipline, reliability, and humility matter.

Another important lesson was to treat people with respect, regardless of their position. This may sound simple, but it is a powerful leadership principle. Titles may create authority, but character creates trust.

These values stayed with me: Work hard, stay grounded, and never forget where you come from.

## (5) What is the biggest misconception about you?

Perhaps the biggest misconception is that people sometimes see the public roles, titles, and achievements and assume that everything was planned from the beginning.

In reality, many opportunities emerged because I remained open, curious, and willing to take responsibility when doors opened. My path was not a perfectly designed master plan. It was a combination of vision, hard work, relationships, and the courage to say yes to opportunities that felt meaningful.

Another misconception may be that I am only focused on marketing. In fact, my deeper focus is on human potential, education, leadership, and creating positive impact through knowledge.

## (6) What books have you read lately?

One book I have recently returned to is Richard H. Thaler's *Misbehaving: The Making of Behavioral Economics*.

Thaler, who was awarded the Nobel Prize in Economic Sciences, is one of the central figures in behavioral economics. His work is important because it shows that human beings do not always behave like perfectly rational decision-makers. In business, leadership, marketing, and education, this is a crucial insight. People are influenced by emotions, habits, biases, social context, and the way choices are presented to them.

For me, this is highly relevant to leadership. Good leaders do not only design strategies. They understand people. They understand why people hesitate, why they resist change, why they sometimes make irrational decisions, and why purpose, trust, and framing matter so much.

That is also why behavioral economics is closely connected to my own thinking. If we want to build better organizations, better educational systems, and better societies, we must begin with a realistic understanding of human behavior.

## (7) Imagine your phone rings and it is you from 30 years ago. If you only had a minute to talk, what would you say? (Yes, I know, "Buy AAPL.")

I would say: Trust your path, but do not rush it.

Invest in knowledge, relationships, and reputation. These three assets compound over time. Do not be afraid of difficult phases, because they will teach you more than easy success ever could.

I would also say: Be ambitious, but stay humble. Say yes to meaningful opportunities, but never lose your values. And remember that the most important success is not what you achieve for yourself, but what you enable in others.

And yes, if there were a few seconds left, I might still add: Buy AAPL.

## (8) What elevator speech would you give children about success in life?

Success in life is not only about having more than others. It is about becoming the best version of yourself and using your talents to help others.

Find something you care about. Learn every day. Be kind. Work hard. Do not give up too quickly. And remember: Every person has potential, but potential only becomes reality through effort, courage, and character.

You do not need to be perfect. You need to keep growing.

## (9) What is the best advice you have ever received, and who gave it to you?

One of the best pieces of advice I received was from Philip Kotler, not necessarily as one single sentence, but through his example: If you want your ideas to matter, they must create value for others.

This shaped my thinking deeply. Knowledge should not remain abstract. It should help people make better decisions, build better organizations, and contribute to a better world.

Another important lesson I learned from many mentors is that reputation is built slowly and can be damaged quickly. Therefore, integrity is not optional. It is the foundation of sustainable success.

## (10) What would you like to see as your life's legacy?

I would like my legacy to be connected to education, empowerment, and positive transformation.

If people one day say that my work helped them discover their potential, make better decisions, lead with more purpose, or build something meaningful, that would be a wonderful legacy.

With PIVOTAL Thinking and the PIVOTAL Infinity Marketing Canvas®, I hope to contribute to a more purpose-driven understanding of strategy and leadership. Business should not only be about growth. It should be about meaningful growth: creating value for customers, organizations, and society.

Ultimately, I would like to be remembered as someone who used education to help people and institutions move forward.

Building a Better World through Education is not just a motto for me. It is the guiding principle of my work and my life.

## (11) Is there a book or idea that you hope will become part of your legacy?

Yes. One book and one idea that I hope will become part of my legacy is *PIVOTAL Strategy: The Infinity Marketing Canvas and Framework – The Success Formula to Turn Purpose into Infinite Market Power and Leave Competition Behind*.

The book has been published already and is now being prepared for global publication by Wiley. For me, this is not only a professional milestone. It is also deeply connected to the question of what kind of contribution I would like to make.

At the heart of the book is the idea of purpose-driven leadership. I believe that organizations can no longer define success only through short-term financial performance. Profitability remains important, but it must be connected to a deeper question: What kind of value does an organization create for customers, employees, society, and future generations?

The PIVOTAL Infinity Marketing Canvas® is my attempt to provide a practical answer to this question. It connects Purpose, Innovation, Value Creation, Outreach, Transfer, Advocacy, and Long-Term Impact into one integrated strategic logic. In simple terms, it helps leaders turn purpose into strategy, strategy into action, and action into meaningful market impact.

What makes this project especially meaningful to me is that it reflects my broader view of leadership: The best leaders do not only compete. They create value. They inspire people. They build institutions that matter. And they leave something behind that is larger than themselves.

If the PIVOTAL framework helps leaders, entrepreneurs, educators, and students think more deeply about purpose, strategy, and long-term value creation then it will be one of the most meaningful contributions of my professional life.

In that sense, the book is not only about marketing. It is about using strategy as a force for positive transformation — fully aligned with my personal mission: Building a Better World through Education.

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# Reflection

# Unfinished: Lessons in Failing Forward

**Jana A. Maynard**
*State College Florida, Manatee-Sarasota*

Editorial Note: Jana A. Maynard graduated from the State College of Florida, Manatee-Sarasota (SCF), in May 2026. At the ceremony, she was presented with the "Outstanding Graduate Award," and she was given an opportunity to speak. Her words that day are the text of this Reflection.

There were semesters when my backpack was full of books, but my body was full of pain. When my diagnosis felt heavier than my assignments, and I wasn't sure I could afford to keep going. There were moments, I sat in my car before class, hands on my steering wheel, convincing myself to walk inside. Moments I drafted an email asking for help, deleted it, and rewrote it… before finally hitting send.

And what met me again, and again, was Grace.

Grace from SCF[1] Scholarship Foundation Board of Directors, whose support made it possible for me to stand here today.

Grace from SCF Faculty and TRIO[2], my space place, who saw me as a person, *not* a deadline, and stepped in to keep me grounded when stress and uncertainty was high.

And Grace from SCF Administration, who helped me find a path forward when I couldn't see one myself.

… And I didn't walk that path alone.

Grace showed up in the spaces where life kept happening.

With my parents, whose support never wavered. With my husband, who believes in every creative idea I dream up… *and* helps build them. And most of all, with my daughter. Seventeen years ago, You became my *greatest* purpose and biggest "why."

Thank you, each of you, who have made a profound impact on my life and journey so far.

❖

[1] SCF refers to the State College of Florida, Manatee-Sarasota.
[2] TRIO refers to the TRIO Student Support Services program at SCF.

If you had asked me when I first walked onto campus what *my* mountain[3] was, I would've told you it was Perfection. Getting it right, not failing. Not letting anyone see the *messy*, unedited version of *me*…

But somewhere along the way, I realized I wasn't climbing a mountain at all. I was learning how to keep moving forward, *even* when I felt completely unfinished.

For years, I've felt capable, while constantly feeling behind. Like everyone else got The Map, The Schedule, The Memo…and I was just wandering through rabbit holes, fueled by self-doubt, a *little bit* of angst, and a *very* loud inner critic. Yet somehow, I kept showing up…

I woke up, put my feet on the ground, took a deep breath….

…and Failed Forward.

That's it! *That* was my entire strategy.

❖

In my photography class, we had an opportunity to submit our work to an exhibit… Gallery ready—Polished, Priced, Framed… and *to me*? That meant Perfect.

But my project relied on sunlight and nature's chemistry, and like life, it *didn't* cooperate. What I had wasn't a masterpiece. It was a Mess…Failed experiments and frantic handwritten notes to keep track of what went right and what went wrong. So, I decided to show all of it! To throw my notes and experiments on display. But when I wanted to cross out the price tag and hide, since it didn't match the description of what was *expected* to be on that gallery wall, Professor Palmer paused and said, "No. Leave it! It'll be a conversation starter" ……Okay?!

…She was Right!

People didn't lean in to see perfection. They *leaned in* to see the Process.

The How, the Why, the Honesty.

They found it interesting, reading my messy handwritten notes and faded images from photosynthesis[4]. And that's when it clicked. Validation doesn't come from being perfect. It comes from having the Courage to be seen in the *middle* of the mess!

❖

When I was young, I spent a lot of time sitting in plastic chairs in church community rooms, going to AA meetings with my mother. I didn't completely understand it all then, but what I was watching was something Powerful.

A Woman showing up. Not polished. Not perfect. *Mostly* exhausted. Sometimes afraid. But she showed up anyway. Which reminded me, *those rooms* taught me something I carry with me still—progress doesn't come from getting everything right. It comes from Consistency. From choosing to be Present. From waking up, breathing, and trying again… *especially* when it's hard.

So, when I talk about failing forward, about messy notes and unfinished work, I'm not talking in theory. I learned that lesson early, from a Powerful Woman, who showed me that worthiness *isn't earned* through perfection, it's built *through* Perseverance…

To keep showing up.

[3] In response to Neil Gaiman's (2012) commencement metaphor of "the mountain" as a guiding external goal, here reframed as an internal expectation of perfection.

[4] Refers to an Anthotype – alternative photographic process using light-sensitive plant pigments and ultraviolet (UV) light.

❖

I was inspired by author Neil Gaiman, who once said, when everything falls apart, when plans fail and certainty disappears, "…Make good art."[5] Not perfect art. Not *safe* art. Not finished art. Make the Honest kind. The *Human* kind.

So, when things go wrong, and *they will*, don't disappear. Don't wait to be finished…We are works in progress! Just show up anyway. *With* the messy notes. With the wrong turns. With the version of yourself that's still figuring it out. Because the most Powerful thing you will ever create is *not* perfection. It's Courage. It's Consistency.

It's showing up again, and again, and again.

*That* is how Confidence is Rebuilt. And how fear *loosens* its grip.

Look around this room! This room is not filled with perfection. It is filled with Resilience, with Persistence, with People who showed up when stopping would have been much easier.

This Moment is Proof!

*Proof* that Support Systems Matter. Proof that Community, *Changes* Lives.

Proof that Becoming, is *just as powerful* as Arriving.

So, take the veil off. *Fail* forward and Stand in your Efforts!

Because unfinished *doesn't mean* unworthy. Give yourself permission to begin. To *be seen*.

Again, and again, and again…

Don't cross out your price tag!

Don't *hide* what it cost YOU, to Become WHO YOU ARE!

Congratulations, class of 2026.

Let's go make something Honest, and Imperfect, and Show up anyway!

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[5] Quoting Neil Gaiman, "Make Good Art" (commencement address, The University of the Arts, Philadelphia, Pennsylvania, May 17, 2012). The following commentary ("Not perfect art…the human kind") represents the author's original thematic extension of Gaiman's core phrase.

## About the Author

Jana A. Maynard is a graduate of the State College of Florida, Manatee-Sarasota (SCF), where she earned a 3.7 GPA and won the "Outstanding Graduate Award." While at SCF, she was part of the TRIO Student Support Services program, the *Phi Theta Kappa* International Honor Society, and the *Sigma Kappa Delta* National English Honor Society (of which she was president). She now is a student in the Honors Program at the University of South Florida. Among her goals are earning a Ph.D. in clinical psychology and creating a non-profit organization that supports neurodivergent individuals and their families.

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"Show up anyway!"

Paper and Glass
Bradenton, Florida
2026

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## Student Corner

# The Economic and Environmental Costs and Benefits of Biodegradable Packaging Materials

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Abstract

In this article, we examine the relationship between the half-lives of biodegradable packaging materials and their per unit cost to the user. A short half-life should be a desirable quality from an environmental standpoint, while low cost should be a desirable quality from an economic standpoint. Not surprisingly, we find an inverse relationship between half-life and cost: as half-life increases, unit cost tends to decrease. In order to assess these relationships, we begin by building a statistically appropriate model to predict unit cost as a function of half-life. We then examine both the environmental and economic implications and trade-offs that exist regarding this relationship.

Keywords

biodegradable packaging materials, environmental persistence, cost-benefit analysis

## Introduction

Packaging materials are a ubiquitous component of nearly every facet of both social and business life in the 21st century. Companies around the world face pressure to utilize sustainable materials, including sustainable packaging. Extended producer responsibility policies and regulations are a key factor in the need for producers to utilize sustainable materials that are

biodegradable (Tumu, Vorst, & Curtzwiler, 2023). Additionally, consumers demand environmentally friendly products, and this demand is increasing over time (Nguyen, Parker, Brennan, & Lockrey, 2020). Biodegradable packaging offers a promising solution to these concerns, but, in order to effectively choose the optimal materials, managers must balance a complex combination of environmental benefits with financial costs. Fortunately, prior research (González-Boubeta, Fernández-Vázquez-Noguerol, Domínguez-Caamaño, & Prado-Prado, 2018) has shown that managing economic costs and using eco-friendly materials are not mutually exclusive.

Researchers have studied the strength, durability, and environmental impact of biodegradable materials in great detail (Panou & Karabagias, 2023; Pikon & Czop, 2014). Our review, though, did not find any studies that connect the cost of these materials directly with their half-life. The half-life measures how long these materials persist in the environment. Firms need to know whether faster degradation carries a higher or lower price, and how physical performance factors, such as tensile strength and the mass required for packaging, alter that relationship.

In this article, we investigate the relationship between the cost of biodegradable packaging materials and their half-life. While we often use the term "half-life" in fields like chemistry, we use it here to denote the amount of time it takes for half of a material's mass to biologically degrade. In other words, longer half-lives imply greater environmental persistence. We control for tensile strength and the mass of material required to package a fixed volume of goods. Controlling for these extraneous variables (tensile strength and mass) allows us to isolate the trade-off between economic and environmental performance. This analysis should be of interest to both scientific and managerial audiences because it bridges the disciplines material science, business economics, and sustainability policy.

This study sheds new light on the economic feasibility of the utilization of sustainable packaging. Specifically, we statistically determine the relationship between cost and half-life. Managers can use these findings to make more informed decisions about what types of packaging materials are optimal from a combined environmental-economic standpoint. Additionally, scientists can use the results contained herein to identify priorities for new packaging material development, and policymakers utilize these results to help align environmental goals with economic realities. We now turn to a review of the relevant literature.

## Literature Review and Background

We now briefly review the literature directly related to this study. In particular, we will look at a brief history and summary of the development of biodegradable packaging materials. Following that, we discuss their environmental benefits, as well as the desirable qualities of these materials. Finally, we will look at the economic costs associated with their use.

The demand for packaged and processed goods has increased dramatically in recent years, and hence, the demand for packaging materials has also increased (Verma et al., 2021). Coincidentally or not, public awareness of environmental concerns has also increased during this same time period. Naturally, this has increased demand for eco-friendly packaging materials. One desirable characteristic of a packaging material is, therefore, its ability to biodegrade naturally. Biodegradation is the ability of a substance to chemically decompose through processes initiated by living organisms (Andrady, 1998).

Researchers have developed a variety of biodegradable packaging materials in recent decades. A complete history, and the relevant science, related to the history of biodegradable materials is beyond the scope of this article. That, said, we briefly note the three main types of such materials, in the chronological order in which manufacturers introduced them. Manufacturers first introduced low density polyethylene materials (Ivonkovic, Zeljko, Talic, & Martinovic Beyanda, 2019). These materials, which contain about 10% starch fillers along with oxidizing additives, though, have the drawback that they decompose into substances that are not, themselves, biodegradable. More recently, researchers developed fully biodegradable materials that decompose according to one of the three following biological mechanisms: chemical synthesis, the use of living organisms, or derivation from biomass ((Ivonkovic, Zeljko, Talic, & Martinovic Beyanda, 2019). One example (of many) of the most recent generation of packaging substances is materials made of polylactide polymers (Auras, Harte, & Selke, 2004; Sweetha et al., 2023). It is intuitive to conclude from the preceding discussion that the amount of time required for these various types of materials to degrade could vary substantially. Quantifying these relationships will be part of the discussion and analysis that we will perform in subsequent sections of this article.

Perhaps the greatest advantage of any type of completely biodegradable material is that it does not permanently take up space and have the potential to cause environmental harm. Taken to the extreme, a material with a degradation time of a century is far superior to one that is permanently part of the environmental landscape. More formally, this means that, from a waste management perspective, the use of biodegradable is highly desirable (Dilkes-Hoffman et al., 2018). One measure of the time it takes a substance to decompose is its half-life. In this context, the half-life of a biodegradable material is the amount of time that it takes for 50% of the mass of the materials to naturally decompose. Since space is limited in things like landfills, the use of materials that are biodegradable is clearly advantageous.

Furthermore, biodegradable materials are not all identical. Other properties of packaging materials are important from both a consumer and producer standpoint. Two of these are the mass of the material and its tensile strength. The mass factor is quite obvious: It is not desirable for packaging material to have a high mass. In this article, we consider the mass (in kg) required to package a fixed volume of a given substance. Tensile strength, in contrast, is the maximum load a substance can endure without breaking (Shah et al., 2023). Tensile strength is among the most critical of mechanical properties for any packaging material.

The preceding overview of the literature sets the stage for the analyses in the following sections of this article. We have seen that, given the increasing demand for eco-friendly packaging (Verma et al., 2021) and advances in packaging technology (Ivonkovic, Zeljko, Talic, & Martinovic Beyanda, 2019), firms' packaging choices matter more now than ever. The analyses to come in subsequent sections of this article will help decision makers in their cost-benefit analyses, by mathematically describing the relationship between the unit cost of these materials (important from an economic perspective) and their half-lives (important from an environmental perspective). We now turn to the methodology we used to assess the relationships between the half-life of biodegradable materials and their economic cost.

## Methodology

The quantitative aim of this study is to model the relationship between the half-life of a biodegradable packaging material and its unit cost. We collected our data by searching online for lists of commonly used biodegradable packaging materials. Using the researchers' knowledge of

biodegradable materials, we focused our search on those materials that are commonly used. Appendix A lists the data sources we used. We present a list of the materials we used in Table 1 below. Note that we list some of the materials more than once. This is because we were able to find data regarding their biodegradability under more than one environmental condition. Also, note the following abbreviations in the table: Poly-3-hydroxybutyrate (PHB), Polybutylene Succinate (PBS), and Polylactic Acid (PLA). As we will see later, we obtained incomplete data for some of these material-environmental condition combinations and, hence, we did not use these data in our final analysis.

For each material, we collected data on the following variables: (1) mass (in kg) of the material required to package 100 $cm^3$ of a substance; (2) average tensile strength (in MPa); (3) Cost (in $/g); and (4) the time it took, t (in days), for x% of the material to degrade (note that there are two variables here, the time, t, and the percentage, x). We report all costs as of August 28, 2025.

Following collection of the data, we calculated the half-life of each material under each condition. In order to do this, we utilize data on the variables t and x (see above). We then calculated the half-lives using the standard formula and solved for half-life (Gordon, n.d.):

$$\text{Half-life} = t*\ln(1/2)/\ln(1-0.01x),$$

where x and t are the percentage of the material (x) that degraded during time t, and ln is the natural logarithm.

**Table 1**
*List of Biodegradable Materials*

| Material Name | Condition |
|---|---|
| PCL | Soil |
| PCL | Soil |
| PCL | Compost |
| PCL | Compost |
| PCL | Compost |
| PHB | Soil |
| PHB | Soil |
| PHB | Compost |
| PHB | Compost |
| PHB | Compost |
| PLA | Soil |
| PLA | Soil |
| PLA | Compost |
| PLA | Compost |
| PLA | Compost |
| PBS | Soil |
| PBS | Soil |
| PBS | Compost |
| PBS | Compost |
| PBS | Compost |

| | |
|---|---|
| Starch | Soil |
| Starch + 5% ZnO NP | Soil |
| Cellulose + Glycerol | Soil |
| Cellulose + Glycerol | Soil |
| PHB/PBAT 55/45 wt% | Soil |
| PHB | Soil, 80% rel. humidity |
| PHB/5GS | Soil, 80% rel. humidity |
| PHB/5GS/0.7MgO | Soil, 80% rel. humidity |
| PHB | River Water |
| PHB/5GS | River Water |
| PHB/5GS/0.7MgO | River Water |
| PHB | Soil, pH 7, 60% Moisture |

*Note.* Some materials appear multiple times because data were available under multiple environmental conditions.

We treat these half-lives as the variable of interest in this study, since we wish to see how they are related to the unit cost. In order to assess that relationship in our forthcoming analysis, we will run a multiple linear regression (using SPSS v 29.0.2.0), where the dependent variable is unit cost, the independent variable of interest is half-life, and the other independent variables that we control for are mass and tensile strength. The details behind these regressions, as well as their corresponding results, will be presented in the following section. We use a level of significance of 0.05 throughout the analyses.

## Results

As previously mentioned, we collected data on the per unit cost, tensile strength, and mass (per unit volume packaged) of 9 different biodegradable packaging materials. We had complete data from a total of 22 data points, as we were able to collect degradation time data for some of the materials under multiple conditions (e.g. soil vs. compost). In Table 2, below, we present the half-life of each material-condition combination, as well as the mean and standard deviation of each variable.

**Table 2**
*Half-Life of Material–Condition Combinations*

| Material | Condition | Half-life (days) | Mass (g) | Cost ($/g) | Tensile Strength (MPa) |
|---|---|---|---|---|---|
| Poly-3-hydroxybutyrate (PHB) | Soil, 37 °C | 241.02 | 140 | 0.00174 | 325 |
| Polybutylene Succinate (PBS) | Soil, 37 °C | 368.78 | 126 | 0.003721 | 325 |
| Starch, Sweet Potato | Soil | 21.92 | 150 | 0.000535 | 57.5 |

| | | | | | |
|---|---|---|---|---|---|
| Cellulose | Soil, Summer | 1.26 | 114 | 0.004185 | 64.3 |
| Cellulose | Soil, Spring | 2.25 | 114 | 0.004185 | 64.3 |
| Pectin | Soil | 6.32 | 150.8 | 0.011225 | 5.95 |
| Chitosan | Soil | 0.60 | 100 | 0.028 | 6.99 |
| Starch Based | Soil, 60% Moisture, 20 °C | 497.85 | 150 | 0.000535 | 57.5 |
| PLA | Compost, 58 °C | 208.64 | 125 | 0.002808 | 50.5 |
| PLA | Compost, Aerobic 58 °C, 60% Humidity | 22.69 | 125 | 0.002808 | 50.5 |
| PLA | Soil, 30% Moisture | 644.72 | 125 | 0.002808 | 50.5 |
| PHB | Soil | 121.13 | 140 | 0.00174 | 325 |
| PHB | Soil | 53.16 | 140 | 0.00174 | 325 |
| PHA | Soil, 35 °C | 96.54 | 100 | 0.004 | 27.5 |
| PHA | Soil, 60% Moisture, 20 °C | 292.47 | 100 | 0.004 | 27.5 |
| PHB | Compost, 58 °C | 47.52 | 140 | 0.00174 | 325 |
| PHB | Compost, 70% Moisture, 55 °C | 12.06 | 140 | 0.00174 | 325 |
| PHB | Sea Water, 25 °C | — | — | — | — |

*Note.* Mass refers to the amount of material required to package 100 $cm^3$ of a substance. Dashes indicate unavailable data.

Once we collected all of the data and calculated all of the half-lives, we began the process of building our model to predict cost as a function of half-life. Not surprisingly, we found that the relationship between cost and half-life was not linear. This may be due to the fact that a material's half-life is directly related to an exponential decay function. Hence, we investigated the relationship between the natural logarithm (ln) of half-life and cost. We found that this relationship is, indeed, linear, and, thus, included the natural logarithm of half-life in our model. As we will see in the following discussion section, this makes it important to correctly interpret our model mathematically.

The crux of our analysis revolves around the following linear regression model:

$$\text{Unit Cost} = B_0 + B_1\text{Mass} + B_2\text{AverageTensileStrength} + B_3\ln(\text{HalfLife}),$$

where Mass is the mass (in kg) of the material required to package 100 $cm^3$ of a substance, AverageTensileStrength is the tensile strength (in MPa), Unit Cost is the cost of packaging 100 $cm^3$ (in $), and ln(HalfLife) is the natural logarithm of the material's half-life.

Table 3 below presents the results of this linear regression model.

**Table 3**
*Results of Linear Regression Model*

| Predictor | B | SE | β | t | p |
|---|---|---|---|---|---|
| Constant | 3.050 | 0.703 | — | 4.340 | < .001 |
| Mass (g) | −0.010 | 0.005 | −0.257 | −1.836 | .083 |
| Average Tensile Strength (MPa) | −0.022 | 0.005 | −0.559 | −4.034 | .001 |
| ln(Half-life) | −0.127 | 0.040 | −0.445 | −3.175 | .005 |

*Note. The dependent variable is unit cost. β denotes standardized coefficients.*

Table 3 shows that the parameter estimates (see the column with "B") for both tensile strength and natural logarithm of half-life are statistically significant at the 0.05 level (see column with "Sig"). The parameter estimate for mass is not quite statistically significant at the 0.05 level. In particular, we can see that there is a negative relationship between LnHalfLife and cost. This implies that, as half-life increases, we would expect, on average, for the unit cost to decrease, holding all other variables constant. The environmental and economic meaning of this, and other findings, will be discussed in detail in the following section. Also notable, but not the focus of this exposition, is the fact that a negative relationship exists between tensile strength and cost. In other words, and perhaps counterintuitively, as tensile strength increases, we expect the unit cost to decrease, everything else held constant.

Another useful aspect of the model above is that its $R^2$ value is 0.657 (which is statistically significant at the 0.05 level). This means that 65.7% of the variability in unit cost is explained by our model as a whole. The fact that this model explains nearly two-thirds of the variability in unit cost speaks to its practical significance, in addition to its statistical significance.

We note that we carefully checked this model to ensure that it did not violate any of the mathematical assumptions underlying regression analysis. Fortunately, we found the following: (1) the residual errors of the model roughly followed a normal distribution; (2) we did not find any strong relationship between the residual errors and the predicted values; and (3) we did not find any strong correlations among the independent variables (all variance inflation factors were below 1.1, while researchers generally consider any variance inflation factor under 10 to be acceptable (O'Brien, 2007). Hence, we have no reason to believe that any econometric problems exist with our model.

We now move on to examine, in practical terms, the meaning of the preceding results.

## Discussion

The results we just found give rise to several important economic implications. First, and most importantly, we look at the specific nature of the relationship between half-life and cost. As previously noted, from an environmental standpoint, a short half-life is a desirable quality, as this means that the material degrades quickly (Lott et al., 2021), and has less potential for environmental harm. Additionally, the increasing consumer demand for environmentally friendly products has the potential to benefit producers using such products in their manufacturing and delivery process (Reddy et al., 2023). Hence, if everything else were equal, manufacturers would make the obvious choice of utilizing materials intended for disposal with the shortest possible half-lives. That said, economically, it is rarely the case that everything else is equal, and such is the case here. Our findings show a statistically significant, negative relationship between half-life and cost. In other words, decision makers must strike a balance between economic and environmental costs. Since we used a logarithmic transformation of half-life, we must be careful regarding how we interpret this economically. Specifically, given our parameter estimate of -0.127, and using the traditional interpretation of logarithmic coefficients (University of Virginia Library, n.d.), we can see that a 1% increase in half-life corresponds to a 0.127% percent decrease in cost. Putting this into real-life terms, we can see from Table 2 that the mean half-life is 222.41 days and the mean cost is 0.4099 cents/g. Utilizing these values, and considering the purchase of a kg of packaging material, we see that if half-life were to increase from 222.41 days to 224.63 days (a 1% increase) we would expect a corresponding decrease in cost from $4.10 to $4.09. Considering a larger increase, of 10%, in half-life we would expect the cost to drop to $4.05.

From a practical standpoint, the cost decreases associated with using longer half-life materials are fairly modest. This implies that the use of high quality biodegradable materials with short half-lives may well be economically expedient in a world where consumers prefer eco-friendly materials (Hussain, Akhter, & Makhtdar, 2024). Managerial decision makers should seriously consider the relatively low-cost, environmentally friendly use of biodegradable materials that decompose quickly. In addition to the obvious environmental benefits, this actually has the potential to increase profit if the firm's eco-friendly practices are appropriately marketed (Ewe & Tjiptono, 2023). As Ewe and Tjiptono (2023) found, these benefits may be especially strong amount young consumers. Attracting consumers at a young age and developing loyalty from them has the potential to provide a decades-long revenue stream.

As a side note, we also found the counterintuitive result of a negative relationship between tensile strength and cost. One would think, at first, that people would be willing to pay more for a stronger packaging material. While the reason for this negative relationship is not certain, one hypothesis is as follows: higher tensile strength is desirable by consumers, this leads to producers focusing on the production of materials with higher tensile strength, which, in turn, leads to relative economies of scale in producing materials with greater tensile strength. This could, ultimately, lead to materials with greater tensile strength have a lower unit cost.

This study has some limitations that we will now note. First, we focused on the most commonly used materials. Less common, niche materials could potentially exhibit different relationships. Additionally, our sample size is relatively low (22). That said, this does not appear to cause any statistical problem, since the hypothesis tests conducted on the regression all take the actual sample size into account, and still provide statistically significant results.

This work also provides areas for future research. One area is to mathematically model the economic cost of using biodegradable materials against the negative economic externalities caused

by the use of traditional materials. A second area is to more thoroughly investigate the relationship between tensile strength and unit cost. While this article focused on the relationship between half-life and unit cost, our tangential finding regarding tensile strength provides an interesting avenue for future work.

In summary, in this article, we found that a statistically significant negative relationship exists between the half-life of biodegradable materials and their unit cost. The fact that people are willing to pay more for products that degrade more quickly should not be surprising. We also found that the effect size of this negative relationship is relatively small. This implies that manufacturers can make use of the relatively more eco-friendly materials (with shorter half-lives) with minimal additional marginal cost. This provides both consumers and manufacturers with a win-win situation: consumers get the eco-friendly products they desire, the environment is treated gently, and producers need only pass on a relatively low cost in exchange for these benefits.

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## Appendix A: Data Sources

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https://www.mdpi.com/2073-4360/13/16/2632
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https://www.specialchem.com/plastics/guide/polyhydroxyalkanoate-pha

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## Discussion Questions

1. Given the costs and benefits of using biodegradable packaging materials, do you think it is economically feasible for firms to utilize materials that degrade relatively quickly?

2. How do you think the relationship between material half-life and unit cost might evolve over time?

3. Do you think there are any specific industries where the use of eco-friendly packaging materials is especially environmentally important or especially cost effective?

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## Student Corner

# Utilizing Posture and Bioinformatic Data to Track the Prognosis in Patients with Chronic Obstructive Pulmonary Disease

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Abstract

Chronic Obstructive Pulmonary Disease (COPD) is a leading cause of mortality worldwide. Patients with COPD require continuous evaluation for progressive respiratory decline, thus tracking the prognosis of COPD patients is critical for effective management and intervention. This study explores the integration of posture correction combined with bioinformatics, which serves as a tool for remote monitoring of COPD progression. Through a comprehensive literature review, this research identifies a significant gap: Current spirometry devices lack integration of posture corrections mechanisms and advanced bioinformatic analysis for home use. The research employs mixed methods, combining content analysis of FDA cleared devices, evaluation research of engineering prototypes, and experimental validation. The researcher designed and fabricated the prototype using Computer Aided Design (CAD) and 3D printing technology. The device utilizes faraday's law to convert air flow into voltage output, providing a quantifiable measure of peak expiratory flow rate (PEFR). The results demonstrate a strong correlation between voltage output and peak PEFR, which validates the devices accuracy. Overall, the prototype successfully attempts to address the identified gap: combining posture optimization with bioinformatic data collection in spirometry.

Keywords

Chronic Obstructive Pulmonary Disease (COPD), progressive respiratory decline, intervention, spirometry, peak expiratory flow rate (PEFR)

## Introduction

In 2024, the World Health Organization (WHO) named Chronic Obstructive Pulmonary Disease (COPD) the fourth leading cause of death worldwide, and they predict it to be this way until 2030 (World Health Organization, 2024). COPD is a pulmonary condition that causes damage to the airways. This damage leads to other problems that constrict air flow, making it hard to breathe (National Heart, Lung, and Blood Institute, 2024). When assessing how the industry can prevent these deaths, the main concern goes to COPD's degenerative nature. This means that when physicians diagnose patients with the condition, the patient's prognosis worsens over their lifetime. Increased frequency of exacerbations leads to periods of shortness of breath (SOB) (National Heart, Lung, and Blood Institute, 2024). Additionally, these flare ups can occur for days or weeks at a time, and the intensity of the exacerbation depends highly on what the trigger is, which varies by patient (Coutu et al., 2023). Therefore, with these variables in mind, finding an accurate method of tracking the rate of progression of the disease proposes a large question for the field of pulmonology and biomedical engineering: how can physicians use posture and bioinformatics to accurately track the prognosis of COPD?

## Literature Review

### Identifying the Gap regarding COPD Spirometry Devices

Thanks to advancements in biomedical engineering, methods to track COPD exist but may constrain themselves to wearable technologies. As the journal *Frontiers in Medicine* indicates, wear-able technologies in tracking COPD with spirometry that allow for remote patient monitoring is a field that looks to improve with the use of "big data" (Coutu et al., 2023). Although researchers are already exploring the practical use of big data, this article dissects the gap and evaluates if fixing posture can aid to make a functional bioinformatic spirometry device, which would classify as small data. This is because of bioinformatics. Using bioinformatics – a field that combines computer science and biology to interpret biological data – and spirometry – pulmonary function test(s) – allows physicians to track trends in the patient's anatomy more effectively when using fewer types of data. The device in question would only test one variable and manipulate that output to create data. Devices that utilize both bioinformatics and spirometry exist and are significant in the respiratory therapy industry (Staff, 2024). Clinicians use these devices for spirometric monitoring. Instead, this review explores at-home monitoring spirometry devices. To identify the gap in postural-spirometry remote devices, the student researcher analyzed the FDA database for medically cleared devices that patients can use remotely. The researcher eventually concluded that no devices are postural (see Appendix 1 for devices reviewed).

**Figure 1**
*Pulmonary Function Testing Device*



*Note.* This bioinformatic device takes in values from the inhalation device (right) and evaluates the data with the machine (left) (Staff, 2024).

Further assessing the gap relies on the academic context of posture and its significance in COPD, which the researcher discusses in this review. Additionally, deciding the nature of how to collect the data, as well as experimentally designing such device's qualities, depends on criteria for accurate spirometry and experimental design.

**Posture and COPD**

Prior to discussing bioinformatics, it is better to situate the knowledge on posture. Posture significantly impacts respiratory mechanics and muscle function, which are important in the management of COPD. Studies have shown how various postures affect respiration, offering insight into the optimization of patient positioning for better respiratory outcomes. A study by Dr. Yang with the School of Traditional Chinese Medicine, and another study by Dr. Zafar with the College of Applied Medical Sciences describe the impacts of body postures on nasal patency in patients. Both research teams conducted studies on non-COPD patients: Yang's study on sleep apnea patients, and Zafar's study on healthy males (Yang et al., 2024; Zafar et al., 2018). The characteristics and symptoms of sleep apnea compare to those of COPD; for example, sleep apnea causes shortness of breath while sleeping from the body's lack of oxygen at night, like COPD. Dr. Yang's study sheds light on how posture affects nasal resistance, with the prone position recording the highest increase in nasal (Figure 2) (Yang et al., 2024). On the contrary, Dr. Zafar's findings reported poor posture considerably reduced diaphragm muscle strength, thus affecting respiratory function (Zafar et al., 2018). These results show the importance of posture management within respiratory management to decrease nasal resistance and to increase the efficiency of breathing in patients suffering from COPD (Yang et al., 2024). Therefore, as both studies note, posture has a significant effect on the control of respiration.

Further explaining the importance of posture, in 1980, J. T. Sharp wrote an article on his academic case study in the *American Journal for Respiratory Disease*, in which he provided an alternative insight into how proper positioning can relieve dyspnea (also known as shortness of

breath) in patients with severe COPD. Researchers would later discredit this statement. The study found that certain postures, especially the leaning-forward position, significantly alleviate dyspnea (Sharp et al., 1980). Clinicians call this position the tripod position and recommend it since it allows for easier respiration. This is because when the patient's chest hunches forward, it provides a temporary relief in inspiratory thoracic tension (Reference figure 2). Although this sounds promising, this positioning connects to another concept that does not pose good results: Dahl's sign, which is a visual tag of the disease's impact and the paradoxical benefit of certain postures (Meegada et al., 2020). Even though this position may seem advantageous, because it relaxes the chest muscles and helps facilitate diaphragmatic excursion, it worsens the patient's respiratory strength because it does not relieve the factors that cause respiratory distress. Thus, Sharp's article is inaccurate. The negligent tripod position simply redistributes the work of breathing without improving pulmonary mechanics. Hence, the tripod position does not posturally alleviate SOB. This furthers the need for treatments that enhance overall respiratory mechanics, rather than just bringing superficial relief.

**Figure 2**

*Prone Position (left) vs. Tripod Position (right)* (Medstrom, 2025; Orford, 2023)




Instead, actual solutions exist. For instance, Dr. Kim with Yonsei University College of Medicine as head of the Physical Therapy Department and Aishwarya Nair and others with the Department of Physiotherapy, Kasturba Medical College, both assessed the impacts of breathing maneuvers and sitting postures on muscle activities in inspiratory accessory muscles in patients with COPD. The studies demonstrated that some postures and breathing techniques improve tidal volume and reduce respiratory rate significantly (Kim et al., 2012; Nair et al., 2019). Therefore, if a patient's posture is maladaptive, it could lead to inaccurate spirometry results. With this knowledge, regular tracking of trends through bioinformatic data collection might help to increase the accuracy and effectiveness of COPD management tools by providing real-time feedback on optimal postures and breathing techniques.

Understanding that posture is a relevant indicator of valid spirometric data, as well as a relieving factor in COPD, it is a reliable inclusion into bioinformatic tracking software. As this literature review identifies and describes, this is not a research gap. Instead, the application of this knowledge with integrated bioinformatic software in a spirometric prototype that also forces

anatomical posture for accuracy is a significant gap in pulmonology. The student researcher discusses a possible model for postural-COPD management devices and its possible benefits.

**Bioinformatic Approach to COPD**

Bioinformatics provides a potent tool in the tracking and management of COPD through the analysis of physiological data. There is not a gap in this. Bioinformatics has made its novel impact while blossoming into the bio-engineering world as a new technique. Although explored, the topic is still novel, especially when coupled with spirometry. Pulmonologists and other medical specialists have the option to use integrated bioinformatic spirometry tests. Therefore, patients can use bioinformatic-spirometry at home, if they keep the anatomically accurate posture. This is a limitation seeing as patients may have a barrier in identifying and keeping the correct posture while the device collects data. The question remains, which parameters do researchers observe while using bioinformatics, and why is posture important in data collection? In 2019, Ravi Reddy and others (2019) with the Department of Medical Rehabilitation and King Khalid University evaluated the reliability of chest wall circumference measurements to assess chest wall mobility and its relation to lung function in healthy nonsmokers, healthy smokers, and COPD patients. The study emphasized the importance of chest wall mobility in respiratory function and suggested that bioinformatics tools could monitor these measurements to better manage COPD. Although this is a critical aspect of relating posture to chest tension, Reddy's study does not directly focus on COPD. It does propose a possible variable: researchers measuring bioinformatics also should account for changes in chest wall mobility and correlate these with respiration.

Bioinformatics provides a valid choice for attempting to track and display trends in patients monitoring their COPD over time. Integration of bioinformatic tools in developing prototypes for COPD management appears as one of the most promising ways to achieve it. Studies that emphasize this support the exigence and need for researchers and engineers to develop bioinformatic spirometry devices. For example, in 2018, Andrew Sedgewick and others (2018) with the Department of Computational and Systems Biology and the School of Medicine at the University of Pittsburgh, framed concept close to integrating COPD and bioinformatic tracking. The team's research utilizes computer models and novel software to create schema pathways for bettering COPD diagnoses. Although this bioinformatic approach did not focus on tracking the progression of COPD with a device, it is a testament to the new pathway that bioinformatics has embarked on in the pulmonology industry.

Furthering the need for a device that tracks COPD at home, Kurt J. Greenlund with the Centers for Disease Control and Prevention helped conduct a study on the cognitive nature of COPD patients that offers a new perspective. The patient's cognitive disabilities would impact the level of care and increase the amount of negligence within care from providers. This study emphasizes that possibly analyzing data from wearable devices using bioinformatics allows researchers to capture changes in the ability to breathe over time and view the disease in a dynamic rather than static way (Sedgewick et al., 2018). This helps these patients with cognitive disabilities and leads toward a more effective management of COPD. This management extends beyond the patient's benefit. Clare Gardiner, a Research Associate with the School of Nursing and Midwifery at The University of Sheffield, sheds light on the role of bioinformatics in identifying biomarkers associated with exacerbations of COPD. Specifically, the study mentions the application of bioinformatic tools into clinical practice (Greenlund et al., 2016). This can and will help the

physician in prediction and management of exacerbations effectively, hence reducing chances of hospitalization and improving health outcomes among patients.

### Medically Prototyping a Device for COPD

This research will determine the originality of the concept. Through a thorough search in the FDA database, the researcher found that there is no such device on the market that integrates bioinformatic tracking with posture correction for COPD management. This would provide uniqueness to this gap and an opportunity for innovation. The need to address the postural gap in the management of COPD inspired the proposal of the device. Overall, the studies highlight the critical role of posture in respiratory function and the promising potential of bioinformatics in COPD management. Researchers can utilize this scope and focus future research to develop a device that utilizes components of posture-related bioinformatics. Overall, this would work to improve outcomes in COPD prognosis and treatment. Integration of these ideas might change COPD management and will provide more effective and tailored care for the patients.

## Methodology

This study uses a blend of content analysis, correlational, evaluation research, and experimental methods to establish the relationship between voltage output and Peak Expiratory Flow Rate (PEFR). The researcher chose PEFR as the spirometry value since it demonstrated volume of air exhaled in a short period of time (Long, n.d.).

### Content Analysis

First, to ensure that the concept followed for the scope of the device is original, the researcher reviewed existing medical devices. Using content analysis, the analyzed data seeks to present a comprehensive, evidence-based overview of FDA-approved spirometry home monitoring medical devices for COPD patients. The primary objective is to compare the characteristics of the devices, specifically their employment of bioinformatics in analyzing data and their availability or suggestion of postural maneuvers with data recording. The search for relevant FDA-cleared medical devices started with a targeted review of the FDA database. The student researcher used keywords such as “spirometer,” “home use,” “COPD,” “cleared,” and “510(k)” to find devices that are regulatory approved for the intended use. The criteria for inclusion in this review remained rigorous: Companies must have FDA clearance, must have designed the product for home use, and must state COPD patients in the device’s purpose or indications for use. This requirement ensure that the analysis focused on devices that manufacturers sold with the targeted patient population in mind.

Following the identification of potential devices via the FDA database and associated press releases, the researcher searched for approved product websites or reliable online retail websites, including those belonging to large pharmaceutical firms or established medical supplies distributors. These sources provided opportunity to gain in-depth knowledge regarding the devices. Data extraction focused on several key areas: determination of the model and name of the device, a direct link to the product page, complete technical specifications and features, detailed descriptions about the methodology used by the device in analyzing or interpreting the collected spirometry data, and availability of user guides or product-related documents.

Additionally, the researcher evaluated the use of bioinformatics in each product through diligent review of the product's description, technical documentation, and relevant scientific research or marketing materials. The researcher also documented keywords such as "artificial intelligence," "machine learning," "algorithms," "predictive analytics," "data mining," or any suggestion of higher-level computational analysis of spirometry data other than primary parameter calculation (i.e., FEV1 and FVC). The aim of this level of analysis was to determine if the tools employed higher-level computational methods to gain deeper insights into the spirometry data that would, in turn, enable personalized COPD management.

The review of postural methods involved briefly reviewing user manuals, product specification sheets, and any educational materials provided by the manufacturers. The researcher aimed to know if the device required or directed the user to be in a specific posture (i.e., sitting, standing, or any other indicated body position) while taking the spirometry measurement. This component of the test ascertained if the equipment accounted for and addressed the possible influence of body posture on the validity and reliability of spirometry measurements.

Through this analysis and projection of key terms, the following devices matched closely to the criteria (see Appendix 1).

Among the eight devices, only two openly speak of the incorporation of the relevant AI or machine learning technologies into their functioning. Alveoair does this by leveraging machine learning on patient data, input including triggers, symptoms, and medication intake, via the integration into the alveofit platform (Monitored Therapeutics Inc., 2025). With that, this supports the idea of harnessing computing power for more personalized assistance toward management of respiratory diseases for patients with COPD. The AioCare application incorporates a cough detection AI algorithm, and although AioCare's applications for AI are quite niche, this suggests opportunities for these technologies to maximize information gleaned from spirometry tests (Patel, 2022). The weak use of bioinformatics in this area could explain to several reasons; these include quite an entrenched status of classical spirometry parameters, the regulation of the incorporation or approval of AI in medical devices, also, the cost and complexity of building and validating such systems.

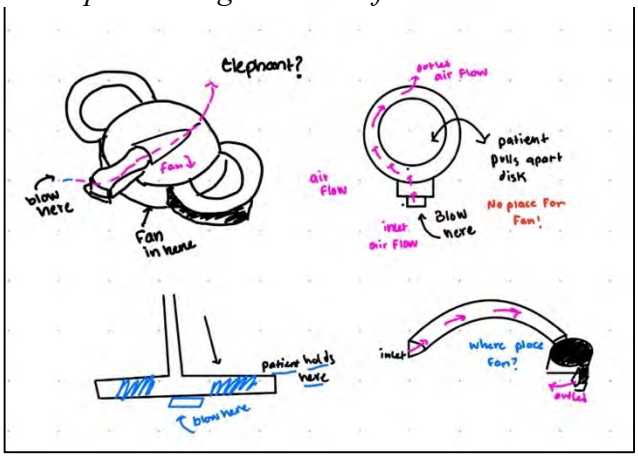
In contrast, postural techniques appear more among the nine devices that the researcher considered. Three devices-AioCare, Spirobank Oxi, and the Nascool Peak Flow Meter-advise or require certain postures during spirometry testing. AioCare gives the most specific requirement: seated posture for dynamic spirometry and standing for the PEF test (Patel, 2022). This indicates acknowledgment that different tests of lung function may find advantage from different bodily positions. Spirobank Oxi advises that the device measures the patient's spirometry tests either seated or standing upright, while Nascool recommends using standing or sitting upright (Nascool, Spirobank, n.d). Their recommendations are due to a scientific acknowledgment that body posture could impact lung volumes and airflow, thus precursors to the validity and reliability of spirometry measures. For example, an upright posture might facilitate full expansion of the lungs with complete expiration. A very interesting point is that AioCare alone provides an integration of bioinformatics (cough detection) and postural approaches (personalized suggestions for the various tests) (Patel, 2022). This indicates that certain home spirometry devices for COPD patients consider sophisticated data analysis and sensitivity to body position separately, yet their introduction in one integrated solution is still remains far from mainstream. These devices continuously fail to implement physical measures that anatomically place the patient a proper postural position. Thus, this situates the deeper need for a device that does exactly that.

## Evaluation Research

The content analysis established the related gap, further constructing the device that seeks to establish trends and create a predictive model of estimating PEFR based on data analysis and validation is key. This would justify the evaluation research methodology, focusing the goal on just evaluating the efficacy of the device. This study would evaluate and prove that the method of using Faraday's Law and posture in a device to track COPD is possible. Additionally, the engineering design process sets guidelines with the development of this device, beginning with problem definition from the extensive literature review that highlighted the lack of existing PEFR monitoring devices that also addressed posture. Studying the textbook implications of this process allowed the identification that this would be a mix of development and new design methods. This means that the design starts from an existing product but ends up being unremarkably similar towards the end of the process (Engineering design textbook). The brainstorming phase involved the generation of several potential designs that would include posture correction features and airflow measurement (see figure 3).

**Figure 3**

*Conceptual Design Sketches for Posture-Corrective Spirometry Device*




*Note.* Product concept sketches during the brainstorming process.

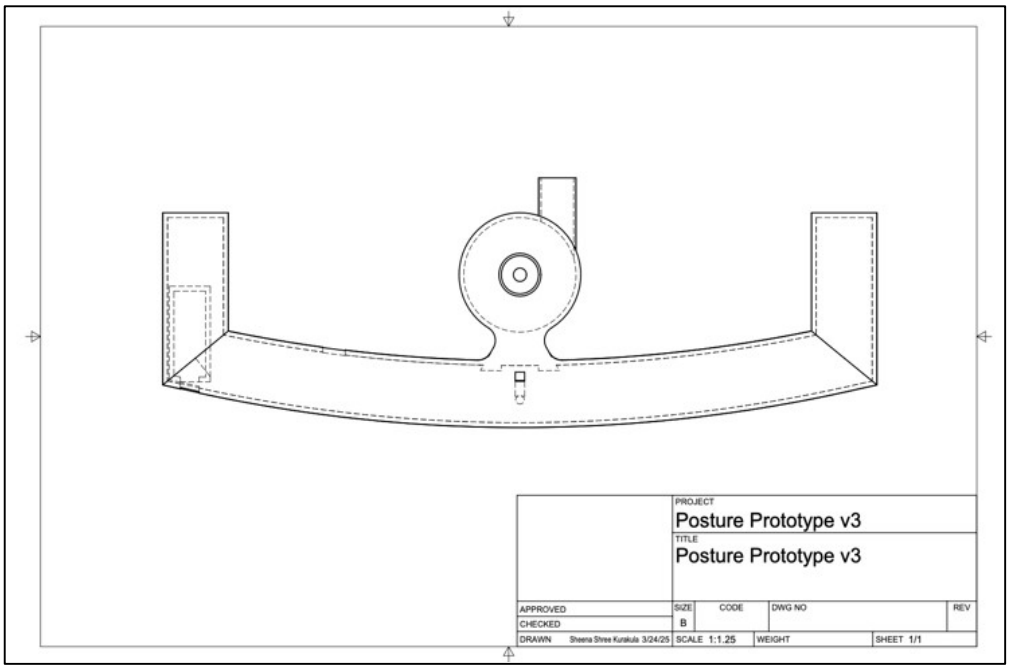
The student researcher developed a model prototype while considering the ergonomic factors that could influence usability and accuracy of measurement. One of the primary challenges involved making the device not only accurately measure PEFR, but also to encourage good posture while exhaling. Research proves that posture significantly impacts pulmonary function, and thus the device needed to bring about an optimum body position without causing any further discomfort to the subject. Chest mobilization maneuvers, which increase the efficiency of ventilation. Thus, the researcher incorporated this concept into the first designs. The researcher learned and implemented by adapting the work of Donrawee Leelarungrayub with the Department of Physical Therapy at Chiang Mai University, in Thailand. By employing chest mobilization techniques, which enhance the biomechanics of the thoracic cage, comprising the sternum, ribs, and thoracic vertebrae, clinicians can improve ventilation and gas exchange. Specifically, these techniques aim to increase the length and function of the intercostal muscles and diaphragm, facilitating effective contraction during inspiration (Leelarungrayub et al., n.d.). The study emphasizes that expanding the chest wall, through movements like rib torsion, lateral stretching, and trunk rotation, improves

the anterior superior movement of the upper costal and lateral-superior movement of the lower costal regions, along with the downward movement of the diaphragm (Leelarungrayub et al., n.d.). This anatomical benefit leads to the conclusion that the device must support the chest wall laterally. This can be done with a design that aims to assist in fully expanding the chest wall (see Figure 4).

**Representation of Final Device in Computer Aided Design (CAD)**

The student researcher settled on the final model to have a mouthpiece to direct airflow into a chamber that had a fan inside, which rotates with the release of air. This results in producing a voltage output proportional to airflow intensity. The student researcher designed the prototype with Fusion 360. The researcher followed the steps to achieve the final model (see Appendix 2).

**Figure 4**
*Orthographic Design of Postural Support Device*




*Note.* Orthographic Sketch of device the prone position (left) and the tripod position (right) (see Appendix 6).

**Assembling the Device**

**L**eelarungrayub's research provides a foundational understanding of the thoracic cage's complex biomechanics and its critical role in respiratory function (Leelarungrayub et al., n.d.). This core principle highlighted that a device with enhanced spirometry would correlate with enhanced chest wall mobility. Although this is true, the true strength of the prototype lies in its integration of advanced fabrication and control technologies.

Shahrubudin and others at the University Tun Hussein Onn, in Malaysia, underscore the transformative potential of 3D printing in medical device development. By employing PLA filament, which the researcher chose for its lightweight and robust properties, one can learn to

leverage the advantages of additive manufacturing to rapidly prototype. Also, PLA is a sustainable option, as the material is biodegradable due to its' natural composition (Shahrubudin et al., n.d.). This approach not only accelerates the design cycle but also enables the creation of complex geometries that would be challenging to produce using traditional manufacturing methods (Shahrubudin et al., n.d.). The ability to iterate and refine the design based on user feedback and performance data is a significant advantage, particularly in the context of medical devices where precision and comfort are paramount.

To further create a working device and visualize the current and rotation, the researcher used an Arduino Nano. This elevates the device's functionality beyond simple mechanical support. The Arduino Nano serves as the central processing unit, enabling precise voltage regulation and data acquisition (Arduino documentation). This is crucial for accurately measuring and analyzing spirometry data. The meticulous mounting of the fan and motor assembly within the chamber, ensuring precise alignment and free rotation, is essential for creating a consistent and reliable airflow conduit. The Arduino Nano's ability to regulate voltage and process data in real-time allows for the accurate measurement of airflow rates and volumes, which are fundamental parameters in spirometry. The careful wire and soldering processes during assembly ensure durable electrical connections, minimizing signal interference and loss. This attention to detail is critical for maintaining the accuracy and reliability of the device's measurements. The mouthpiece, which the researcher designed for a snug and comfortable fit, further enhances measurement accuracy by preventing air leakage and ensuring that all airflow directs through the sensor system.

**Correlational Research**

To further transmit and interpret this data, the prototype uses Faraday's Law of Electromagnetic Induction:

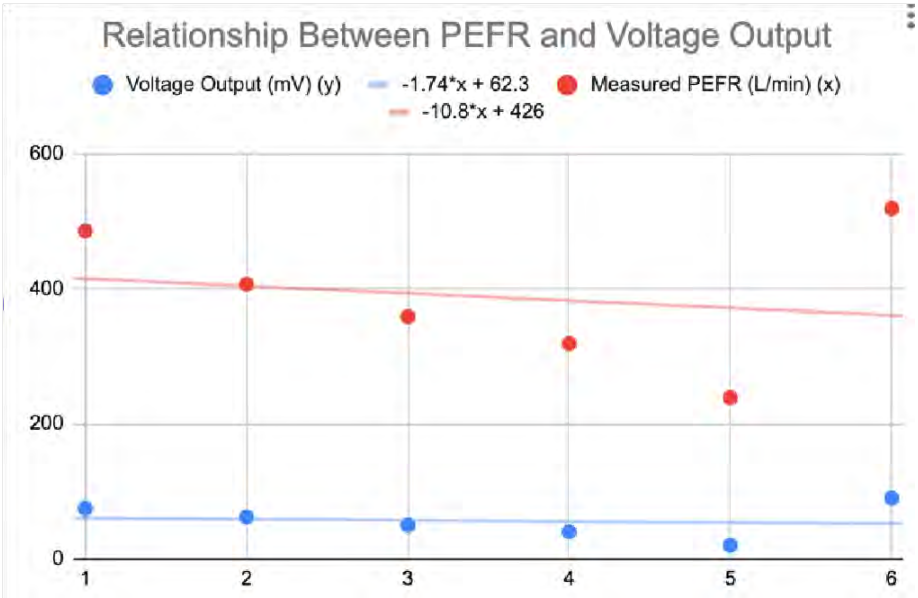
$$\varepsilon = -N\frac{d\Phi_m}{dt}$$

This is where a variation in magnetic flux induces an electromotive force (EMF) in a conductor (Faraday, 1831). Here, the fan serves as a rotor and attaches to a small direct current (DC) motor, which serves as a generator. When the user exhales, the airflow makes the fan rotate, thereby generating a voltage output directly proportional to the rotational speed of the fan. PEFR readings is the average of the strongest consistent value. Since this relationship is proportional, the idea behind using this for spirometry is to derive an equation that can correlate the output voltage to a PEFR reading. This would justify the methodology of using correlational research to make this mathematical connection. To make the results consistent, the researcher made the code time-based. Rather than relying on instantaneous peak voltage readings, which fluctuate, the Arduino Nano continuously samples the voltage output at short intervals (every few milliseconds). This stream of data buffers over 0.5-second windows. Within each window, the algorithm identifies the voltage value that occurs most frequently. This "most consistent voltage" represents the stable airflow measurement, effectively filtering out transient spikes or drops from turbulent airflow. The system then uses filtered voltage as the input for the PEFR conversion equation, ensuring a more accurate and reliable measurement. The Arduino code then takes this voltage and converts it to a PEFR value using a derived equation (see process for deriving equation in Appendix 3):

**Figure 5**
*Voltage-To-PEFR Conversion Data and Correlation Analysis*

| Trial # | Voltage Output (mV) (y) | Measured PEFR (L/min) (x) |
|---|---|---|
| 1 | 75 | 485.68 |
| 2 | 62 | 406.68 |
| 3 | 50 | 358.68 |
| 4 | 40 | 318.68 |
| 5 | 20 | 238.68 |
| 6 | 90 | 518.68 |

$$PEFR = \frac{(Voltage + 39.67)}{0.25}$$




*Note.* Data Chart and Visualization of the Data These images serve as a visual representation of the data collected throughout the trials. The first chart documents testing the device by blowing into the model and keeping track of the output voltage amounts from each trial.

**Experimental Research**

To obtain the data and inputs, the researcher used aspects of experimental research. Continuously testing the variable, voltage, in a controlled environment led to the ability to test and validate the mathematical equation above. Since per Faraday's Law, if the rotation around a magnet, in this case a fan, is proportional to the voltage created then the researcher assumes it to be a linear and proportional relationship with PEFR. Therefore, to find this equation one must find

a linear equation of the form: y = mx + b, where 'y' is the voltage output, 'x' is the PEFR, 'm' is the slope, and 'b' is the y-intercept.

The researcher used Arduino programming to allow efficient control of data acquisition, filtering, and conversion processes. This was also experimental, as it required constant inputs to test the validity of the code. It follows a structured workflow to ensure accurate measurements:

The researcher used C++ in the program Arduino IDE. The initialization stage initiates serial communication and configures input/output pins. Data acquisition periodically samples voltage measurements from the motor. The peak detection is the highest stable voltage across all trials. Averaging methods help decrease noise and enhance precision as they calculate the average of three comparable measurements. When the light blinks, the LED light turns on and serial monitor displays the final PEFR. The program guarantees that temporary variations do not interfere with the measurements, thereby optimizing the precision of PEFR calculations. By averaging and filtering out noise, the system minimizes errors from variable forces of exhalation or interference from the external environment (see Appendix 4 and Appendix 5 for code).

## Results

The testing procedure confirmed that the device output voltage strongly correlated with standard spirometry PEFR values. Data analysis indicated that the relationship between voltage output and PEFR was linear, allowing for the determination of a precise conversion formula. The device recorded stable consistent voltage values, and the researcher implemented filtering mechanisms to provide precise data capture. Also, the researcher found the effect of posture to be applicable if people adopted proper exhalation procedures.

### Ethical Considerations

Due to the nature of the study, the researcher did not employ participants, which meant it did not require an Institutional Review Board (IRB) approval. Instead, the researcher conducted testing by exhaling at different pressures. The researcher decided on maximizing efficiency throughout the data process whilst obeying the general IRB board guidelines. The design of the device minimized possible risks, considering that it was noninvasive and there was no need for any physical alterations to the user. Additionally, the researcher followed strict hygiene procedures with proper sanitation and sterilization methods.

### Constraints and Limitations

While the device displayed high accuracy in PEFR estimation, there were several limitations. Variability in methods of exhalation by the user brought in inconsistency in readings, since the effort was not necessarily maximal with each exhalation. Some attempts did not have enough air pressure to make the fan spin, which caused a mechanical error. Also, ensuring that the epoxied fan onto the 5-volt DC motor shaft was efficiently spinning the collar was an uncertain factor. Ambient factors such as temperature and humidity from the environment were able to affect sensor readings, which can alter voltage outputs. Long-term reliability of the fan-motor assembly was another concern, since prolonged use may result in mechanical wear, leading to a drop in efficiency over time. Future enhancements will target these issues by instituting improved

calibration methods, integrating more environmental sensors, and strengthening the mechanical aspects of the device to improve longevity and stability.

Additionally, the researcher tested the device with one participant interacting with it. This is a severe limitation that alters the perspective, possibly telescoping the results and containing a chance of bias. Regarding the calculations for finding the equation that converts the voltage to the PEFR, the method simply assumes that the relationship between both is linear and proportional. This hypothesis derives from the implications of Faraday's Law: Faraday's Law confirms that induced electromotive force (EMF) per turn is linear with rotational speed, which establishes a direct relationship between the fan's angular velocity and the voltage output. However, the assumption that PEFR related linearly to fan rotational velocity is a simplification. In reality, drag force on the fan is proportional to the velocity squared, meaning the model may be nonlinear. If the fan's rotations are proportionally linear to the voltage the fan generates then the voltage may be proportionally linear to the PEFR. This is model assumes the fan reaches an equilibrium condition during the patient's exhale. Ideally, this may require device-specific sensitivity calibration to decrease motor variations and keep the relationship linear. This may not be the case as the relationship can be diverse in other mathematical ways. Further iterations should explore and characterize the mathematical models for voltage-PEFR relationships.

**Future Implications and Discussion**

The methodological approaches convey and invoke the functional concept of the device, establishing a measurable link between bioinformatically determined postural influence and Peak Expiratory Flow Rate (PEFR) based on Faraday's Law. The proven implementation of a time-based consistency filter on the Arduino Nano addresses the inherent voltage noise to ensure the reliable acquisition of data from the servo motor. Although the theoretical principles and technical functionality of the device can establish credibility, an assessment of its practical working would require thorough testing of user-patient interaction. While functional as a proof-of-concept, researchers would need to carry out patient-focused trials in a real-user setting to assess thoroughly the usability, comfort, and compliance factors related to the required postural changes. Patient-centered designs are critical in ensuring that the engagement of patients with the device continues, allowing accurate and reproducible readings across a population of users.

## Conclusion

In conclusion, the device represents a promising innovation for the measurement of PEFR, bridging biomechanical postural influence and bioinformatic calculations. Successful demonstration of technical viability includes integration of 3D printing for rapid prototyping, the Arduino Nano for data acquisition, and a time-based consistency filter for signal refinement. However, to advance from scientific concept to a clinically deployable instrument, studies that comprehensively address patient interaction are necessary. Such studies will validate the device under real-life conditions, providing additional input for ergonomics to enhance user comfort across varied patient populations. Ultimately, successful realization of user interaction and clinical validation of future versions will guarantee maximum use of the device in supporting respiratory health monitoring and management.

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## Appendix 1: Content Analysis of Reviewed Devices

### GoSpiro Home Spirometer

GoSpiro Home Spirometer is introduced as a wireless device designed for use in both home and clinical environments, with the ability to capture diagnostic-quality forced spirometry (FVC) and slow spirometry (SVC) measurements (Long, n.d.). It can integrate with MTI CarePortal, a cloud-based portal that enables clinicians to remotely monitor patient well-being. Though the system provides functionality such as automatic, rule-based reporting and alerts for rapid patient triage, and the GoSpiro device itself provides built-in quality control functionality, such as cough detection and plateau recognition, no utilization of advanced computational analysis methods, such as artificial intelligence or machine learning, to the underlying spirometry data to obtain COPD-specific insight above and beyond standard parameters is apparent (Long, n.d.). The device uses an avatar-based coaching mechanism to guide patients through the testing process, providing preprogrammed instructions rather than real-time bioinformatics analysis. Neither the product manual available nor the relevant literature identifies any postural demands or suggestions peculiar to the utilization of the GoSpiro Home Spirometer.

### Cap Medic

CapMedic is an innovative device that is fitted to metered-dose inhalers (MDIs) and dry powder inhalers (DPIs) to give real-time audio-visual feedback for the appropriate use of inhalers (Gardiner et al., 2010). It also acts as a home spirometer, monitoring FEV1 and PEF levels. One section describes AioCare as using artificial intelligence to detect coughs (See section E) (Patel, 2022); it is possible that CapMedic, with its focus on respiratory monitoring and a cloud-based system, might also incorporate some form of artificial intelligence to deal with similar goals or to analyze inhaler use trends (Gardiner et al., 2010). However, the extent to which bioinformatics is used in analyzing basic spirometry data for chronic obstructive pulmonary disease management is not clearly described. CapMedic provides guidance on the correct angle and position of the inhaler when it is being used, with an emphasis on keeping the head in an upright position to facilitate efficient delivery of the medication. However, this postural guidance is limited to the inhalation technique, as opposed to the spirometric function of the device. There is no specification or recommendation of the posture required when using CapMedic for spirometric testing.

### Alveoair Digital Spirometer

Alveoair is a home spirometer for patients with asthma, COPD, cystic fibrosis, and ILD to monitor their lung status. It connects to the Alveofit mobile app, which is claimed to have an "inbuilt intelligent machine learning system" (Monitored Therapeutics Inc., 2025). The system analyzes triggers, symptoms, and medication use patterns to provide relevant insights to help users better manage their respiratory conditions. The app employs "AIML enabled technology" to aid users in the correct performance of spirometry tests (Monitored Therapeutics Inc., 2025). This obviously points to the application of bioinformatics in analyzing respiratory data and providing personalized feedback. One research study mentioned the use of the Alveoair device with participants in an upright seated position. However, the prevailing product descriptions and user manuals do not suggest that the machine or the Alveofit app generally demands or advises users

to assume a particular posture for usual home application. Even though the app provides guidance on properly taking the test and provides feedback on errors, it does not detect posture as an important variable for standard measurements.

**NuvoAir Air Next Spirometer**

The NuvoAir Air Next Spirometer is an FDA-approved device for home usage, which is used to record pulmonary function and conduct spirometry in adults and children (CapMedic, n.d.). It connects to the NuvoAir Home app via Bluetooth and enables ongoing monitoring and transmission of highfidelity pulmonary data to medical professionals (CapMedic, n.d.). While NuvoAir's platform employs advanced monitoring technology and analytics, there is no explicit mention of the utilization of bioinformatics, artificial intelligence, or machine learning to specifically interpret the spirometry data acquired by the Air Next device for insights outside of conventional spirometry parameters (CapMedic, n.d.). Additionally, the information available on the NuvoAir website does not indicate that users need to assume any specific posture when conducting spirometry tests. The instructions instead concentrate mostly on the correct usage of the device itself and the associated app, including how to place a new turbine and maintain correct technique for exhalation.

**AioCare**

AioCare is a mobile solution for the monitoring and control of pulmonary conditions like asthma and chronic obstructive pulmonary disease (COPD), which allows users to perform spirometry tests in their own homes (Patel, 2022). The system includes a mobile spirometer that connects to a smartphone app, and it is specifically mentioned that "AioCare uses an AI algorithm to automatically detect the cough during the spirometry test" (Patel, 2022). This shows how artificial intelligence has been used in respiratory data analysis that relates to an event that took place during an assessment. According to AioCare's user manual, during "Dynamic Spirometry," the patient should be in a seated position, feet flat on the floor. It also mentions that, for reasons of safety, spirometry tests are usually performed in the sitting position. For the "Peak Expiratory Flow (PEF) test," the manual mentions that it is usually measured standing (Patel, 2022). The direct instruction offered implies that AioCare recommends specific positions for different types of lung function tests to ensure accurate measurements.

**Spirobank Oxi Spirometer**

Spirobank Oxi is a highly compact spirometer and pulse oximeter for remote patient monitoring, home care, and clinical trials (NuvoAir, n.d.). It is connected to a smartphone application through Bluetooth to facilitate real-time spirometry and oximetry measurements, thereby allowing the sharing of data with clinicians (NuvoAir, n.d.). While the app provides data management, visualization, and even a live video examination facility for remote consultation, there is no mention of bioinformatics, artificial intelligence, or machine learning being utilized to analyze the spirometry data to provide insights into COPD at a deeper level. The device's expertise lies in accurate measurement of standard parameters and effective remote communication (NuvoAir, n.d.).The instructions for the use of the Spirobank Oxi software suggest that "while performing a test it is advisable that you are sitting upright or standing." This recommendation

indicates that an upright posture is viewed as being advantageous to achieve valid spirometry outcomes with this device. Note, this means that the device does not force the patient into the proper anatomical posture, just advises. G. Safety Pocket Spirometer

The Safety Pocket Spirometer is a handheld spirometry device that has Bluetooth and is FDA-cleared for home usage. It calculates a few spirometric values and is equipped with a user-friendly mobile application that is compatible with both Android and iOS, enabling users to monitor their lung health and export reports (AioCare, n.d.). While the device includes provisions like developer mode with SDK support, suggesting future potential for third-party applications, there can be no suggestion that the Safey Pocket Spirometer itself uses inherent bioinformatics, artificial intelligence, or machine learning to analyze the spirometry data as it relates to COPD (AioCare, n.d.). The product and applicable information do not state any explicit postural requirements or suggestions for the use of the Safey Pocket Spirometer in home spirometry.

**Nascool Peak Flow Meter**

Nascool Peak Flow Meter is a digital meter for measuring FEV1 and PEF and connects to a smartphone app via Bluetooth for the monitoring of asthma and COPD (MIR Medical International Research, n.d.). The app allows patients to track triggers, medication, and symptoms, and the app can generate an asthma action plan. Although the app provides facilities for the management of respiratory conditions, there is no mention of the use of advanced computational analysis, artificial intelligence, or machine learning with the spirometry data for obtaining COPD-specific information alongside standard measurements and rule-based zone signs (MIR Medical International Research, n.d.). The instructions for use of the Nascool Peak Flow Meter are: "Stand or sit well and straight." This strictly implies that the manufacturer promotes holding the upright position while taking the measurement to obtain precise results (MIR Medical International Research, n.d.). Again, this is not a device that implements this but advises this concept.

**Figure 6**
*Content Analysis Chart*

| Device Name | Uses Bioinformatics | Uses Postural Methods |
|---|---|---|
| A. GoSpiro Home Spirometer | No | No |
| B. CapMedic | Possibly | No |
| C. Alveoair Digital Spirometer | Yes | No |
| D. NuvoAir Air Next Spirometer | No | No |
| E. AioCare Home Spirometer | Yes | Yes |
| F. Spirobank Oxi Spirometer | No | Yes |
| G. Safey Pocket Spirometer | No | No |
| H. Nascool Peak Flow Meter with Bluetooth APP Spirometer | No | Yes |

*Note.* This chart serves as a condensed analysis of the criteria imposed on the various devices.

## Appendix 2: Instructions for Designing the Device in Autodesk Fusion 360

1. A basic circle was drawn to outline the main structure of the device.

2. The circle was extruded in a cylindrical fashion, with a 0.1-inch outer wall offset employing midplane extrusion for symmetry.

3. A section view was utilized to verify the internal structure, ensuring the internal chamber was hollowed as required.

4. The cylinder was shelled to form the primary airflow chamber.

5. An intake for airflow was imagined by drawing a smaller circle tangent to the walls present to enable free airflow.

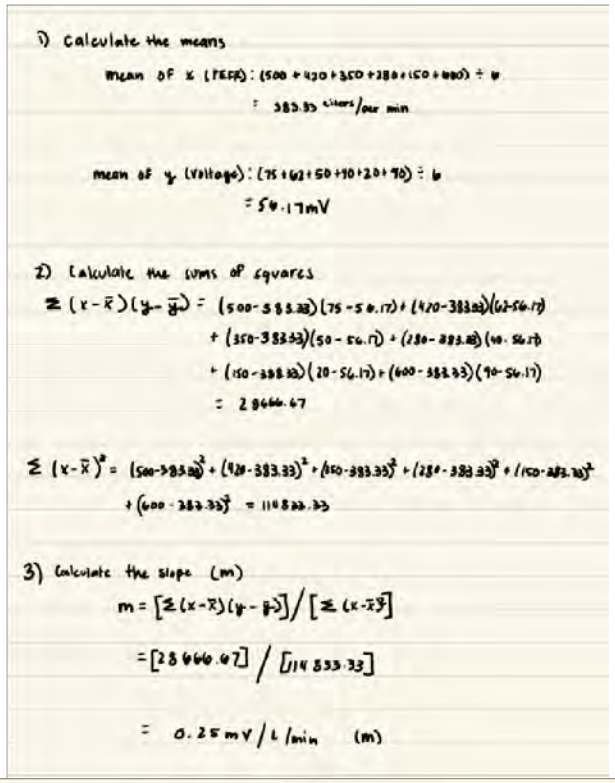
6. The smaller circle was extruded inward to connect with the internal cavity, creating the airflow channel.

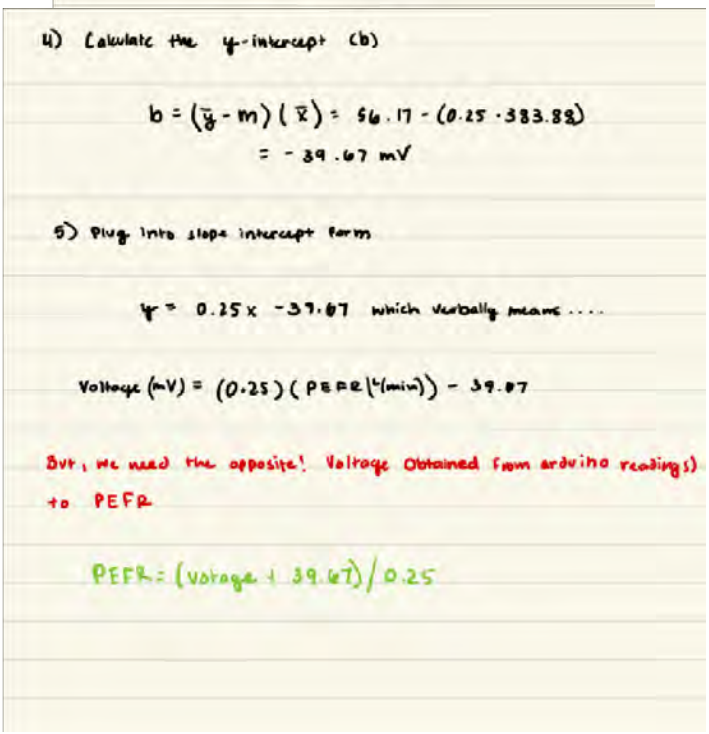
7. The fan casing and mouthpiece attachment were crafted through extruding and offsetting processes of additional components to provide for the rotation system.

8. Handles were incorporated with a swept boss/base feature to facilitate ergonomic handling and stability.

9. The ultimate model underwent refinement to incorporate sections that facilitate smooth airflow transitions, thereby reducing turbulence and enhancing measurement accuracy.

Appendix 3: Process for Deriving the Equation that Finds PEFR from Voltage



## Appendix 4: Code for Bioinformatic Posture Device (C++ Language)

```
int LED = A0;//declares a variable setting
LED=A0 int motor = A7;//declares a variable
setting motor = A7
int voltBits = 0;//a starting value for
something defined below int volts = 0;//a starting value for
something defined below int prevVolts = 0;//a starting value for something
defined below
  int savedVolts[3] = {0, 0, 0};//saves a 1x3 matrix of the read volt values
starting at one. int avgVolt = 0;//saves the final average
volt value
  int maxVolt = 0;

  void setup() {  // setup code to run once:
  pinMode(LED, OUTPUT);//we want to output a voltage to the light so we
declare the LED pin as an output pin
  pinMode(motor, INPUT);//we want to read the input voltage coming from the
moto so we declare the motor pin as an input pin.
  analogWrite(LED, 150);//writes a value equal to 150*(5/255)V to the LED in
this case around 3V
  Serial.begin(9600);
  }
  void loop() { while
((savedVolts[0]==0)||(savedVolts[1]==0)||(s  avedVolts[2]==0)){//loop  will
continue  until  a  value  is  found  for  all  3  savedVolts  values.
Serial.println("waiting  for  values");     volts  =  analogRead(motor);   if
(volts>4){//checks that the voltage value is no longer changing and that it
is reading a value greater than zero(plus some room for error)
     maxVolt = maxValue(motor);
  Serial.println("We have sucesfully returned from maxValue function");
   Serial.println("Maxvolt is:");      Serial.print(maxVolt);     for (int
  i=0; i<3; i++){//goes through
i=1 i=2 and i=3
       if (savedVolts[i]==0){//checks if
the savedVolts matrix value is empty       savedVolts[i]=maxVolt;//if it is
empty it assigns it the volt value
          Serial.println("We  have  sucesfully  wrote  to  savedVolt  matrix
column:");
               Serial.print(i);        break;//no need to change any other
values so break out of the for loop and keep looking for more values
       }
     }  }  delay(50); }
 Serial.println("All  values  have  been  determined  and  we  can  now  take  the
average");
   Serial.println(savedVolts[0]);
     Serial.println(savedVolts[1]);            Serial.println(savedVolts[2]);
  avgVolt=(savedVolts[0]+savedVolts[1]+sav
edVolts[2])/3;//finds  the  average  volt  value  for  increased  accuracy  while
(true){//will  never  exit  loop    analogWrite(LED,  150);    delay(500);
analogWrite(LED, 0);  delay(500);//blinks LED
   Serial.print("The average volt value is: ");//prints out the average volt
value so it is displayed in the serial monitor. Use computer and open Arduino
IDE.
   Serial.println(avgVolt);
   }
```

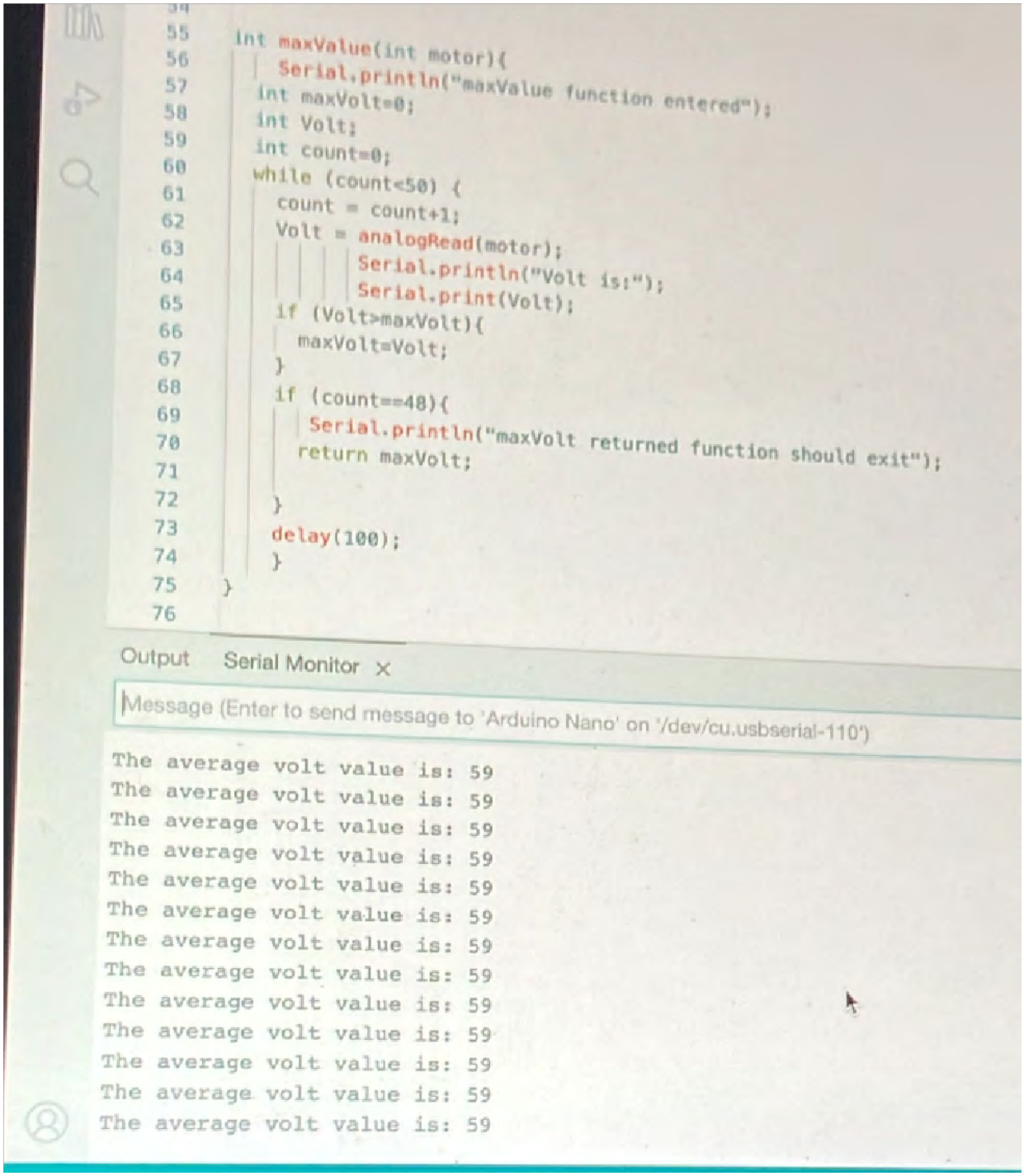
```
  }

  int maxValue(int motor){
     Serial.println("maxValue function entered");  int maxVolt=0;  int Volt;
int count=0;  while (count<50) {   count = count+1;   Volt = analogRead(motor);
            Serial.println("Volt is:");          Serial.print(Volt);    if
  (Volt>maxVolt){      maxVolt=Volt;    }    if (count==48){
      Serial.println("maxVolt returned function should exit");
        return maxVolt;

     }    delay(100);
     }
```

## Appendix 5: Real Life Application of Code

**Figure 7**
*Output When Code is Run*




*Note.* This figure shows the output when the code is run. The result is viewable in the Serial Monitor of the Arduino IDE software.

## Appendix 6: Orthographic Drawings of Device

**Figure 8**
*Side View of Device*

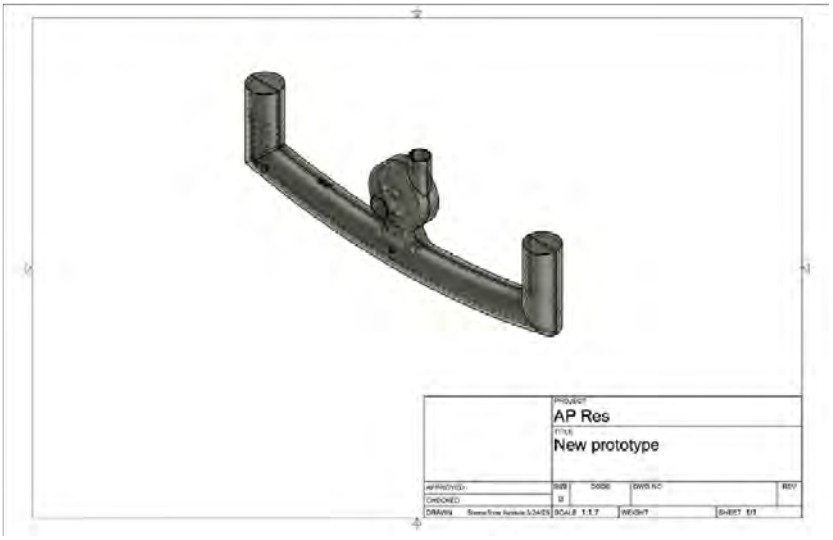



**Figure 9**
*Top View of Device*



**Figure 10**
*Front View of Device*

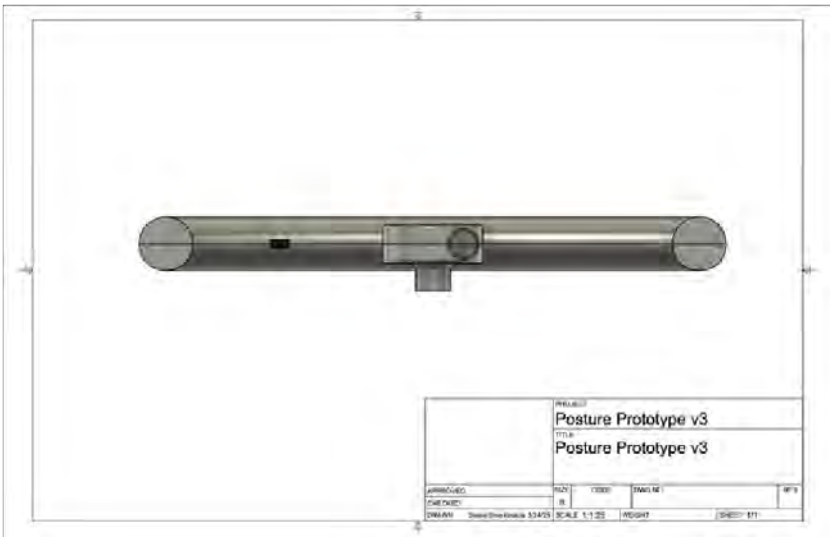
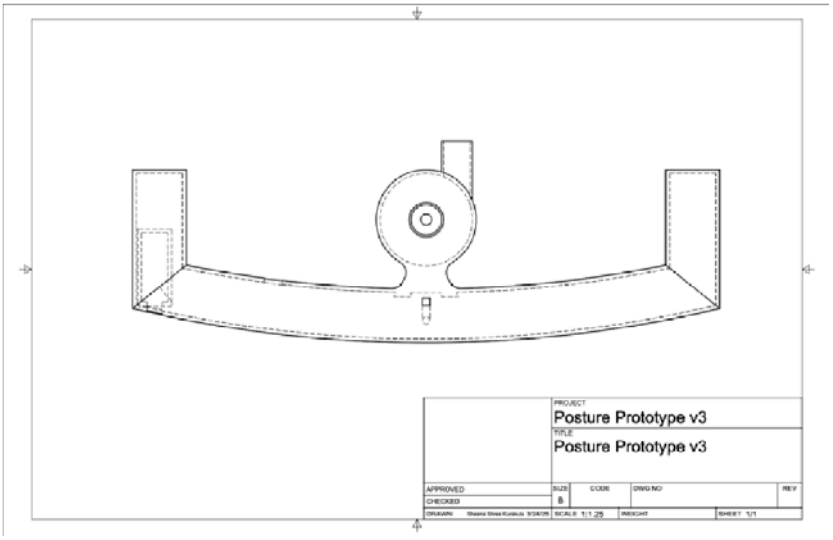



**Figure 11**
*Internal View of Device (cross section)*



## Appendix 7: Photos from the Assembly of the Device

**Figure 12**
*Arduino Nano Connected to the Device*

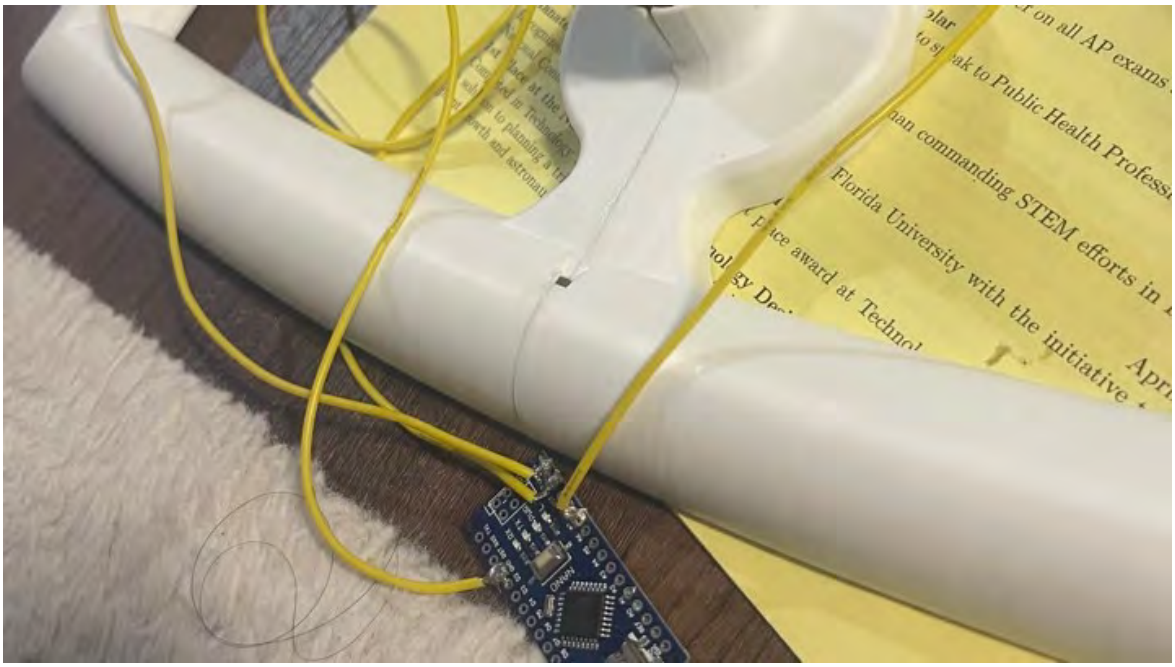



**Figure 13**
*Motor Installed in the Motor Cavity*



**Figure 14**
*Internal View of Fan in Device*

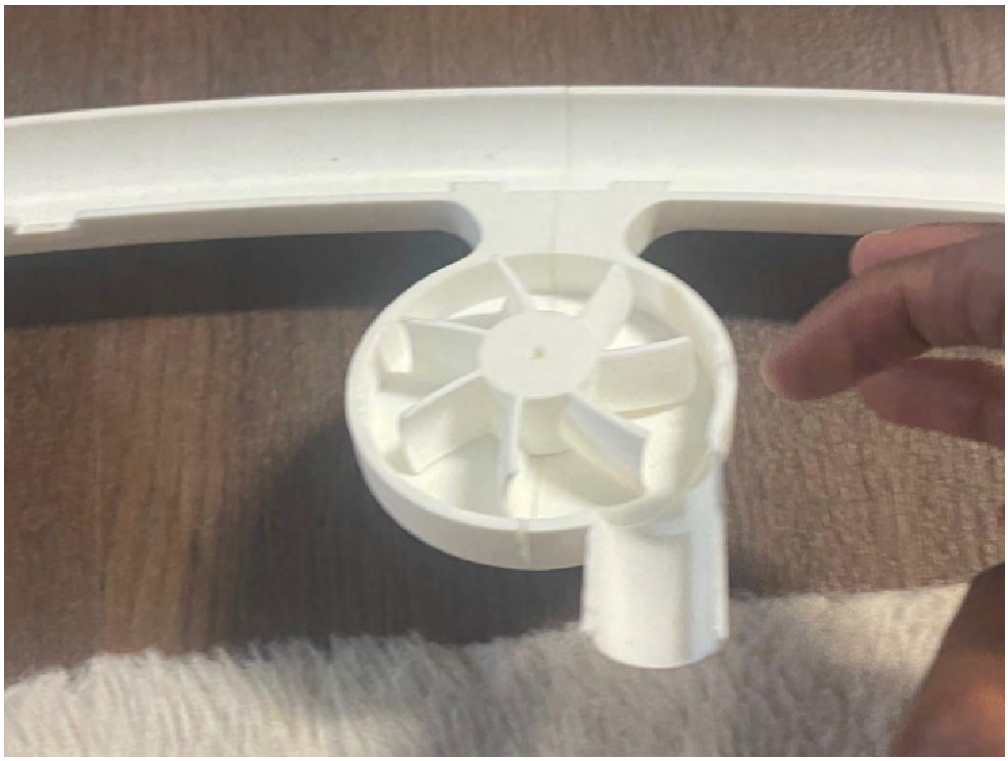
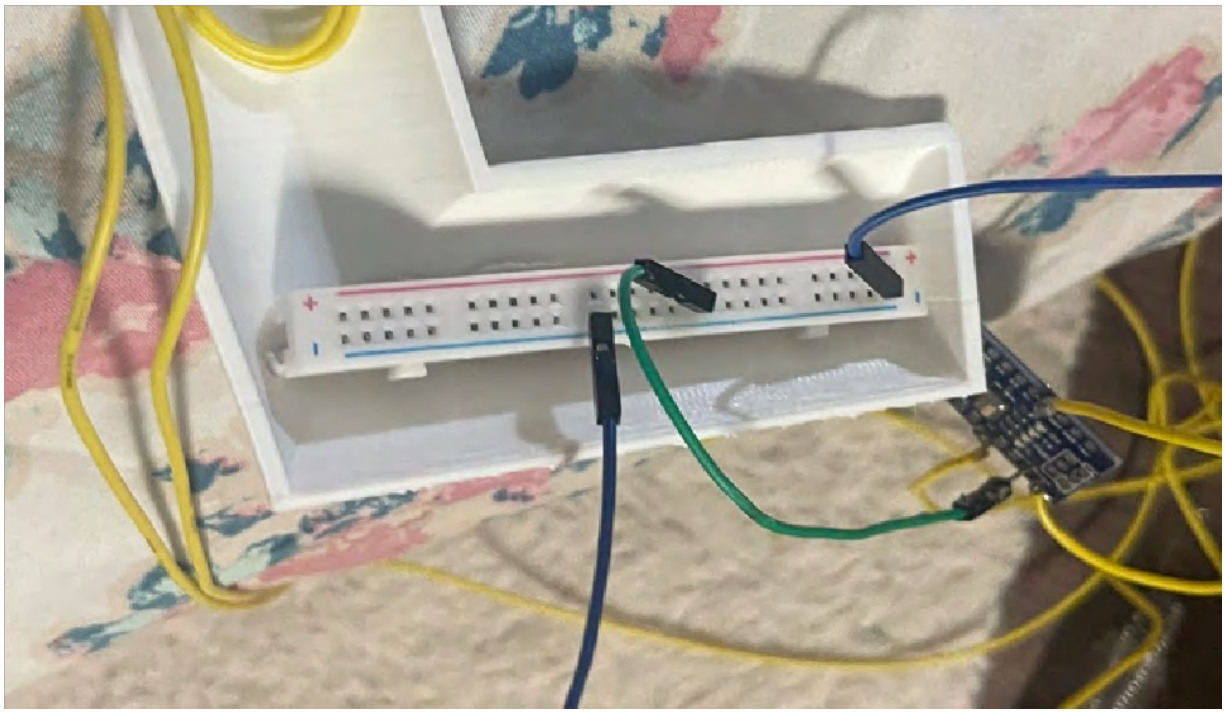


**Figure 15**
*DC Motor Installed in the Motor Cavity; Error in Dimensions of Motor*



**Figure 16**
*Breadboard Supplying Power to Various Components*



## About the Author

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## Discussion Questions

1. What are the limitations of using Faraday's Law to measure PEFR, and how could future iterations of this device address these limitations to improve clinical reliability?

2. How might this device's approach to combining postural optimization with spirometry be adapted for other respiratory conditions beyond COPD, such as asthma or cystic fibrosis?

3. How could bioinformatics be further enhanced in this device to be more personalized in managing COPD exacerbations and detection of flare ups?

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# Book Review

## Book Details

Severini, T. A. (2026). *Analytic methods in sports: Using mathematics and statistics to understand data from baseball, football, basketball, and other sports* (3rd ed.). A Chapman and Hall Book. CRC Press. 480 pages + illustrations. ISBN-13: 978-1-03283-600-3.

## Reviewer

Howard Bartee, Jr., Ed.D.

## Synopsis and Evaluation

The *Analytic Methods in Sports (2026)* book is a comprehensive examination of how reasoning, modeling, and different tools impact the way fans, athletes, coaches, data analysts, and sports management practitioners view sports. Within this book, the author combines statistical concepts with analytical techniques to create different data visualizations within the field of sports by using sports datasets from different genres in the field of sports. According to Pedersen and Thibault (2022), "used correctly, statistical information completes the research process, but if used improperly, statistics can be misleading at best and incorrect at worst" (p. 140). Oftentimes, "people will say a good test must have objectivity, reliability and validity, but it is actually the data that must be good because important decisions are made based on the data" (Baumgartner et al., 2021, p. 203). From reviewing the 10 chapters in this book, it was encouraging to see how the author focuses on technology through the lens of data analytics in the field of sports.

### *Sports Technology*

As the field of sports changes with the addition of improved technology, the book brings attention to different statistical tools. The use of machine learning methods seeks to allow analysts to move beyond regular math to higher levels of math usage. The book, through the use of open sports datasets, shines a light on different aspects of player behavior, team strategy, and game dynamics. The integration of technology tools makes what was once abstract in the old days more concrete in today's evolving world of sports. With fantasy sports growth, prediction models are now shaping the expansion of technology into different platforms and tools that now shape decision making within different sports, like football, basketball, and baseball.

### *Sports Data Analytics*

At the same time, the lens of data analytics is expanding as this book explains how sports now include their own life cycle – from data collection to data visualization. The book focuses on data quality and data analysis, and how different sports generate different types of data. For example, in baseball and basketball, a focus may be on the play-by-play logs, while in football and hockey, the attention may be on analytic approaches that look at other factors, such as time of possession. In both instances, the interpretation provides analysts and bio-mechanists with information they can translate and make available for coaches, players, and executives to use. With this real-time information, these stakeholders can frame data analytics as a practice in data science grounded in rigor, clarity, and detail for those emerging sports technology and data analytics professionals with backgrounds, both inside and outside of sports.

### *Implications of Sports Technology and Sports Data Analytics*

The implications of analytics methods in sports extend far beyond sports technology and data analytics that Severini presents in the book to various levels of engagement. At the *league level*, the book suggests that analytic insights can inform rule changes, scheduling adjustments, and competitive balance initiatives, ensuring that sports remain both fair and entertaining, while at the *management level*, the book also suggests that analytics will continue to shape contract negotiations, improve injury prevention programs, and assist with long-term roster planning as teams adopt sports technology and data analytics. Additionally, at the *fan level*, the book suggests that there is deeper engagement through fantasy sports, different platforms, and interactive visualizations that make complex data accessible and enjoyable. Finally, in this book review, analytic methods are not merely tools for understanding sports; they also influence how sports evolve, how decisions are made, and how the ecosystem of athletes adapt to a today's data-rich world, which is why my book recommendation is one of a sports must-read.

### In the Author's Own Words

"For many of the examples given in this book, there are several possible sources for the data, and a specific source is not given. This is generally the case when the data analyzed are based directly on game results. Although all sites for a given sport contain the same basic data, different sites often contain different specialized data, such as 'splits,' data for specific situations, or 'advanced statistics' that have been calculated from the basic data. Many of the datasets analyzed in this book are available in Excel format by following the link on my website (http://www.taseverini.com)." (Severini, 2026, p. 4)

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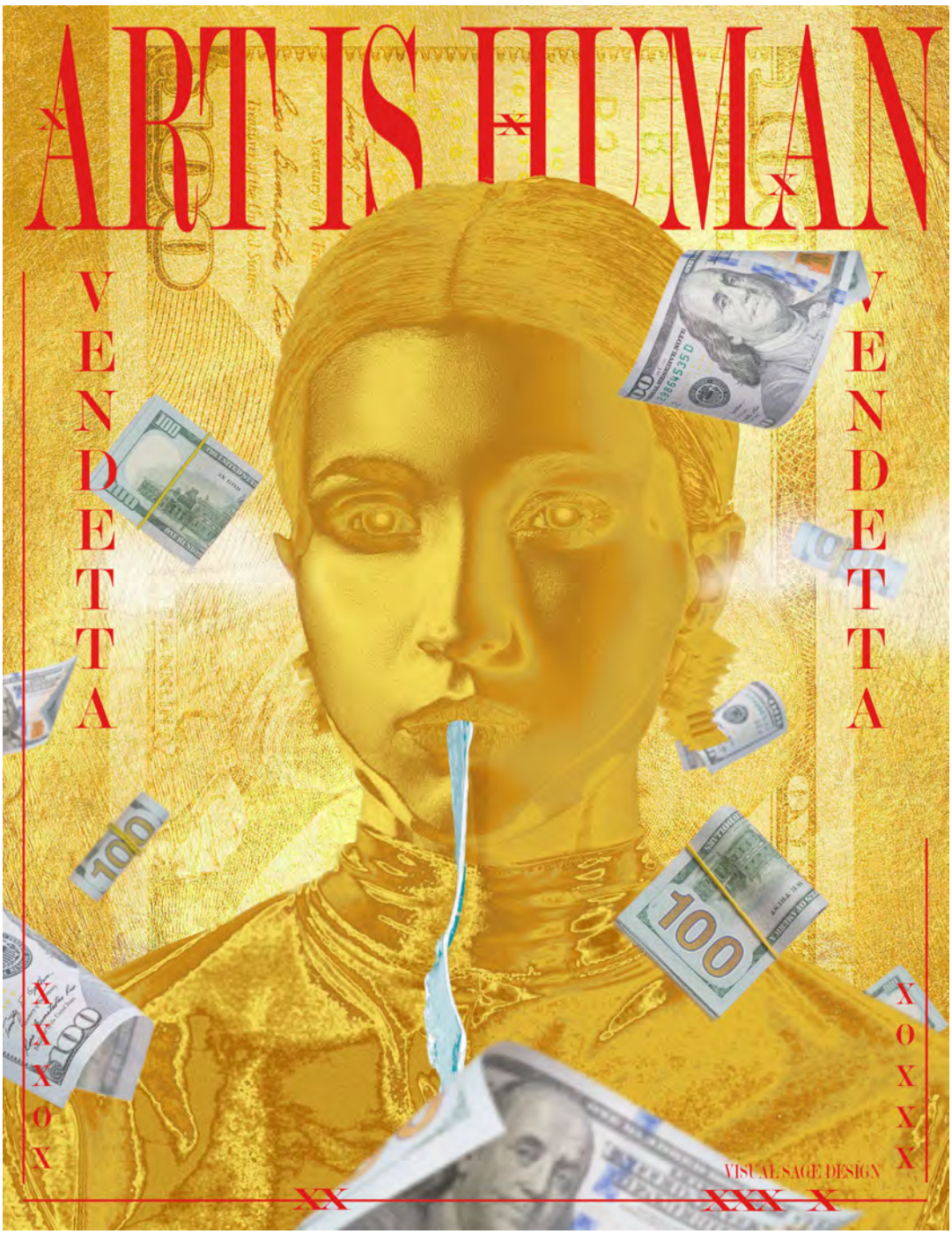
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**Reviewer's Details**

Howard Bartee, Jr. Ed.D. (hobartee@pvamu.edu), is an Assistant Professor in the School of Public and Allied Health at Prairie View A & M University, in Prairie View, Texas. His area of expertise is in Education with a specialization in Sports Management. His research interests include sports management and communication, sports analytics, and organizational behavior within the context of health and kinesiology.

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"Art is Human"

Affinity (Digital Media)
8.5" x 11"
2026

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# Featured Artwork

## Caramia S. Frallicciardi
*State College of Florida, Manatee-Sarasota*

On page 4:

"Golden Mato"
Photography, Samsung S20+
10.08" x 13.44"
2026

A photo of one of two golden tomatoes from my Aunt's garden. My Aunt had called out to me proudly to come look at some tomatoes she was growing. I was intrigued and stepped out to the backyard and saw two glowing hints of yellow buried beneath leaves and vines. Peering through the net, I saw this tomato settled below the canopy of leaves and neighboring plants. I positioned my camera in a way that mirrored my true view, like I found a hidden gem.

On page 16:

"The Flower, Vase, and the Drape"
Acrylic on Canvas
16" x 20"
2026

A still life. I wanted to break out of my mold of hyper-realism and focus on impressionist marks, more stylized, and centered on creating feelings. I worked with one flat brush and blended by layering colors on top each other. Subdued colors make up the reflection on the lower half of the canvas. Multi-hued greens and yellow greens are spread in rounded strokes to form the vase. The subject is lit with cool toned lighting, brightening the lilac drapery and the center of the vase.

On page 46:

"Home Grown and Store Bought"
Acrylic on Canvas
12" x 12"
2026

The first painting in a series I started over the summer of 2026, which focuses on illustrative paintings of my Aunt's garden. This one includes the use of strong greens and fiery oranges, amplifying the contrast between the two sets of vegetables: home-grown zucchinis and store-bought orange peppers. I was walking to the kitchen slightly after mid-day and noticed vegetables sprawled out on the counter with harsh light hitting them. The sun was so bright, it made the peppers glow and reflect onto the zucchinis. I decided to picture this moment and pair it with a teal background, using watered-down acrylics to sparsely paint tan strokes in the background and shadow of the vegetables.

On page 120:

"Art is Human"
Affinity (Digital Media)
8.5" x 11"
2026

"Art Is Human" is a piece I made regarding the topic of Generative Artificial Intelligence (GenAI). The imagery displays the wealthy classes relation with AI and the profit it generates, at the expense of lower and middle classes access to local resources (such as potable water). A humanoid robot sits pristine, dipped in gold, in front of a massive golden $100-dollar bill. Stacks of cash cascade around the robot. Water is pouring from its mouth and steam flowing from its ears.

The typography encapsulates human resistance – a message towards companies' unethical employment of AI. A stark blood red text symbolizes passion, humanity and resistance. The X's and O's placed along the piece serve as a sarcastic interpretation of the sign off "hugs and kisses."

There are many definitions attempting to narrow what classifies something as art. Upon the research and creation of this piece – I've found the beginning for my own definition.

Art is a creation of the natural world (mostly human), that includes intent and process. A machine can only imitate, synthetically, a process or final piece based on the input it's fed. Generative AI can never be art.

## About the Artist

Caramia S. Frallicciardi Caramia is an artist and student graphic designer, currently completing her associate's degree and planning for a bachelor's degree in graphic design. She has dedicated both her personal and school life to refining her art skills and expanding her worldview to create more artistically skilled and relevant creations. She began viewing art as an escape from the world and now has begun to see another purpose for her art: using her art as a form of political and social commentary. Her pieces have placed and been highly ranked in several local art contests.

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