AI and the Human Element: Exploring the Collaboration Between Entrepreneurs and Artificial Intelligence in Decision-Making and Venture Outcomes

by

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ABSTRACT

The convergence of artificial intelligence and entrepreneurship education has opened a novel frontier in pedagogical innovation. The deployment of Orbit—a bespoke generative AI tool—within MIT's 15.390 entrepreneurship course, which follows the structured Disciplined Entrepreneurship framework, is examined through a System-of-Systems perspective. This approach reveals how the tool functions not as an isolated feature but as an integrated element within a multifaceted educational ecosystem. Drawing on quantitative usage data across three consecutive academic semesters (Spring 2024-Spring 2025) complemented by course evaluation metrics, our mixed-methods approach reveals the multidimensional impact of AI-enhanced entrepreneurial education. The findings demonstrate that Orbit, particularly in its refined v2 iteration, functions as a powerful External Enabler that significantly reduces both the opacity and agency-intensity inherent in complex entrepreneurial frameworks. This enabling function manifested through measurable increases in student adoption, idea generation, and iterative engagement with critical DE steps. Beyond efficiency gains, we identify a substantive Transformation of Learning where students developed distinctly different engagement patterns—characterized by increased iteration, greater willingness to tackle complex entrepreneurial challenges, and enhanced overall course experiences. This transformation appears to deepen rather than merely accelerate learning, as evidenced by improved course evaluations alongside increased time investment in coursework. However, our analysis reveals that this transformation operates within the constraints of what we term AI's "Jagged Frontier"—an uneven landscape of capabilities leading to differentiated impacts across DE tasks and student segments. The evolution from Orbit v1 to v2 underscores how thoughtful system design and curriculum integration critically influence the effectiveness of educational AI tools. This research contributes a nuanced understanding of how specialized AI tools can enhance entrepreneurship education while highlighting that their benefits depend on deliberate design choices, strategic pedagogical integration, and recognition of current technological limitations. The SoS framework proves instrumental in capturing these emergent dynamics, offering valuable insights for educational technologists, entrepreneurship educators, and institutions navigating the AI-enhanced learning landscape.

Thesis supervisor: Bill Aulet
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AI Use[1]

In Memory of My Uncle, Rob Lewis

'Cause the only time that I feel at ease
Is swinging up and down in a coconut tree
Oh what a life of luxury
To be like an apeman

4/17/63 - 5/13/25

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Chapter 1

Introduction

The landscape of higher education stands at a pivotal intersection with artificial intelligence. As generative AI technologies rapidly evolve, they offer not merely administrative efficiency but potentially transformative approaches to teaching and learning, particularly in dynamic, practice-oriented fields like entrepreneurship. These sophisticated tools promise personalized guidance, scalable support, and novel pathways for students to engage with complex entrepreneurial concepts. Yet amid the technological enthusiasm, a critical question emerges: How do specialized AI interventions actually influence student learning experiences, engagement patterns, and educational outcomes within established pedagogical frameworks?

Entrepreneurship education presents a particularly fascinating context for exploring this question. Traditionally anchored in case studies, mentorship, and experiential learning, this domain now encounters AI tools capable of providing on-demand assistance, structured feedback, and guided exploration of entrepreneurial methodologies. While general-purpose AI applications have received considerable research attention, there remains a significant gap in our understanding of how bespoke, pedagogically-focused AI tools interact with specific educational frameworks and diverse learner characteristics in authentic academic environments.

This thesis addresses this gap through a comprehensive investigation of "Orbit" - a specialized generative AI tool developed at The Martin Trust Center for MIT for Entrepreneurship, and implemented within the 15.390 entrepreneurship course at MIT. Rather than adopting a simplistic cause-effect perspective focused solely on the technology, this research employs a System-of-Systems (SoS) framework to examine how Orbit functions as an integral component within an interconnected educational ecosystem. This approach enables us to explore the dynamic interplay between four constituent systems: the AI tool itself, the student/team learning unit, the structured Disciplined Entrepreneurship (DE) framework, and the broader educational environment.

The core research questions guiding this inquiry are:

1. Within the 15.390 Disciplined Entrepreneurship learning System-of-Systems, how does the introduction and evolution of the Orbit AI tool, from v1 to v2, and between semesters, influence student/team engagement patterns with the DE framework and overall learning system performance, including indicators of transformed engagement and learning outcomes (as indicated by course-level outcomes and DE process progression)?

2. What are the defining characteristics of interactions at key interfaces within the entrepreneurial learning SoS, and how do these characteristics evolve with the transition from Orbit v1 to v2, and between semesters, impacting tool adoption and use?

3. How do observable student/team engagement segments and user personas appear to mediate their interaction with the Orbit AI tool and their navigation of the DE process within the SoS?

4. Within the Orbit-DE Framework interface, which specific steps or phases of the Disciplined Entrepreneurship framework exhibit the highest and lowest levels of engagement via the Orbit tool, and what does this suggest about Orbit's current capabilities in supporting the entrepreneurial process?

5. Based on the SoS analysis of Orbit v1 and v2, and between semesters, what system design principles and architectural modifications for the Orbit tool, and what pedagogical integration strategies for the 15.390 course, can be recommended to more effectively foster transformative entrepreneurial learning (beyond mere acceleration) within this AI-enhanced learning System-of-Systems?

Through mixed-methods analysis of quantitative tool usage data spanning three academic semesters (Spring 2024, Fall 2024, and Spring 2025) alongside qualitative insights from course evaluations, this research reveals Orbit's multifaceted impact. The evidence demonstrates that Orbit functions as an effective External Enabler that fundamentally alters the conditions for entrepreneurial learning. Beyond merely accelerating existing processes, it facilitates a genuine Transformation of Learning, fostering deeper, more iterative engagement with entrepreneurial concepts. However, this transformation is consistently mediated by what we term the "Jagged Frontier" of AI's capabilities—the uneven landscape of what current AI can effectively support, resulting in differentiated impacts across student populations and entrepreneurial tasks.

The chapters that follow provide a comprehensive exploration of this complex educational system-of-systems. Chapter 2 establishes the theoretical foundations through a Literature Review spanning SoS theory, AI in education, entrepreneurship pedagogy, and relevant learning frameworks. Chapter 3 details our Methodology, including research design, data collection approaches, and analytical strategies. Chapter 4 presents empirical Results from our multi-semester analysis, while Chapter 6 synthesizes these findings through our SoS lens, exploring emergent properties and interactions between system components. Finally, Chapter 7 articulates key Conclusions and offers actionable Recommendations for tool developers, educators, and researchers navigating this evolving intersection of AI and entrepreneurial education.

This research contributes not only to our understanding of how AI tools transform entrepreneurial learning in time-constrained educational settings but also provides a sophisticated theoretical framework for analyzing similar technological interventions across educational domains

Chapter 2

The Entrepreneurial System of Systems

2.1 The Entrepreneurial Learning System-of-Systems Framework

The increasing complexity inherent in modern educational environments, particularly with integrating novel technologies such as generative artificial intelligence (AI), necessitates robust analytical frameworks. System of Systems (SoS) theory offers a valuable lens for understanding and navigating such intricate landscapes [2] [3] [4]. This approach is particularly important when examining the diverse impact of generative AI on entrepreneurial learning. The rationale for employing an SoS framework in this context stems from its capacity to deconstruct a complex, interconnected network of interactions into more manageable components, thereby facilitating a clearer analysis of the whole [5].

Lock et al. define a system of systems as "a collection of systems both technical and socio-technical which pool their abilities to present a more complex system, whilst retaining their individual autonomy" [3]. This definition highlights a key characteristic of SoS: the constituent systems operate with a degree of independence while contributing to the overarching functionality and purpose of the larger system. When considering how generative AI influences a broad and interconnected domain like entrepreneurial education, an SoS perspective allows for the environment to be broken down into constituent parts. This deconstruction enables a focused analysis of the interactions, functions, and behaviors of each part, as well as how these parts function synergistically [5]. Specifically, in the context of entrepreneurial learning, this involves dissecting the environment into a socio-technical system comprising elements such as the technology itself (e.g., generative AI tools), the learners, the educators, and the knowledge resources available. [3]

The integration of generative AI into the entrepreneurial process and, by extension, the entrepreneurial classroom, introduces a complex web of new and modified systems and interactions. [6] To adequately analyze these dynamics, adopting a systems thinking lens is important for overcoming the inherent complexity [4]. As Vivekanandan et al. suggest, "to overcome the complexities in education, systems thinking approach would help in conceptual modelling of the education and learning space, including: actors, processes, artefacts, technology, interactions (internal and with external agents), organisational policies and communication systems" [4]. This aligns with London's assertion that "a central focus of systems thinking is understanding the attributes of a complete system as related to the combined attributes of the component elements" [7]. Indeed, this approach has become fundamental in understanding complex networks [2].

Within the proposed Entrepreneurial Learning System-of-Systems, we can identify distinct constituent systems—for instance, the pedagogical system, the technological system (including generative AI), the learner system, and the assessment system. Each of these systems often operates with its own managerial oversight and objectives. However, it is through their interactions and interfaces that the overall entrepreneurial learning experience evolves. The combination of these individual systems gives rise to emergent behaviors and capabilities whose value exceeds the combined value of the constituent elements. Boardman and Sauser articulate this concept by defining a system as "a collection of entities and their interrelationships gathered together to form a whole greater than the sum of the parts" [2]. This emergent behavior, which characterizes the entrepreneurial learning process itself, cannot be fully understood by examining any single constituent system in isolation. [3]

A key aspect of SoS theory is the concept of emergence, where the collective interactions of constituent systems produce novel properties or behaviors not present in the individual systems. Boardman and Sauser note that "a SoS has emergent capability designed into it by virtue of the other factors" [2]. This is particularly relevant when considering the introduction of new elements, like generative AI, into an existing educational framework. As they state, "some parts of the envisaged SoS, constituent systems, already exist; these are commonly known as legacy systems. Secondly, there is some new system in view, to which these legacy systems will contribute" [2]. The challenge, then, is to ensure that "the existing purposes can help bring about the new SoS purpose" [2]. To achieve beneficial emergent behavior, such as enhanced entrepreneurial learning outcomes, it is essential to cultivate an environment where such emergence can thrive. This involves designing and managing the interfaces and interactions between systems to "create a climate in which emergence can flourish" [2].

The socio-technical nature of such educational AI systems, as highlighted by researchers like Bulathwela and Scacchi, further underscores the complexity. It is not merely a technological integration but an interplay between human actors (learners, educators), institutional structures, pedagogical approaches, and the technology itself.[8,9]

This framework, visually represented in a subsequent diagram (see Figure 2.1), conceptualizes entrepreneurial learning as an SoS comprising four primary constituent systems allowing for a structured analysis of the impact of generative AI.

2.2 Constituent System 1: The Student/Team as a Learning System

Conceptualization

Within the broader Entrepreneurial Learning System-of-Systems (SoS), the individual student, and by extension the student team, can be conceptualized as a dynamic and evolving learning system. Students are not static entities; their knowledge, understanding, and skills undergo continuous transformation throughout their educational journey. This inherent dynamism allows us to view the student/team system as an active learning component that exists

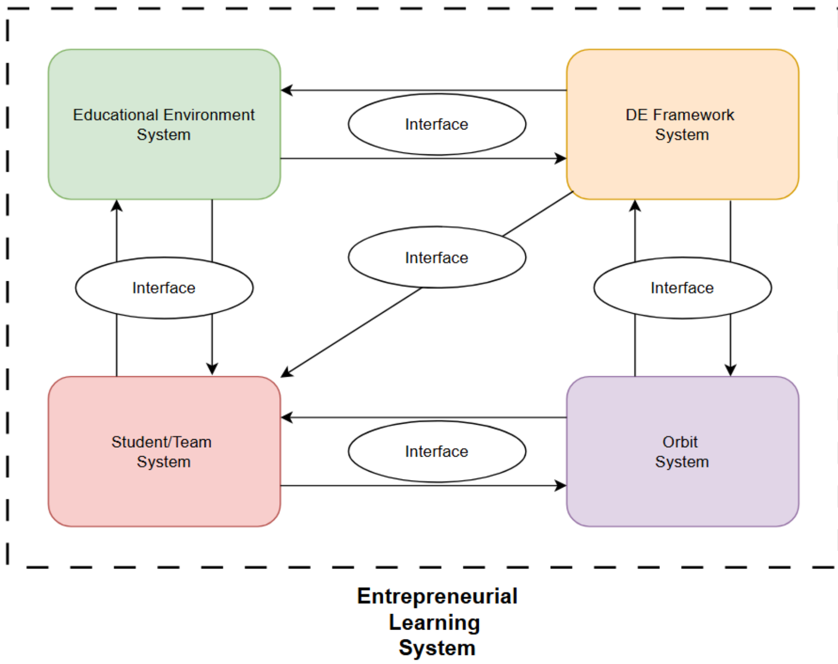

Figure 2.1: General concept of the entrepreneurial system-of-systems and its constituent systems

and interacts within the larger entrepreneurial SoS. Far from being passive recipients of information, students are active participants, engaging with the educational environment in multifaceted ways. The student/team system demonstrates its agency and interaction through several channels:

- Intra-team collaboration: Students engage with each other within their teams, fostering shared understanding and collaborative problem-solving.
- Educational system engagement: Through assignment submissions and other academic activities, students demonstrate their evolving comprehension and application of learned concepts.
- DE framework and Orbit system interaction: Students engage with the Disciplined Entrepreneurship (DE) framework, often mediated by the educational system and tools like the Orbit platform, showcasing their grasp of core entrepreneurial concepts.
- Direct tool engagement: Students interact directly with specific tools, such as Orbit, through usage patterns and engagement metrics, providing insights into their learning processes

Viewing students and teams as dynamic, constantly evolving entities is essential for understanding how they influence other constituent systems and shape the emergent properties of the overall System-of-Systems. This adaptive perspective reveals the true nature of their impact throughout the entrepreneurial learning process

Student System and Learning Models

The development and functioning of the student/team learning system can be further understood through established learning theories, such as Kolb's model of experiential learning [10]. Experiential learning posits that deep understanding is achieved when students actively engage with experiences and reflect upon them. This concept is eloquently captured in the oft-cited aphorism, "Tell me and I might forget. Teach me and I may remember. Involve me and I learn," a sentiment that underscores the importance of active participation in the learning process. This is particularly resonant in a field like entrepreneurship, which is fundamentally characterized by "doing" [11]. The efficacy of experiential learning in entrepreneurial education is supported by empirical evidence, such as the study by Awad et al., which found a noticeable improvement in entrepreneurial outcomes among higher education students in the Middle East who engaged with a simulated business environment compared to those who did not. In the context of a course like 15.390, students learn by actively conducting research, refining ideas, and developing actual business concepts. [12]

Kolb's experiential learning model outlines a four-stage cycle that learners progress through continuously. [10]:

- Concrete Experience: Students encounter new experiences or reinterpret existing ones
- Reflective Observation: Students reflect on the experience from various perspectives
- Abstract Conceptualization: Students form new ideas or modify existing abstract concepts based on their reflections
- Active Experimentation: Students apply their new ideas to the world around them, testing what they have learned

In the specific context of the 15.390 course, these stages manifest as students gain concrete experience by attempting each step of the DE framework. Students engage in reflective observation when examining their processes and outcomes, often enhanced by Orbit's feedback. They practice abstract conceptualization by comparing their experiences against theoretical frameworks presented in lectures and course materials. The cycle completes with active experimentation as students refine their approaches based on feedback, iterating on their ideas and deepening their entrepreneurial understanding.

Student Cognitive Load

Another critical factor influencing the student learning system is cognitive load. Cognitive Load Theory (CLT) defines cognitive load as the "conscious process of thinking" [13] that is imposed on an individual's working memory during learning and problem-solving. This load can be categorized into two main types: intrinsic cognitive load and extraneous cognitive load [14]. Intrinsic cognitive load is inherent to the complexity and nature of the material being learned. For instance, students experience intrinsic load due to the inherent complexity of the various steps within the DE framework. Extraneous cognitive load, on the other hand, is generated by the way information is presented or the activities required of the learner, rather than the learning material itself [14]. Students might experience extraneous cognitive load in the process by which they are expected to learn and apply the DE framework. While the intrinsic cognitive load associated with entrepreneurial concepts may be relatively fixed, tools like Orbit have the potential to reduce extraneous cognitive load by providing a structured and supportive platform for engaging with the content, complementing traditional educational methods.

Student Self-Efficacy

An individual student's self-efficacy, or their belief in their own capabilities to succeed in specific situations, plays a significant role. Davis et al. theorize that "self-efficacy beliefs are theorized to function as proximal determinants of behavior" [15]. This concept extends to interactions with technology, particularly AI. In AI contexts, "users with higher AI self-efficacy (generally referred to as a user's personal confidence in using AI technology) were found to be more likely to have higher performance accomplishments and continuous usage intentions" [16]. Furthermore, Hong (2022), as cited by Shao et al., found that users "(1) who perceived higher mastery of AI technologies and (2) who knew people with AI proficiencies were more likely to have higher AI self-efficacy" [16].

The student's relationship with AI tools like Orbit can also be analyzed through the lens of the Technology Acceptance Model (TAM), which emphasizes perceived usefulness (PU) and perceived ease of use (PEOU) as key determinants of technology adoption [15]. Davis defines perceived usefulness as "the degree to which a person believes that using a particular system would enhance his or her job performance" [15]. He further notes that "people tend to use or not use an application to the extent they believe it will help them perform their job better" [15]. Conversely, perceived ease of use refers to "'the degree to which a person believes that using a particular system would be free of effort'" [15]. Davis highlights that "even if potential users believe that a given application is useful, they may, at the same time, believe that the systems is too hard to use," and thus "usage is theorized to be influenced by perceived ease of use" [15].

These two factors often interact. Feedback loops can exist where positive experiences (e.g., receiving high-quality responses from an AI tool) can increase both perceived usefulness and perceived ease of use, encouraging further engagement. Research indicates that "perceived ease of use was the strongest predictor of users' adoption intention of AI-powered chatbots, followed by perceived intelligence, perceived usefulness, perceived trust, and anthropomorphism" [16]. Shao et al. also categorize predictors of AI technology acceptance into demographic (e.g., age, gender), psychological (e.g., self-efficacy, ethical considerations), and technological factors (e.g., PEOU, PU) [16]. The applicability of the TAM model to educational settings is supported by Choi et al. [17], who found it relevant to the adoption of intelligent personal assistants (IPAs) by university students.

Other individual student characteristics that contribute to the student/team learning system include their self-efficacy with entrepreneurship itself, their individual personas and interests, their cognitive load capacity, and their general engagement levels with AI and new technologies. Understanding these complex aspects of the student/team system is essential for analyzing its role within the entrepreneurial learning SoS and its interaction with generative AI.

System Definition and Components

For the purpose of this research, the student system is defined as comprising individuals enrolled in and attending the 15.390 entrepreneurship course, specifically during the Spring 2024, Fall 2024, and Spring 2025 semesters. The team system within this context involves several key components:

- Team Composition: This includes factors such as team size and whether the team formed around a pre-existing idea or is starting fresh.
- Team Dynamics: The interpersonal relationships, communication patterns, and collaborative processes within the team.
- Team Work Distribution: How tasks and responsibilities are allocated and managed among team members.

2.3 Constituent System 2: The Disciplined Entrepreneurship Framework as a Process System

Overview and Conceptualization

The Disciplined Entrepreneurship (DE) framework, developed by Bill Aulet, serves as a structured process designed to teach the principles and practices of entrepreneurship [18]. This framework directly challenges the notion that entrepreneurial ability is an innate trait, a common debate within the field [19]. While acknowledging that certain traits can contribute to an entrepreneur's success [20], Aulet posits that entrepreneurship fundamentally requires a specific mindset and a set of skills that can and must be cultivated over time. A key emphasis within Aulet's approach is the importance of teamwork and a departure from the "heroic individual" narrative often associated with entrepreneurship. This philosophy is reflected in educational settings like the 15.390 course, where the focus is often on team performance rather than individual achievements.

The DE framework is systematically organized into 24 distinct steps, which are to be completed sequentially. These steps are grouped under six overarching themes:

1. Who is Your Customer?
2. What Can You Do for Your Customer?
3. How Does Your Customer Acquire Your Product?
4. How Do You Make Money Off Your Product?
5. How Do You Design and Build Your Product?
6. How Do You Scale Your Business?

Within these themes, the 24 steps are as follows (step numbers represent their order in the DE framework process):

- Who is Your Customer?
  1 Market Segmentation
  2 Select a Beachhead Market
  3 Build an End User Profile
  4 Calculate the Total Addressable Market (TAM) Size for the Beachhead Market
  5 Profile the Persona for the Beachhead Market
  9 Identify Your Next 10 Customers
- What Can You Do for Your Customer?
  6 Full Life Cycle Use Case
  7 High-Level Product Specification
  8 Quantify the Value Proposition
  10 Define Your Core
  11 Chart Your Competitive Position
- How Does Your Customer Acquire Your Product?
  12 Determine the Customer's Decision-Making Unit (DMU)
  13 Map the Process to Acquire a Paying Customer
  18 Design a Scalable Revenue Engine
- How Do You Make Money Off Your Product?
  15 Design a Business Model
  16 Set your Pricing Framework
  17 Calculate the Lifetime Value (LTV) of an Acquired Customer
  19 Calculate the Cost of Customer Acquisition (COCA)
- How Do You Design and Build Your Product?
  20 Identify Key Assumptions
  21 Test Key Assumptions
  22 Define the Minimum Viable Business Product (MVBP)
  23 Show That "The Dogs Will Eat the Dog Food"
- How Do You Scale Your Business?
  14 Calculate the Total Addressable Market Size for Follow-on Markets
  24 Develop a Product Plan

The utility of a structured approach like DE in entrepreneurial education is supported by scholars such as Neck et al., who argue that effective entrepreneurship education should focus on teaching a method, rather than merely conveying specific content: "teaching entrepreneurship requires teaching a method… Learning a method, we believe, is often more important than learning specific content"[20]. In time-constrained environments, such as an intensive course like 15.390, having a clear, concise, and established framework like DE offers significant benefits by providing a roadmap for students.

The DE framework is more than just a checklist; it functions as an interconnected process system. From a systems engineering perspective[5,21], it possesses a defined process architecture and systemic integrity [7]. This system comprises inputs, transformation processes, and outputs.

- Inputs to the DE process system include the initial idea or concept, new data gathered throughout the process, and the user's evolving understanding of their business concept and their acquired skills.
- The processes are the 24 steps themselves, each requiring specific analyses and actions.
- Outputs include a progressively refined business concept, tangible artifacts created by the user at each step (e.g., market segmentation charts, persona descriptions, value proposition statements), and an enhanced understanding of the entrepreneurial journey.

The steps within the DE framework exhibit strong interdependence, not isolation. Users progress linearly through the system, with the output of one step often forming a critical input for the next. This iterative refinement, guided by a predefined method, is a hallmark of the framework. Banathy proposes viewing educational systems through three lenses: a system-environment lens (focusing on relational arrangements and dynamics), a function/structure lens (providing a snapshot of the system), and a "motion picture" lens (observing the system as it evolves through time)[21]. To understand the DE framework as a process system, the "motion picture" lens is particularly beneficial, as it allows for an examination of how the business concept and the student's understanding transform as they navigate through the sequential steps.

The framework inherently contains segmentations that could almost be viewed as sub-systems, such as those focusing on the market (segmentation, beachhead selection), the customer (end-user profile, persona), the business model (LTV, pricing, COCA), and the go-to-market strategy (positioning, sales process). Each step also has associated deliverables and criteria for completion, which define what must be accomplished before moving forward. The framework implicitly assumes certain user knowledge requirements, or at least a capacity to acquire them, as they progress. While the framework provides structure, it also aims to mitigate some of the inherent complexities and time requirements of venture creation by breaking them into manageable parts.

Interaction with the Orbit System and Data Touchpoints

The Disciplined Entrepreneurship framework is an integral component of the Orbit tool's functionality. It defines the core structure around which the tool is built, and the DE process is mirrored by the tool as it guides users through their entrepreneurial journey. The DE framework interfaces directly with Orbit by providing the operational scaffold, defining the nature of the AI-generated responses, and shaping the refinement prompts offered to users.

For the purposes of this research, the DE framework will be instrumental in analyzing the Orbit tool and user engagement with it. The framework's structure provides critical metric definitions for evaluating this engagement. Data touchpoints such as step progression data and completion rates within Orbit can be directly mapped to the DE framework. This allows for an analysis of aspects like the creation of steps, the generation of ideas within those steps, the iteration on those ideas, the development of unique ideas and step completions, and how specific ideas are attached to and developed through the DE steps within the Orbit environment. Understanding this interaction is key to assessing how the AI tool supports the student's progression through this established entrepreneurial process system.

2.4 Constituent System 3: AI as an External Enabler and Technological System (Orbit)

Overview and Dual Functionality of Orbit

The Orbit tool, central to this research, exhibits a dual functionality within the entrepreneurial learning ecosystem. It operates simultaneously as a distinct technological system and as an "external enabler" of the entrepreneurial process, a concept drawn from Davidsson's framework [22]. As a technological system, Orbit is a rule-based entity, engineered with a specific set of tasks and built upon the foundational structure of the Disciplined Entrepreneurship (DE) framework. Its primary operational function is to process user inputs in a predictable, systematic manner and to return structured responses aligned with the DE methodology. Users can typically engage with various steps of the DE framework through the Orbit interface, not necessarily in a strict linear order, allowing for flexibility in their learning and development process.

Beyond its technical architecture, Orbit also functions as an external enabler, significantly influencing the entrepreneurial landscape for its users. This section will explore both facets of Orbit, its technical evolution, and the socio-technical factors influencing its adoption and impact, including the "jagged technological frontier" of generative AI [23] and human-AI interaction dynamics [17,24]. Data touchpoints, such as differences in DE step distribution engagement between Orbit v1 and v2, and other version-specific metrics, will inform this analysis.

AI as an External Enabler: The Davidsson Framework

Davidsson et al. introduce the concept of "external enablers" to describe phenomena or entities that precipitate significant changes in the conditions under which entrepreneurship occurs [22]. Artificial intelligence, particularly generative AI as embodied in tools like Orbit, fits squarely within this definition. Davidsson provides several mechanisms through which external enablement can be assessed, including compression, resource conservation, generation, uncertainty reduction, and agency-intensity. AI, and by extension Orbit, can facilitate each of these:

- Compression: In the context of Davidsson's framework, compression refers to time-saving. Orbit enables users to save time by rapidly generating specific content and analyses relevant to the DE framework step being addressed. This allows users to iterate more quickly through the DE process.
- Resource Generation and Conservation: Orbit can enable resource generation and conservation by freeing up users' time and cognitive bandwidth. By automating aspects

of content generation and analysis within the DE framework, Orbit allows users to allocate their attention to other critical entrepreneurial tasks.

- Uncertainty Reduction: Orbit can help reduce uncertainty by translating abstract entrepreneurial concepts from the DE framework into more concrete, contextualized examples and actionable insights.
- Agency-Intensity: Davidsson suggests that AI can both decrease and increase agency-intensity. Agency-intensity may increase when AI is generic and not tailored to a specific use case. It can also be decreased when AI systems are built upon predefined, specific platforms, as is the case with Orbit, which is structured around the DE framework. This tailored approach can make the path clearer for users.

The role of Orbit as an external enabler is further evidenced by the improvements made from its initial version (v1) to its subsequent iteration (v2). These changes, which included upgrading the underlying AI model, refining the user interface (UI) for better intuitiveness, and enhancing the overall layout, were aimed at amplifying its enabling capabilities. As Winkler et al. note, "Generative AI is reshaping entrepreneurship functions (e.g., marketing finance, HR) as well as core processes (e.g., opportunity recognition, business modeling, resource marshaling)" [25]. They further state, "Generative AI is conceptualized to have several benefits towards improving learning outcomes, increasing the efficiency of the educational process, and supporting a student-centered approach" [25].

The "Jagged Technological Frontier" of Generative AI

While generative AI systems like the one powering Orbit can significantly enhance user productivity and learning, their capabilities are not uniform across all types of tasks. Dell'Acqua et al. describe this uneven performance landscape as the "jagged technological frontier" [23]. This term refers to tasks or domains where AI performance may be less accurate, less effective, or even erroneous compared to human performance. The concept of the jagged frontier encourages a nuanced view of AI's capabilities, recognizing that its proficiency varies across the spectrum of cognitive tasks to which it is applied.

Research by Dell'Acqua et al. suggests that AI tends to underperform in tasks that are predominantly creative or require deep contextual understanding, while excelling at more analytical, pattern-recognition, or information-retrieval tasks [23]. This observation could offer an explanation for potential variations in user engagement across different steps of the DE framework within Orbit. For instance, steps requiring highly creative ideation (e.g., initial product conceptualization) or nuanced qualitative judgment might see different engagement patterns or perceived utility compared to more analytical steps (e.g., market sizing or competitive analysis). Data on step distribution and engagement levels with Orbit across different semesters may illuminate these patterns.

2.4.1 User Types and Differential Effects of AI

The impact of generative AI tools is not uniform across all users. A study by Otis et al. on the use of generative AI by entrepreneurs in Kenya revealed significant differences in outcomes between high-performing and low-performing entrepreneurs. [26] The study found that high-performing entrepreneurs who used the AI tool performed 18% above the baseline control group, whereas low-performing entrepreneurs performed 8% worse than the control group, despite both groups receiving the same technology, instructions, and quality of AI responses.

The critical differentiator appeared to be the quality of user inputs and their ability to interpret and implement the AI-generated responses effectively. Low performers were more inclined to uncritically implement generic advice from the AI. In contrast, high performers engaged more interactively with the tool, using it to tailor responses to their specific needs and iterating on the AI's suggestions to refine the advice received. These findings are pertinent when interpreting engagement data from Orbit. For example, an observed difference where users self-identifying as "Founder With an Idea" created almost twice as many DE steps per idea on average across three semesters compared to users self-identifying as "Founder Without an Idea" could reflect differing levels of initial context, engagement strategies, or ability to leverage the tool effectively. (See Figure Y.Y for visualization of persona-based steps per idea). This accounts for users who come in with an idea, since they create more ideas than "Founder Without an Idea" personas as well.

Technology Acceptance Model (TAM) and Socio-Technical Considerations

Beyond its function as an external enabler, Orbit can be analyzed as a socio-technical system, emphasizing the critical human element in AI interaction. Farrow notes that "As AIED (AI in Education) becomes increasingly mainstream, attention is shifting from the technical to the socio-technical perspective" [6]. The Technology Acceptance Model (TAM), originally proposed by Davis [15], provides a useful framework for understanding user adoption of technologies. Choi et al., in their study on intelligent personal assistants (IPAs) in educational settings, verified the relevance of TAM and expanded upon it to better capture AI adoption by students [17].

Their expanded model incorporates factors such as:

- Computer Self-Efficacy (CSE): A user's belief in their ability to use computers to handle complex tasks
- Self-Management of Learning (SML): A student's capacity for autonomous learning.
- Perceived Social Presence (PSP): A user's feeling of interacting with the technology on a human-like level.
- Perceived Trust (PT): The degree to which a user believes the tool is reliable and its outputs are credible.

The evolution of Orbit from v1 to v2 can be viewed through these TAM factors. The UI changes aimed at making the tool more intuitive likely enhanced Perceived Ease of Use (PEOU). The upgraded underlying AI model, designed to produce quicker and more accurate responses, would contribute to increased Perceived Usefulness (PU) and also bolster Perceived Trust (PT), as users experience more reliable outputs. Furthermore, the full integration of Orbit v2 into the course curriculum, moving from a suggested tool (v1) to an integral component, likely increased PT. This integration signals endorsement and belief in the technology's efficacy from an authoritative source (professors and the curriculum itself), aligning with Dwivedi's assertion (quoting Darnell) that "'AI needs to be intentionally and methodically integrated into Entrepreneurship instruction to create real value for students'" [27].

Research by Cassell et al. on social interactions with intelligent agents suggests that a feeling of "collaboration" with a technology system can increase its use and the initiative users take to interact with it.[24] Observations of improved team collaboration metrics (e.g., Gini coefficient improvement from 0.023 to 0.013) across semesters of Orbit usage might hint at users experiencing an increased sense of collaboration, potentially with the tool itself or mediated by the tool within their teams. However, more specific data collection is needed to determine the precise causes of this trend.

Orbit System Definition and Evolution (v1 to v2)

The Orbit tool system, as a constituent part of the entrepreneurial learning SoS, can be defined by several components:

- The Tool Interface: Including text input fields, navigation elements, and output displays.
- The AI Models: The underlying large language models (e.g., GPT-4-turbo in v1, GPT-4o in v2) that power its generative capabilities.
- Data Collection Mechanisms: How the tool captures user interactions and inputs.
- Response Formatting: The structure and presentation of prompts and AI-generated responses.
- Internal Logic: The processes that translate model outputs into user-facing responses aligned with the DE framework.

The evolution from Orbit v1 to v2 encompassed several key changes: a migration of the core AI model from GPT-4-turbo to GPT-4o (Omni), deeper integration of the tool into the course curriculum, and significant UI edits aimed at a more intuitive design. Throughout both versions, its primary interface with the student and the learning process has been through the structure of the Disciplined Entrepreneurship framework.

2.5 Constituent System 4: Educational Environment as a Contextual System

Overview and Conceptualization

The educational environment in which entrepreneurial learning occurs is not merely a passive backdrop but an active, contextual system that significantly shapes and is shaped by the other constituent systems (the student/team, the DE framework, and the Orbit tool). As London suggests, "In the environment of the 'system' of higher education curricula development, systems thinking principles can be applied in several ways" [7]. This system encompasses the course structure, pedagogical approaches, available resources, and the overarching institutional context, all of which create a unique set of environmental constraints and affordances. Understanding this system, including its assessment mechanisms and feedback loops, is important for analyzing the emergence of the overall Entrepreneurial Learning System-of-Systems. Data touchpoints for this analysis will include comparisons of section differences, semester-specific data, and course evaluations.

2.5.1 Defining the Educational Environment System

The educational environment system is a critical component influencing the emergence of the entrepreneurial learning system. Vivekanandan et al. propose a framework for deconstructing educational environments into several components, including hardware, software, people, delivery, management and procedures, regulators, and government [4]. They also emphasize the profound importance of the interconnectedness between these systemic components. Complementing this, Banathy offers three lenses for viewing educational systems: the system-environment lens (focusing on relational arrangements and dynamics), the function/structure lens (providing a snapshot of the system), and a "motion picture" lens (observing the system as it evolves through time) [21].

For the purposes of this study, these frameworks will be adapted to analyze the 15.390 course environment, focusing on how this system interacts with the other constituent systems, thereby contributing to the emergent properties of the overall SoS. Drawing from Vivekanandan, the key components considered are:

- Hardware: Tangible resources such as the Disciplined Entrepreneurship textbook.
- Software: Methodologies and tools, including the mandate for and instruction surrounding the Orbit tool.
- People: Human actors within the system, including professors, guest lecturers, and teaching assistants (TAs).
- Delivery: The methods of instruction and interaction, such as lectures, classroom engagement activities, inter-team interactions, presentations, assignments, and projects, all contributing to knowledge and skill transfer.
- Management and Procedures: The organizational and temporal structures, including the course schedule, curriculum design, learning objectives, and the semester timeframe.

From Banathy's perspectives, the system-environment lens will be employed to emphasize the dynamic interactions between these components, while the "motion picture" lens will be used to examine how the educational environment influences the other systems (student, DE framework, Orbit) over the duration of the course. This includes focusing on the development of entrepreneurial skills and the achievement of defined learning objectives.

Interfaces and Interactions

Internal System Interfaces

The interfaces within the educational environment system itself are significant. Temporal components, such as the fixed semester timeframe and the course schedule, create varying levels of interaction intensity with tools like Orbit. Assignments and milestones also shape these temporal dynamics. For instance, students typically submit assignments and progress updates weekly, with larger milestones occurring less frequently. Peaks in Orbit engagement often correspond to these academic deadlines and the specific DE framework steps being covered in the curriculum at that time, rather than necessarily reflecting a steady, continuous usage pattern throughout the semester.

The roles of professors and TAs are crucial interface points. They facilitate the integration of Orbit into the curriculum, provide technical assistance and pedagogical support for the tool, and may design lectures and activities that are augmented by or directly involve Orbit usage. The curriculum itself, by setting schedules, defining learning outcomes, and establishing rules of conduct (e.g., guidelines for Orbit use), acts as a primary structuring interface.

Interfaces with Other Systems and Emergent Effects

The educational environment system interfaces profoundly with the other three constituent systems, leading to emergent behaviors and outcomes.

The limited duration of a semester inherently creates an affordance for tools like Orbit that promise efficiency and accelerated learning. The pressure of deadlines and the structure of assignments often drive specific Orbit usage patterns. For example, analysis of usage data from the Spring 2025 semester might reveal significant engagement spikes towards the end of February, corresponding to the general pace of the course and specific topics or deliverables due at that time. This pattern, where increased engagement aligns with assignment cycles, suggests that the academic structure, rather than purely self-directed exploration, often dictates the rhythm of tool interaction.

The way the course is structured, including the sequence of topics and the emphasis placed on certain DE steps, directly influences how students engage with both the DE framework and the Orbit tool. An increased pedagogical focus on Orbit, particularly through its formal integration into the curriculum (as seen in the transition from v1 to v2), can lead to increased student mastery of the DE steps, as the tool provides a platform for repeated practice and application. The educational environment, therefore, not only provides the context but actively shapes the learning process and the perceived value and utility of the enabling technological system.

By examining these components and interfaces, we can better understand how the educational environment as a contextual system contributes to the overall dynamics and effectiveness of the Entrepreneurial Learning System-of-Systems.

2.6 Interfaces and Emergence in the Entrepreneurial Learning System-of-Systems

Understanding the Entrepreneurial Learning System-of-Systems (SoS) necessitates a detailed examination of the interfaces between its constituent systems and the subsequent emergent properties that arise from their interactions. Emergence, in this context, refers to the creation of new, unplanned, high-level properties or behaviors that result from the complex interplay of lower-level interactions and processes within the SoS [2]. These emergent properties are not inherent to any single constituent system in isolation but manifest because the system as a whole is "more than the sum of its parts" [2].

Interfaces Between Constituent Systems

The dynamic interactions at the interfaces between the four constituent systems, i.e., the Student/Team, the Disciplined Entrepreneurship (DE) Framework, the AI tool (Orbit), and the Educational Environment, are fundamental to the functioning and evolution of the SoS.

Orbit $\leftrightarrow$ Student/Team Interface

This interface is characterized by a bidirectional flow of information and influence

- Users provide inputs such as initial ideas, requests for iterative refinement of AI-generated content, and potentially selections related to specific DE framework steps. Their usage patterns (e.g., frequency, duration, steps engaged with) also constitute an input into the system's data.
- The AI delivers information, provides guidance structured around the DE framework, and interacts visually with the user. It also tracks versions of user work and provides feedback. Key relational factors at this interface include user trust in the AI, perceptions of social presence [24], and overall technology acceptance as described by Choi et al. [17].

Student/Team $\leftrightarrow$ DE Framework Interface

This interface is primarily cognitive and process-oriented.

- Students engage with the DE framework by attempting to understand and apply its 24 steps. This interaction is influenced by the cognitive load associated with each step and the students' self-regulation strategies in their learning process [28].
- Challenges in learning specific steps and the rates of progression through the framework are key indicators of this interface's dynamics. While the DE framework provides the process "scaffolding," the Orbit tool can mediate this interface by facilitating how students approach and evaluate entrepreneurial problems within the DE structure. By enabling students to "think entrepreneurially" through rapid feedback and iterative testing of strategies, Orbit can support the development of entrepreneurial skills and confidence [20].

DE Framework $\leftrightarrow$ Orbit Interface

This interface is foundational to Orbit's design and functionality.

- The DE framework provides the structural and conceptual backbone for Orbit. The tool is designed to mirror and support the DE process.
- Orbit's ability to assist users across the DE steps is subject to the "jagged frontier" of AI capabilities [23], where it may excel in some areas (e.g., analytical tasks) and be less effective in others (e.g., highly creative or nuanced tasks).
- Orbit acts as an external enabler [22] for students working through the DE framework by providing mechanisms like time compression, resource generation, and uncertainty reduction. Neck et al. describe three approaches to teaching entrepreneurship: the

"entrepreneur world" (focusing on the individual), the "process world" (focusing on methodologies), and the "cognition world" (focusing on entrepreneurial thinking) [20]. The DE framework clearly represents the "process world." Orbit, by facilitating instant feedback and iteration within this process, strongly supports the "cognition world," enabling students to develop entrepreneurial thinking skills. The interaction between the structured DE process and Orbit's cognitive support aims to create a more holistic and effective learning experience.

Educational Environment ↔ Student/Team Interface

This interface is shaped by the pedagogical and structural aspects of the course.

- Course structure, including schedules, deadlines, and milestones, directly affects student engagement patterns with their work and with tools like Orbit.
- Learning outcomes defined by the curriculum influence student behavior and focus.
- Interactions with lecturers, professors, and TAs (e.g., helpfulness, availability) provide support and guidance.

Educational Environment ↔ DE Framework Interface

The educational environment contextualizes and operationalizes the DE framework.

- The curriculum dictates how the DE framework is integrated into the course, including the pace at which content is covered.
- Assignments and deliverables are often directly derived from the DE framework's steps and expectations.
- The course structure may emphasize certain elements of the framework over others, influencing where students focus their efforts. Alignment between the curriculum and the framework's progression is key. Evidence of this interface can be seen in patterns of engagement across different DE framework steps, which may reflect course emphases.

Educational Environment ↔ Orbit Interface

This interface has evolved, particularly with Orbit's development.

- The integration of Orbit shifted from being a suggested tool (v1) to a fully integrated component of the curriculum (v2). This change in the educational environment likely influenced student perception and usage of the tool.
- The course structure provides instructions on Orbit usage and may implicitly or explicitly set feature requirements or expectations for the tool.
- Conversely, Orbit can provide data and insights back to the educational system (e.g., on student progress, common challenges), potentially informing curriculum adjustments. The observed improvement in overall course ratings (e.g., from 5.5 to 6.1) following Orbit's deeper integration may, in part, reflect a positive impact of this interface.

Educational Environment $\leftrightarrow$ All Systems

The educational environment sets the overarching system boundaries [7] and facilitates overarching feedback loops that affect all other constituent systems.

The Nature and Importance of Emergence in the SoS

The primary emergent property of this Entrepreneurial Learning System-of-Systems is a transformed and potentially enhanced entrepreneurial learning experience. This emergence is critical because it allows for a holistic understanding of the impact of AI tools like Orbit. Instead of viewing the effects of AI in isolation, focusing on emergence allows us to see how AI influences the interactions between all components and how these interactions, in turn, lead to unforeseen, higher-level outcomes.

The outcomes produced by these multi-system interactions are complex, reflecting the nuanced nature of entrepreneurial learning itself. By focusing on the emergent properties of the SoS, we can account for both positive changes, such as enhanced critical thinking and deeper learning, rather than simply viewing AI as a tool for automating learning tasks. For instance, data showing an increase in DE steps created per team, alongside increased course satisfaction and reported time spent on the course, may indicate beneficial emergent learning behaviors.

The significant value and contributions of a system like Orbit can often be most clearly identified in these emergent properties. For example, an AI tool designed around a specific framework (DE) and operating under defined conditions within an educational environment might help students better navigate the "jagged frontier" of AI or collaborate more effectively on specific areas of study.

Mechanisms of Emergence and the Role of Interfaces

By definition, emergent properties cannot be predicted or pre-planned [2] yet in our Entrepreneurial Learning SoS, the very emergence we seek to quantify is the transformed entrepreneurial learning experience itself. Rather than measuring AI's effects on each component in isolation, we focus on this higher-level outcome: how the interplay of learners, pedagogy, technology, and environment gives rise to an unexpectedly enhanced learning journey. In doing so, we treat the emergent learning experience not as a black-box unknown but as the key phenomenon we deliberately observe and analyze. Emergence occurs through the dynamic and often non-linear interactions at the interfaces between the constituent systems[2] . The design of these interfaces can help to influence emergence. Cestino et al., expanding on Davidsson et al.'s external enabler framework, describe how environmental changes can influence the entrepreneurial system, particularly through such enablers, stating that "environmental changes enable the emergence, novelty, and persistence of entrepreneurial initiatives" [29].

The interconnections within this system-of-systems are important factors for understanding the functionality. Between students and the Orbit tool, factors like trust, engagement, and usability determine how effectively students leverage AI capabilities. Meanwhile, students' interaction with the Disciplined Entrepreneurship framework—shaped by their comprehension, perception of relevance, and ability to manage cognitive load—influences how deeply they internalize entrepreneurial processes. The alignment between the DE framework and Orbit creates operational synergy, with the framework's structure directly shaping AI responses and guidance. Surrounding all these interactions, the educational environment provides essential context through course structure, assignments, deadlines, and pedagogical support—establishing the motivational framework and constraints that drive system-wide interactions and ultimately lead to emergent outcomes.

Feedback Loops and Non-Linear Relationships

Feedback loops are essential elements within the SoS, where the current state of the system is compared with previous states, and based on internal rules and environmental inputs, adjustments are made that affect other parts of the system [30].

Reinforcing Feedback Loops

These occur when a change in the system's state amplifies that change. For example, if students interact productively with Orbit and achieve positive results, their perceived trust in the tool and their self-efficacy may increase. This, in turn, can lead to more frequent and deeper interactions with Orbit, further enhancing learning.

Balancing Feedback Loops

These loops work to counteract a change, often maintaining equilibrium or driving a system towards a goal. For instance, if students become overly reliant on the initial outputs from Orbit and accept them without critical reflection, their understanding of the underlying DE framework elements (as taught in lectures) might decrease. This lack of understanding could eventually lead to poorer performance on assignments or a realization that more iteration is needed, prompting increased engagement with Orbit in a more critical manner to refine their work.

The relationships within this SoS are often non-linear. A small change in one constituent system or at one interface does not always produce a proportionally small or predictable change elsewhere. For example, a seemingly minor UI improvement in Orbit's editing functionality could significantly lower the barrier to iteration, triggering a much deeper level of student engagement with the DE framework as they find it easier to refine and test their ideas. By studying the emergent properties of this SoS, including the nature of its interfaces and feedback loops, we can better design the constituent systems. Understanding how and why specific emergent properties occur allows for a more targeted approach to system improvements, such as AI tool design, curriculum development, and the refinement of educational strategies. A future version of Orbit (e.g., v3), for instance, could be developed with a keen understanding of these emergent learning outcomes to further improve student and team interaction with the tool and the overall learning experience.

2.7 Bridging Gaps: An SoS-Informed Approach to Research

A System of Systems (SoS) framework was developed to capture the complex interactions within the entrepreneurial learning environment, especially as the bespoke AI tool Orbit is integrated. Deconstructing the environment into four constituent systems—the student/team learning system, the Disciplined Entrepreneurship (DE) process system, the Orbit AI system as an external enabler, and the educational environment as a contextual system—reveals each system's distinct characteristics and, critically, the interfaces and emergent properties that arise from their interaction. Framed in this way, the SoS perspective offers an effective method for understanding how generative AI shapes entrepreneurial education. The adoption of this SoS framework is particularly pertinent given the identified gaps in current research. There remains a notable scarcity of empirical studies specifically examining the role and impact of AI in entrepreneurship education[1] [29,31–34]. Understanding these effects is of paramount importance for both educational institutions seeking to innovate their pedagogical approaches and for technologists developing AI tools for learning. The Orbit tool, as implemented within the 15.390 course at MIT, presents a valuable opportunity for a natural experiment. Its design as an AI application specifically tailored for the entrepreneurial use case, built upon the well-defined DE framework (which provides a set of rules and a limited operational scope), and its consistent application to a relatively homogenous student demographic across several semesters, offers a unique setting to investigate these influences.

However, researching such a novel and rapidly evolving area is not without its challenges. The very novelty of the Orbit tool means that longitudinal data is inherently limited. Furthermore, the swift evolution of the tool itself (e.g., from v1 to v2, changes in underlying AI models) and its educational integration introduce variables that must be carefully considered. These include potential shifts in data collection methods over time and the difficulty in generalizing findings if the tool were applied to different frameworks, institutions, or educational and professional environments. To mitigate these challenges, this research will employ a meticulous approach to data analysis. This includes the use of custom-built Python analysis services to cross-reference and ensure the accuracy and consistency of data interpretation across different versions and datasets. The study will also maintain a focus on the specific experimental conditions of the 15.390 course over three defined semesters, acknowledging these boundaries when discussing findings. The System of Systems lens adopted in this literature review directly informs the research methodology that follows. By conceptualizing the entrepreneurial learning environment as an SoS, the methodology will focus not only on the direct effects of the AI tool (Orbit) but also on the interactions between all constituent systems and the emergent outcomes of these interactions. This approach will guide the selection of research questions, data collection strategies, and analytical techniques aimed at capturing the dynamic and interconnected nature of AI integration in entrepreneurial education. The subsequent methodology section will detail how this SoS perspective is operationalized to investigate the impact of Orbit on student learning, engagement, and the overall entrepreneurial education experience.

[1] It is quite ironic how many research papers in this area have mentioned the lack of research in this area.

Chapter 3

Methodology

3.1 Research Design

3.1.1 Approach and Philosophy

The primary objective of this research is to develop a comprehensive understanding of student engagement with the Orbit generative AI tool, developed at MIT, and to assess its effects on learning outcomes within the specific context of entrepreneurship education. The investigation centers on the application of the Disciplined Entrepreneurship (DE) framework as utilized in MIT's 15.390 entrepreneurship course. Consequently, the scope of this analysis is limited to students who were enrolled in and actively participated in this course across designated semesters. To analyze the diverse dataset generated from tool usage and student interactions, two custom-built Python analysis services were developed. These services were specifically designed to translate, sanitize, and analyze the data through multiple lenses, providing a robust foundation for quantitative assessment. The results derived from these services were systematically cross-referenced against each other and further validated through direct data analysis, which involved the execution of individual Python scripts and meticulous spreadsheet-based verification, ensuring a high degree of analytical rigor.

Beyond observing tool engagement levels, a core goal of this research is to gain a deeper understanding of the complex system interactions that occur within the entrepreneurial education environment when a tool like Orbit is introduced. This includes examining the effects these interactions have on the overall learning ecosystem. The phased rollout of the Orbit tool, particularly its evolution from version 1 (v1) to version 2 (v2), presented a valuable natural experiment, allowing for comparative analysis of different stages of tool maturity and integration. This research adopts a pragmatic philosophical stance. Pragmatism is particularly well-suited for investigating complex, real-world phenomena such as the integration of generative AI in education [35]. This approach emphasizes a focus on "what works" within the system and understanding the tangible effects of these interventions. By prioritizing practical outcomes and actionable insights, a pragmatic methodology allows for the flexible selection and combination of research methods that best address the problem at hand.

In order to achieve a holistic understanding of the system interactions and their impact, this study places value on both quantitative and qualitative data. A mixed-methods approach is therefore employed. Quantitative metrics gathered directly from the Orbit tool (e.g., usage statistics, step completion rates) provide objective measures of engagement. Simultaneously, qualitative data, aimed at capturing the subjective experiences and perceptions of students, offers crucial insights into the nuances of learning, tool adoption, and the overall educational experience. This combination allows for a richer, more textured interpretation of how Orbit influences the entrepreneurial learning journey.

3.1.2 System-of-Systems Rationale

The decision to view the research problem and the entrepreneurial learning environment through a System of Systems (SoS) lens influences the analytical approach undertaken in this study. The interconnected nature of the constituent elements creates a complex web of interactions. An SoS approach is particularly well-suited for examining such multifaceted phenomena, allowing for an analysis that considers not only individual components but also their synergistic relationships and emergent properties [31]. This rationale underpins the selection of methods and the interpretation of findings, aiming to capture the holistic impact of AI integration.

3.1.3 Nature of Research

The research conducted is primarily exploratory in nature. Its aim is to suggest rationale and generate insights into the complex dynamics at play, rather than to provide definitive, generalizable proof in a traditional positivist sense. The central goal is to gain a deeper understanding of the evolving nature of generative AI and, more specifically, how a particular implementation of this technology, specifically MIT's Orbit AI tool, affects students within an entrepreneurial learning environment. In addition, this research aims to provide actionable insights that can inform potential changes and updates to the tool, curriculum, or pedagogical approaches. This is aligned with the pragmatic, mixed-methods approach, which leverages both qualitative and quantitative analysis to identify areas for improvement and to understand the practical implications of the findings. The research methods employed are committed to presenting valid, transparent, and holistic results that accurately reflect the observed phenomena within the defined context of the study.

3.2 System-of-Systems Framework

3.2.1 Constituent Systems

Drawing from the System of Systems (SoS) analysis, the entrepreneurial learning environment under investigation was deconstructed into four primary constituent systems. Each system is defined by specific boundaries, components, and relevant data points that inform this research.

Orbit Tool System

The first constituent system is The Orbit Tool System, encompassing both its initial (v1) and subsequent (v2) iterations. Orbit is defined as an AI-powered entrepreneurial chat interface specifically engineered to support the Disciplined Entrepreneurship framework. The boundaries of this system are delineated by the User Interface (UI), through which students interact and the backend data collection database that logs these interactions. A significant evolution within this system was the change in its core AI model: v1 utilized GPT-4-Turbo, while v2 migrated to GPT-4o, a change driven by the latter's superior processing speed and expanded context window capacity. Further differentiating the versions were several UI enhancements in v2. These included the introduction of tracking capabilities for user-directed changes in DE step content, which provided valuable data on content iteration. Additionally, editing tools were repositioned to the top of the UI for improved accessibility, and the overall interface was updated to create a more intuitive layout. For analytical purposes, the distinction between v1 and v2 was primarily managed by implementation date, with v2 launching in the Fall 2024 semester, thereby enabling a natural segmentation of data by semester.

Student/Team System

The second system is The Student/Team System. This system is defined as the cohort of students enrolled in and actively attending the 15.390 entrepreneurship course during three specific semesters: Spring 2024 (January 1 - May 31), Fall 2024 (September 1 - December 31), and Spring 2025 (January 1 - May 13 [1]), representing the most current data available for this research. Several types of data characterize this system. Self-reported user demographic data includes student-selected 'personas' (e.g., "founder with an idea," "founder without an idea," "inventor"), their stated industry 'interests' (such as AI, software, or healthcare), and their 'previous entrepreneurial experience.' Additional user data encompasses their academic 'department' (e.g., Mechanical Engineering, Engineering Management, or cross-registered status). Content data derived from this system includes 'idea data,' where users' entrepreneurial concepts were analyzed and categorized using AI models via a custom interface designed to ensure anonymity and security. 'Step data' focused on the quantity of DE steps created per idea and the number of iterations on these steps (iteration data being available from v2 onwards), rather than the qualitative content of the steps themselves. It's important to note the relational structure here: steps are linked to ideas in a many-to-one fashion. For engagement analysis, team metrics were derived by aggregating member data. Team composition, specifically team size, was also included. A crucial scope limitation for this system is that while Orbit was accessible more broadly, this study's findings are concentrated on users within the 15.390 context, primarily because comprehensive qualitative data was not available for all users, and a wider scope would introduce excessive uncontrollable variables.

[1] This is the date of the most recently available data and does not include the end of the Spring 2025 semester

Disciplined Entrepreneurship (DE) Framework System

The third constituent system is The Disciplined Entrepreneurship (DE) Framework System. This system is defined by the 24 steps and the prescribed sequential process of the DE framework. For the analytical purposes of this research, the framework itself is treated as a static entity. Its core components include the 24-step entrepreneurial process as detailed by Bill Aulet in *Disciplined Entrepreneurship* [18], the defined sequence for progressing through these steps, the specific definitions and expected outcomes for each step, and the inherent learning objectives embedded within each stage of the framework.

Educational Environment System

Finally, the fourth system is The Educational Environment System, specifically MIT's 15.390 entrepreneurship course. This system is characterized by its structure, pedagogical methods, and assessment practices. Key elements defining this system include the mandates and timelines provided by course instructors and TAs, which typically guide the pace of engagement with DE steps according to the course syllabus. The course structure encompasses the established timeline, teaching methodologies (including the emphasis on particular aspects of the DE framework), and the nature of team-based assignments and projects. A notable aspect of this system was the evolving Orbit usage mandate: v1 was suggested as a resource, whereas v2 was more formally integrated into the curriculum. Assessment of learning objectives and overall course experience within this system was analyzed using aggregated course evaluation metrics from MIT's official course evaluation website. These evaluations included questions on whether subject expectations were clearly defined, if learning objectives were met, the contribution of assignments to learning, fairness of grading, the pace of the class, average hours spent in and out of class, and the overall rating of the subject, each with specific rating scales. For focused analysis, key questions selected were the overall subject rating, whether learning objectives were met, and the average hours spent in and out of class, as these were deemed most likely to reflect Orbit's impact. It is acknowledged that during this research period, no additional qualitative metrics beyond these aggregated evaluations were systematically collected. Future research could expand on this by incorporating student surveys, interviews, and potentially individual anonymized course evaluations, subject to MIT policies and ethical approvals.

3.2.2 Key Interfaces

The SoS framework also necessitates an examination of the key interfaces where these constituent systems interact, and what metrics can be derived from them.

The Orbit $\leftrightarrow$ Student/Team interface is characterized by direct student engagement with the AI tool, which generates a rich usability experience. Through this interface, students demonstrate behaviors related to information seeking, content generation and refinement, and their developing trust in AI. Metrics for this interface were collected and analyzed from data logged by the Orbit database. These metrics include overall tool usage (an aggregation of session duration, frequency of use, and features accessed), the number of DE steps completed, and patterns of content generation. These quantitative metrics are linked to theoretical constructs such as perceived ease of use, perceived usability, and user self-efficacy.

The Orbit $\leftrightarrow$ DE Framework interface describes the fundamental operational connection between the AI tool and the entrepreneurial methodology it supports. At a high level, Orbit is built upon an AI model interface and a prompt generation interface. The steps of the DE framework are instrumental in creating the general structure for these prompts. User-provided content is then integrated into this prompt structure, tailored to the current DE step in the process and whether the student is requesting the tool to modify a previous response. Metrics collected to analyze this interface include the popularity of different DE step sequences among users, the overall popularity of individual steps, step completion rates, and the depth of interaction, as indicated by the number of iterations or versions created for each step.

The Student/Team $\leftrightarrow$ DE Framework interface captures how students interact with the DE framework, primarily by progressing through its steps within the Orbit environment, and by engaging with DE concepts as presented in the broader educational environment. Key metrics for understanding this interaction include the time spent by students between engaging with different DE steps and the observed step sequences (e.g., linear progression versus non-linear "jumping" between steps).

The Student/Team $\leftrightarrow$ Educational Environment interface reflects students' interactions with the course structure, assignments, and schedule, which in turn influence their engagement with specific DE steps at particular times. For example, the expectation of covering 24 DE steps over a semester implies a pace of roughly two steps per week, which can shape tool usage. Metrics used to analyze this interface include patterns of Orbit usage over time, a comparison of tool usage with course milestones and deadlines, and aggregated course evaluation data.

The DE Framework $\leftrightarrow$ Educational Environment interface describes how the DE framework is integrated into the 15.390 course. This includes how the framework influences the course's learning objectives and what specific assignments are created based on DE deliverables. Metrics relevant to this interface involve comparing Orbit v1 (less integrated) to Orbit v2 (more integrated) and measuring engagement patterns over time to identify how course structure might influence usage patterns related to the framework.

The Educational Environment $\leftrightarrow$ Orbit interface highlights how the course design and timeline interact with the AI tool. The specific DE steps being taught or emphasized in the course at any given time are expected to influence tool usage patterns for those particular steps. A critical aspect of this interface is the evolution of Orbit's integration into the curriculum (v1 as suggested versus v2 as fully integrated). Metrics for this interface include comparisons of usage data and engagement patterns across v1 and v2, and an analysis of engagement with different DE steps over time in relation to the course schedule.

3.2.3 Identifying Emergent Properties

A central tenet of the SoS perspective is the concept of emergence, which refers to properties that arise from the complex interactions of components within a system. In the context of this SoS analysis, these emergent properties are derived from the interactions between the four constituent systems previously defined. Viewing the inherent complexity of the entrepreneurial learning environment through the SoS lens allows for the segmentation and analysis of these interactions at a more defined and granular level, facilitating the identification of such higher-order phenomena. The primary emergent property of focus in this research is transformed entrepreneurial learning, a qualitative shift that goes beyond merely accelerating existing learning processes. This transformed learning may manifest as different student engagement patterns, improved or novel problem-solving approaches, enhanced critical thinking skills, and a deeper, more nuanced understanding of the entrepreneurial material. Other potential emergent properties could include previously unknown patterns of tool engagement, changes in team collaboration dynamics, or SoS-level improvements in perceived value or efficiency that cannot be traced back to a single constituent system.

Measuring emergence presents inherent challenges, as emergent properties are, by definition, often unknown beforehand and can be difficult to predict or quantify directly [2]. Consequently, the analytical approach employed in this study will rely on techniques such as pattern recognition, inference from observed data, and comparative analysis. The research will look for any significant changes of state within the SoS that appear to contribute to or indicate the presence of emergent properties. Several strategies will be employed to identify these emergent properties. A key strategy involves the comparison between Orbit v1 and Orbit v2. Differences in engagement, learning outcomes, or interaction patterns following the changes in the tool and its integration may point to emergent effects. The analysis will attempt to synthesize various contributing factors, such as UI improvements, curriculum integration, and changes in the AI model, to understand their collective impact. Furthermore, Orbit log data will be evaluated for unexpected patterns in content creation or tool usage. For instance, are students utilizing Orbit in ways not explicitly prescribed by the course? Are there distinct patterns of use or outcomes between student group engagement levels that suggest more than just quantitative differences in use? Course evaluation data will also be examined to gain a high-level view of user sentiment and perceived changes. The analysis will search for noticeable shifts in student feedback that could be attributed to the introduction and evolution of the Orbit tool, looking for interesting or potentially unexplainable patterns and correlations that might surface.

Ultimately, the identification of emergence cannot be determined by analyzing the results from a single interaction or system in isolation. Emergence is a holistic phenomenon that depends on a collection of interactions leading to new, system-level behaviors. [7] Therefore, the analysis will focus on these collective behaviors to infer emergent properties. For example, the research will investigate whether there are patterns in DE step progression that, while not explainable by a single factor alone, become understandable when considering the combined influence of Orbit v2's introduction, its deeper curriculum integration, and its improved user interface, potentially leading to a significant change in student engagement and learning.

3.3 Methodological Limitations

3.3.1 Data Scope Limitations and Mitigations

Several limitations related to the scope and availability of data warrant acknowledgment, as they influence the analytical possibilities and the interpretation of findings. One set of challenges pertains to the timing of specific data collection features within the Orbit tool. Comprehensive DE step data collection, for instance, only commenced in May 2024. This timing means that a full semester-long analysis of step creation patterns for the Spring 2024 semester cannot be reliably conducted. However, data from the latter part of that semester can still be utilized for comparative analysis, particularly for identifying any emergent patterns in step creation towards the end of the term when compared to subsequent semesters with full data. Furthermore, the capability to track step versioning, indicating iterations on content, was not introduced until Orbit v2. For this reason, the majority of comparisons and analyses relating to step and step version data will focus on Orbit v2 (Fall 2024 and Spring 2025 semesters). While this is a limitation for v1 data, its impact is somewhat superseded by the broader constraint of when comprehensive step data collection began. Similarly, detailed idea data was not collected prior to January 2024, which informed the decision to focus the primary analysis on the three defined semesters: Spring 2024, Fall 2024, and Spring 2025.

Another important consideration is the completeness of user-provided demographic data. Many fields within the Orbit user profile were not mandatory. Consequently, data for several fields that are pertinent to this analysis—specifically 'interests,' 'personas,' 'previous entrepreneurial experience,' and 'affiliation' (department)—are missing for some students. To mitigate this, when these variables are analyzed, the approach will be to look at these fields in aggregate for the subset of users who did provide this information. This will allow for comparisons between different student segments based on these characteristics, rather than attempting to generalize these specific findings to the entire semester cohort where data is incomplete.

The reliance on aggregated course evaluation data rather than individual-level responses presents an additional limitation. While providing valuable high-level insights into student sentiment and perceived learning outcomes, aggregated data does not allow for nuanced analysis linking individual tool usage patterns to specific evaluation responses.

3.3.2 System-of-Systems Boundary Conditions

Explicitly defining the boundaries of the entrepreneurial learning System of Systems allows for the recognition and acknowledgement of external factors that are not captured and clarifies the scope of the investigation. For this research, the SoS boundary encompasses the interactions of students enrolled in the MIT 15.390 course specifically within the period from January 2024 to May 2025. Within the technological dimension, the analysis is confined to the Orbit tool, and further, only to its core functionalities as outlined in the system descriptions.

Many of these boundaries are naturally occurring, such as the semester timelines and course enrollment, which lend themselves to logical groupings for analysis. Other boundaries are intentionally established to control for outside variables that could confound the findings. These include, for example, the exclusion of other technologies students might be using, additional functionalities within the Orbit tool that are not central to its DE framework support, and course assignments not relevant to the DE framework. This focused approach allows for the analysis and subsequent conclusions to be specifically applicable to the Orbit tool as it operates within this predefined context: students within the specified semester time horizon, engaging with the tool in relation to the Disciplined Entrepreneurship framework, as opposed to a broader set of all possible Orbit users from outside groups who might be engaging with different frameworks or in different educational or professional environments.

Chapter 4

Results

This chapter aims to show the empirical research findings. The data was gathered directly from the Orbit tool data logs using a mixed-method approach of qualitative and quantitative data. The focus is to show the findings from the research objectively and show how they relate to the emergence of the entrepreneurial environment. The research was conducted in the context of the 15.390 entrepreneurship course and that will be reflected in how the data is presented. The findings are viewed through a system-of-systems lens as they apply to the emergent entrepreneurial environment. First, the results will show overall tool performance, adoption metrics, engagement, and course outcomes, comparing Orbit v1 to Orbit v2 as well as a semester-by-semester comparison. The results will then look at student and team characteristics and behavior relating to Orbit engagement, such as engagement levels, persona, and interests, and how the evolution of Orbit affects overall engagement. Concerning the DE framework, the results will explore specific engagement patterns as they relate to the steps in the framework. Using the system-of-systems lens, the results will explore engagement patterns and system-level interactions that emerge from system behaviors

4.1 Tool Adoption Usage Metrics

In this section, we will broadly examine metrics relating to the usage and adoption of the Orbit tool, looking at overall adoption rates, user activity, and content generation over three semesters: Spring 2024, Fall 2024 and Spring 2025.

4.1.1 User Adoption and Activity

There are three important metrics need in order to understand the dynamics of Orbit tool adoption and how user engagement occurred over the study period. They are the timeline of new user creation, the monthly active users (MAU), and the timeline of idea creation. Together, these metrics provide a comprehensive view of how users onboarded onto the platform, engaged with it, and used it for entrepreneurial activities, particularly in relation to semester cycles and the evolution of the Orbit tool from v1 to v2.

User Creation Timeline

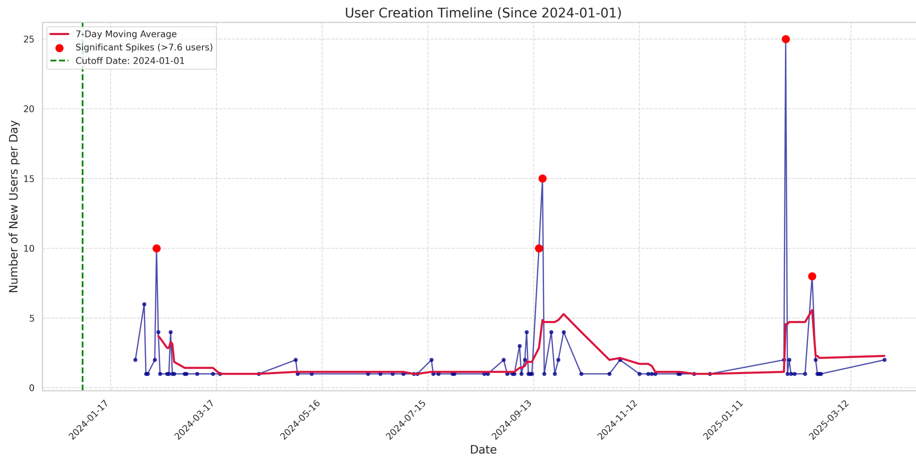

Figure 4.1: User registration over time

New user creation is heavily concentrated around the beginning of academic semester, with significant spikes in registration around these times. In late January/early February, there is a spike in user registration with new users peaking at up to 10 users per day. This spike aligns with the the beginning of the Spring 2024 semester. A more substantial series of spikes occurs around mid-September 2024, with daily new users reaching up to 15, and the 7-day moving average peaking above 5. This corresponds to the start of the Fall 2024 semester and the introduction of Orbit v2. The largest spike occurs around late January/early February 2025, with daily new users temporarily reaching 25, and another significant spike shortly after reaching nearly 10. This indicates a very strong onboarding period for the Spring 2025 semester with the mature Orbit v2, possibly related to the matured integration of Orbit into the 15.390 curriculum.

Between these semester-start peaks, the rate of new user creation drops to very low levels, often near zero, particularly during summer months (e.g., May-August 2024) and inter-session periods. Users who were observed for this research were those who attended the course in any of the three semesters in study. It should be noted that it is possible for users to have signed up outside of the course on their own, and not by mandate. The magnitude of the onboarding spikes appears to increase over time, with the Spring 2025 (Orbit v2) semester showing the highest daily influx of new users. This could suggests that promotional efforts, tool reputation, or the perceived necessity of the tool (especially with deeper curriculum integration of v2) led to more concentrated and larger onboarding in semesters after the introduction of the tool.

Overall Activity Levels: Monthly Active Users (MAU)

The pattern of active users closely resembles the user creation timeline. This demonstes that Orbit usage is closely tied to the academic calendar. Distinct peaks in active users are again observed during the beginning and other core periods of each semester. There is a peak in the Spring 2024 semester of approximately 45 active users was recorded in February 2024,

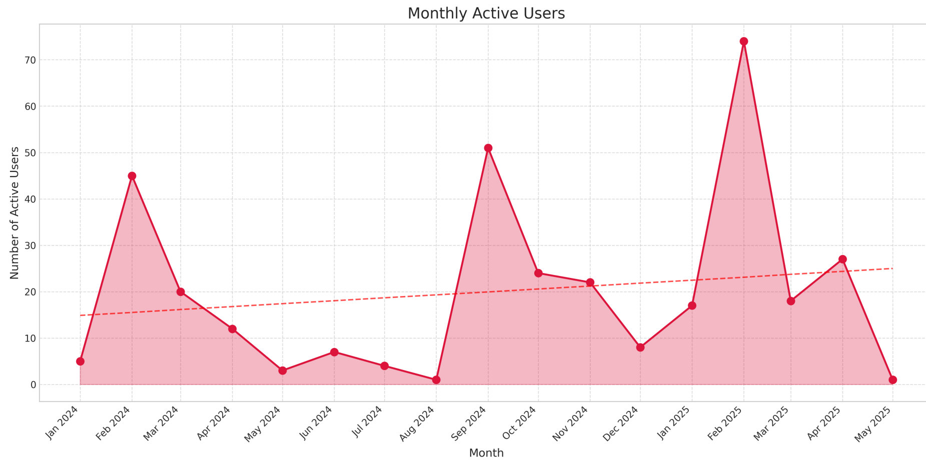

Figure 4.2: Orbit user creation by month

following the initial user creation spike. Activity surged again in September 2024, reaching a peak of approximately 51 active users, which aligns with the strong onboarding period. The Spring 2025 semester saw the highest level of monthly active users, peaking at approximately 74 users in February 2025, corresponding to the largest user creation spike. Following the semester engagement pattern, periods corresponding to semester breaks and termination show significantly lower MAU counts. This cyclical pattern reinforces the tool's primary use within the context of the 15.390 course. A notable trend is the progressive increase in peak MAU across the semesters. The peak of 45 users in Spring 2024 (Orbit v1) was surpassed by the 51 users in Fall 2024 (Orbit v2), and further eclipsed by the 74 users in Spring 2025 (Orbit v2). This upward trajectory of peak engagement suggests that Orbit v2 attracted and retained a larger active user base.

Analyzing the MAU and user registration trends together provides a picture of the overall tool adoption. Both new user intake and ongoing activity are overwhelmingly driven by the start and progression of academic semesters, which is not surprising since Orbit v2 was integrated into the curriculum in the Fall 2024 semester. The introduction of Orbit v2 (Fall 2024 onwards) correlates with larger initial onboarding spikes (user creation) and higher subsequent peaks in monthly active users. This suggests that the evolving tool and its deeper integration were more effective in attracting new users and keeping them engaged. The increasing user creation and MAU in Orbit v2 semesters could be caused by an improved user experience. User interface enhancements and the perceived value of Orbit v2 may have contributed to more students not only signing up but also actively and regularly using the tool. The strong correlation between user creation/MAU peaks and academic semester timing highlights the influence of the educational system. The deeper integration of Orbit v2 into the 15.390 curriculum likely played a significant role in driving both higher initial adoption and relatively sustained active user numbers.

The upward trends of both the MAU and the user creation rate strongly suggest an increase in Orbit's adoption patterns. There is a clear link between onboarding and usage, and the academic schedule of the 15.390 course. This demonstrates a significant increase in initial adoption and sustained active engagement during the semesters using Orbit. These metrics are crucial indicators of user engagement within the learning environment.

4.1.2 Aggregated Content Generation

In order to better understand the overall adoption of the Orbit tool, it is important to look at the rates at which content is actually being produced. This shows important insight into not only how many users are engaging with the tool tool but alsowhat they are doing with it. Figure 4.3 illustrates the number of unique users actively engaging with Orbit each month from January 2024 through May 2025. This metric complements user creation data by showing sustained engagement beyond initial registration.

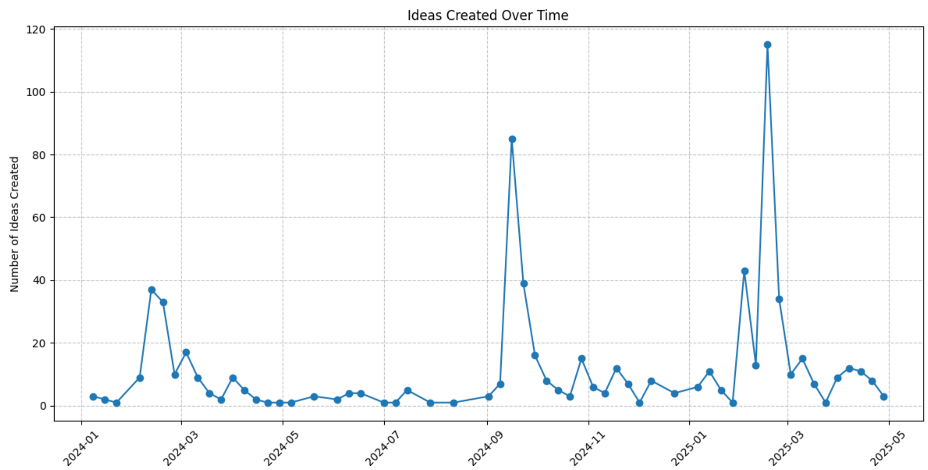

Figure 4.3: Ideas created over all three semesters

There is a significant peak in idea creation occurring in late February/early March 2024, with new ideas reaching approximately 35-40 ideas per week. The start of the Fall semester saw a very sharp spike in idea creation around mid-September 2024, with weekly new ideas gaining approximately 85. The most substantial peak in idea generation was observed in mid-February 2025, where the number of new ideas created per week exceeded 110. The magnitude of these peaks in idea creation increased notably from Orbit v1 to Orbit v2. The peak of roughly 35-40 ideas per week in Spring 2024 was significantly surpassed by the 85 ideas/week in Fall 2024 and further by the more than 110 ideas per week in Spring 2025. This suggests that Orbit v2, along with its integration, facilitated or encouraged a higher volume of initial idea generation among users. Following these intense initial peaks at the beginning of each semester, the rate of new idea creation typically declined sharply, though it often remained at a low to moderate level for several subsequent weeks before dropping off during the semester breaks. This pattern might reflect an initial burst of brainstorming and idea logging as the courses begin, followed by a period of developing existing ideas rather than continuously generating new ones at the same high rate.

The primary way ideas are developed in Orbit is through engagement with the DE steps. The total steps by week graph 4.4 shows the aggregate number of new DE steps created weekly. Similar to idea creation, step creation peaked during semesters. The Spring 2024 (Orbit v1) peak for new steps was around 380 per week. While the Fall 2024 (Orbit v2)

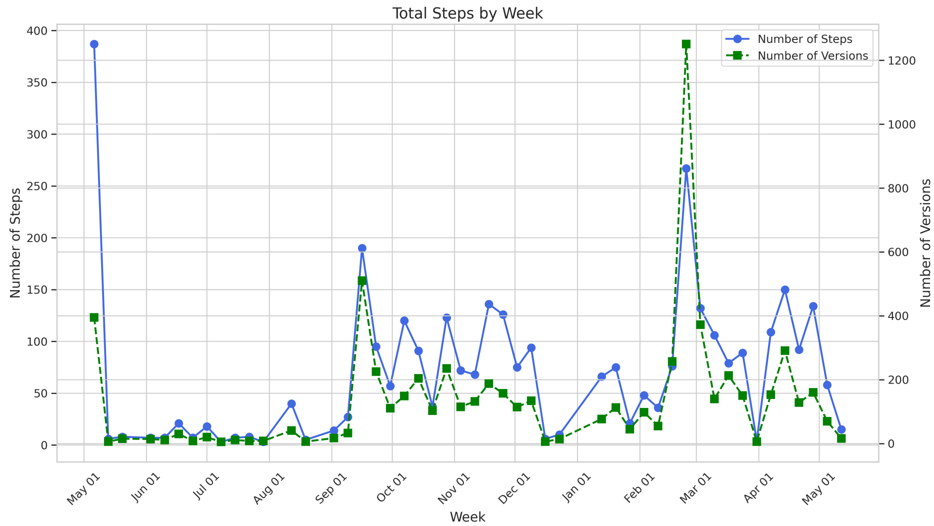

Figure 4.4: Total steps created by week

step creation peak was around 190, it was part of a more sustained period of activity. The Spring 2025 (Orbit v2) semester showed a strong peak of around 270 new steps per week. This indicates substantial ongoing work within the DE framework, particularly during active course periods.

The refinement of DE steps through versioning is a key indicator of iterative work. Total steps by week **??** also tracks the "Number of Versions" created weekly (green dashed line). While versioning occurred throughout all semesters, the Spring 2025 (Orbit v2) semester stands out with a dramatic spike, where the number of new versions created per week surged to approximately 1250 in late February/early March. This level of iterative activity was substantially higher than in previous semesters. This surge in versioning, especially in Spring 2025, suggests that users were not only creating and progressing through steps but were also engaging in significantly more intensive refinement and development of their work within Orbit v2. This points to the tool's increasing role in supporting a deeper, more iterative learning process.

4.1.3 Orbit Adoption

The user creation timeline, MAU trends, and aggregate data on idea, step, and version creation, when viewed together, provide a comprehensive picture of tool adoption and usage. New user intake, ongoing monthly activity, and the generation of new entrepreneurial ideas and their subsequent development through steps and versions are driven overwhelmingly by the start and progression of academic semesters. The introduction of Orbit v2 (from Fall 2024 onward) correlates with larger initial onboarding spikes, higher subsequent peaks in monthly active users, a higher volume of ideas generated per week, and a dramatic increase in iterative activity (versions). This suggests that the evolved tool and its deeper integration through the Spring 2025 semester were more effective in attracting new users, keeping them engaged, and supporting a higher throughput and deeper refinement of entrepreneurial concepts.

These findings illustrate the dynamic nature of the interfaces between the student/user system and the Orbit tool system. The increase in user creation, MAU, idea generation, and especially versioning in Orbit v2 semesters could reflect an improved user experience. Enhancements to the UI/UX and the perceived value or utility of Orbit v2 for these core tasks may have contributed to more students not only signing up but also actively and regularly using the tool for foundational and iterative entrepreneurial activities. In addition, the strong correlation between these metrics and the timing of the academic semester highlights the influence on the interfaces between the Orbit system and the educational environment system. The deeper integration of Orbit v2 into the 15.390 curriculum likely played a significant role in driving higher initial adoption, sustained active user numbers, and a greater focus on both generating and iteratively refining content within the platform.

The high-level engagement patterns are important to understanding how the Orbit system fits into the broader system-of-systems environment. These timelines and aggregate figures provide compelling evidence of Orbit's adoption and usage patterns. They clearly link onboarding, ongoing activity, and core content generation (ideas, steps, versions) to the course and semester schedules of the 15.390 course, and demonstrate a significant increase across these metrics during the semesters when Orbit v2 was deployed. These are fundamental indicators of the tool's growing footprint, user engagement, and its evolving role in facilitating both the initial stages of entrepreneurial exploration and the subsequent iterative development of ideas.

4.2 DE Framework

While understanding the overall adoption trend of the AI Orbit tool is important, the dynamics of how students and teams navigate and progress through the Orbit system are foundational in establishing its perceived value. One goal of the research was to understand the patterns of progression through the 24 DE steps, identifying which steps see the most (and least) engagement, where users tend to iterate or disengage, and how deeply ideas are typically developed within the framework. This analysis is crucial for identifying which parts of the framework see broad engagement and where users most frequently conclude their work or disengage from the linear progression.

4.2.1 Engagement with DE Steps

While this specific analysis focuses on aggregated data across the study period, it's important to note a broader trend observed and discussed later. The average number of DE steps engaged with per team showed an increase from the Orbit v1 period to the Orbit v2 period, and further from Fall 2024 (Orbit v2) to Spring 2025 (Orbit v2), indicating a progressively deeper engagement with the tool's features and the DE framework in later semesters.

The types of steps that were engaged with by each team varied slightly between the Fall 2024 and Spring 2025 semesters, but the majority of the step engagement patterns remained relatively constant. The number of steps increased from v1 to v2 and from Fall 2024 to Spring 2025. This indicates again a deeper engagement with the features of the tool in the later semesters. Figure 4.5 shows three charts representing different aspects of user progression through the Disciplined Entrepreneurship (DE) framework within the Orbit tool. Each chart

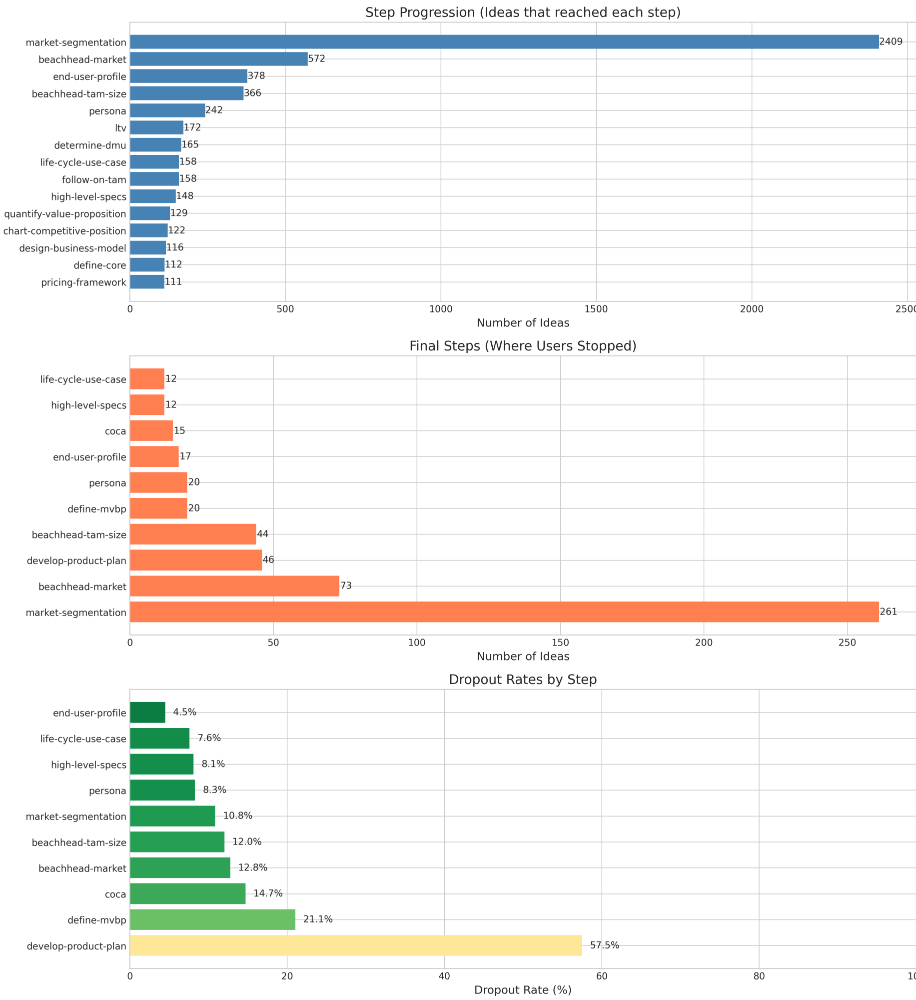

Figure 4.5: Step progression and dropout rates

provides a different perspective on how ideas move through the DE steps, where users often stop, and at which points they are most likely to discontinue progression to the subsequent step. This "Step Progression" chart illustrates the number of unique ideas that engaged with each listed DE step. The first step in the DE framework, Market Segmentation, is the most widely engaged step, with 2409 ideas having reached it. Following this, "Beachhead Market" (titled “Selecting a Beachhead Market” in the Disciplined Entrepreneurship textbook for those following along at home) was reached by 572 ideas. "End User Profile" and "Beachhead TAM (total addressable market) Size" were reached by 378 and 366 ideas, respectively. Subsequent steps, such as "Persona", "LTV (Lifetime Value)", and "Determine DMU (decision making unit)", with 242, 172, and 165 ideas respectively, show a progressive decrease in the number of ideas reaching them, indicating a funnel effect as ideas move through the framework.

The final steps metric identifies the DE steps at which users most commonly ceased further progression on an idea within the tool. It identifies the DE steps at which users most commonly ceased further progression on an idea within Orbit. This highlights critical junctures in the entrepreneurial journey. Consistent with its high initial engagement, "Market

Segmentation" is also the most frequent step where users stopped, with 261 ideas ending their documented journey here. This suggests many users utilize Orbit for initial market exploration but may not proceed further with all explored ideas. With 73 ideas, "Beachhead Market" is the second most common stopping point. Other notable final steps where a significant number of ideas concluded include "develop-product-plan" (46 ideas), "Beachhead TAM Size", "Define MVBP (minimal viable business product)", and "Persona". These findings pinpoint specific stages in the DE process where ideas are often either considered sufficiently developed for the user's immediate purpose, abandoned, or perhaps taken offline from the tool.

The dropout rates quantify the percentage of ideas that reached a given step but did not proceed to the next expected step in a linear DE progression. This rate helps to understand the points of high attrition. The step "Develop a Product Plan" exhibits the highest dropout rate by a substantial margin, at 57.5%, indicating that it is a critical hurdle or decision point where more than half of the ideas reaching this stage do not proceed further in a linear fashion within Orbit. "Define MVBP" has the second-highest dropout rate at 21.1%. The "End User Profile step, however, shows a relatively low dropout rate of 4.5%, suggesting that ideas successfully defined to this level of detail are more likely to continue to the subsequent steps in the framework.

There is substantial initial engagement at the "Market Segmentation" stage, which is also the most common point for ideas to conclude. As ideas progress, there is a natural and significant funneling effect, with fewer ideas reaching each subsequent step. The "Develop Product Plan" and "Define MVBP" stages stand out as having particularly high dropout rates, suggesting these are key points where users may pivot, pause, or find the subsequent steps more challenging to address within the tool. The overall pattern indicates that while Orbit facilitates broad exploration at the outset of the DE process, a smaller, more committed subset of ideas is carried through to the later, more complex stages of planning and validation. A compelling observation is that a majority of the steps to have the highest number of user interaction are analytical in nature (the marketing-related steps for example) and less on the creative side (unless that creative type step is in the beginning of the process, such as building an end-user profile). This could possibly suggest that the Orbit tool delivers higher value for steps that require an analytical approach as opposed to a more creative one.

4.2.2 Depth of Iteration on DE Steps

The research into step interaction shows some interesting trends relating to user engagement with Orbit. While analyzing the breadth of interaction through measuring interaction frequency is important, a full analysis still requires a more in-depth exploration. For this, the research looked at which steps users interacted with at a deeper level though an analysis of step versioning, or users' iteration patterns for an individual step. From the frequency exploration, the research found that the average number of DE steps engaged with per team increased from the Orbit v1 period to the Orbit v2 period, and further from Fall 2024 (Orbit v2) to Spring 2025 (Orbit v2), indicating a progressively deeper engagement with the tool's features and the DE framework in later semesters. Now, it's time to jump into detail on the patterns of this engagement.

The number of versions created for each DE step helps analyze the depth of iterative work

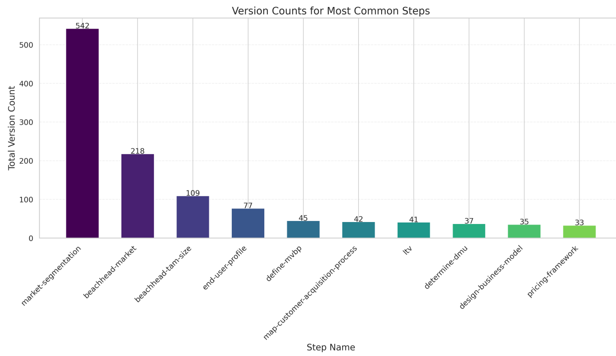

Figure 4.6: Step iteration counts for the most common steps

and refinement undertaken by students within the Orbit tool. The data shows that "Market Segmentation" is the DE step with the most intensive iterative activity, accumulating a total of 542 versions. This exceptionally high count signifies a profound degree of exploration, refinement, and rethinking by students as they grapple with this initial and critical task of identifying and defining potential markets. At first glance, one might assume this follows from market segmentation's having the highest engagement frequency, but the two observations are not ipso facto causally linked. Users can create a step infrequently but when they do, they could create far more iterations of that step than any other.

Along with market segmentation, "Beachhead Market" also demonstrates substantial iterative work, with 218 versions created, and "beachhead-tam-size" accounts for 109 versions. Collectively, these three foundational steps, all centered on the early stages of market identification, selection, and sizing, represent the vast majority of the iterative activity captured by versioning. This pattern strongly suggests that students, with the support of Orbit, engage in considerable back-and-forth, refinement, and development when defining their target customer and the scope of their initial market.

A pronounced decrease in version counts is observed for DE steps that follow these initial market-focused stages. For instance, "End User Profile", while crucial, has 77 versions. An initial hypothesis was that users may engage deeper with the more creative tasks due to their ambiguous nature, however the data did not show this hypothesis to be entirely true. This observed drop-off indicates that the intensity of iterative refinement, as captured by versioning within Orbit, diminishes as students progress further into the DE framework.

To further understand the temporal dynamics of this iterative work, the research looked into the weekly trends in version creation for the DE steps with the most versions, or iterations, shown in **??**. From the version counts, these steps are "Market Segmentation", "Beachhead Market", "Beachhead TAM Size", "End User Profile", and "Define MVBP". The data was gathered from the initial tool metric collection in May 2024 to the middle of May 2025.

This timeline aligns with previous trend data, and clearly shows pronounced peaks in version creation activity that align with typical academic semester periods. A significant peak occurs around September/October 2024 during the Fall 2024 semester, with "Market Segmentation" reaching over 100 versions per week. An even more dramatic peak is visible around February/March 2025 during the Spring 2025 semester, where market segmentation spikes to over 120 versions weekly, and other early steps like "Beachhead Market" also

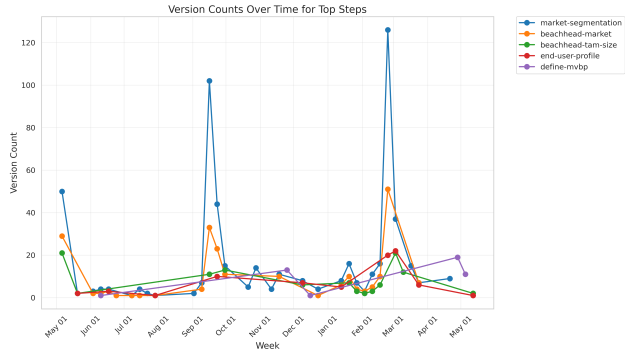

Figure 4.7: Common step version counts over time

show substantial increases. Activity for all tracked steps drops significantly during inter-semester breaks, (for example between the middle of December 2024 through January 2025. Throughout the observed period, market segmentation consistently exhibits the highest version counts during peak activity times, underscoring its role as a highly and persistently iterative initial step. During peak semester activity, a cascade effect is often visible. For instance, in early March 2025, the peak in market segmentation iteration is followed closely by peaks in versioning for beachhead market, then Beachhead TAM size, and end user profile, suggesting teams iteratively work through these foundational steps in a concentrated period. "Define MVBP generally shows more moderate iterative peaks compared to the earliest steps, though it exhibits some sustained version creation, particularly in late March/April 2025. In Spring 2024 (Orbit v1), market-segmentation iterations never climbed higher than about 50 versions per week at their early-May peak - substantially below the later Orbit v2 highs of over 100 versions per week in Fall 2024, and more than 120 per week in Spring 2025. This pattern echoes other metrics showing that Orbit v2 drove both greater engagement and deeper iteration.

The concentration of high iterative activity on the earliest DE steps suggests that these initial phases are where students perceive the greatest ambiguity and need for refinement, perhaps where they receive the most formative feedback (from instructors, peers, or the AI itself), or where the Orbit tool's features most effectively encourage or support such iterative exploration. The tool seems to enable users to grapple with the intricate task of defining their initial market. Time-based analysis shows that this focused iteration happens almost exclusively during active semester periods. The lower version counts for later DE steps could be caused by several factors. Students might achieve greater clarity and solidify their core concepts after the intensive early-stage work, thus requiring less overt iteration within the tool for subsequent steps. Alternatively, users might still be engaging with these later steps but may be saving fewer distinct versions, perhaps making refinements in an untracked manner, maybe through engagement with the teaching staff or though more team collaboration. It's also possible that there is a natural drop-off in sustained, deep engagement with the tool for some users as they move further into the framework. This pattern could also reflect aspects of the "jagged technological frontier", where Orbit's AI and interface might be more adept at supporting the types of tasks involved in early market exploration (analytical) than the more complex, synthesizing (creative) tasks of later DE stages, leading to less AI-prompted or tool-facilitated iteration. Because the versioning feature was both more fully implemented and more prominently emphasized in Orbit v2 (Fall 2024 and Spring 2025), the version counts from those semesters reflect user interaction with the enhanced tool. The sharp rise in iteration counts, particularly in the early steps, and the pronounced peaks during v2 semesters show that students engaged with those new iterative capabilities. Moreover, the dramatic jump in total versioning in Spring 2025 suggests that, as Orbit matured and users grew more comfortable, users engaged in even deeper iteration.

Orbit effectively transforms the DE framework into an actionable pathway, with user engagement highest in the early stages. The tool excels at supporting "Market Segmentation" exploration and iteration, along with other early market definition steps like "Beachhead Market" and "Beachhead TAM size." However, a "jagged technological frontier" emerges as users progress to later steps. The interface between the Orbit system and the DE framework system, specifically where the DE steps are integrated into the tool, might benefit from refinement, keeping the "jagged frontier" concept in mind.

Teams lean heavily on Orbit for the ambiguous, early-stage work: they iterate deeply on foundational steps (e.g., market segmentation) to reduce uncertainty. When later steps see a sharp decline in both engagement and iteration, it may mean students have reached clarity and moved on, found those tasks harder to tackle within the tool, or simply lost motivation. The interface between the Orbit and Student/Teams systems successfully onboards users into the DE process and supports intensive early work, but the support for sustained iteration through the Orbit tool appears to taper for more advanced framework components.

Time-series data clearly points out the role of the educational environment system interface. Iteration surges line up with active semesters, assignment deadlines, and modules that focus on specific DE steps. In Orbit v2, the deeper integration of the tool into the 15.390 curriculum drove even greater overall engagement per team, reinforcing how course pacing and emphasis shape when students iterate, and how intensively they do so.

Overall, examining version counts in total and across time reveals that Orbit isn't just a DE step tracker, but an evolving workspace where users actively develop and refine their ideas. The data strongly indicates that the tool facilitates, and users heavily engage in, a deeply iterative approach to the foundational elements of market segmentation and beachhead market definition, particularly during peak semester periods and with increasing intensity in Orbit v2. However, this intensity of tool-supported iteration appears to lessen for DE steps further down the framework, pointing to important nuances in how different stages of the entrepreneurial process are engaged with via the AI tool.

4.2.3 Navigation Patterns

Action sequence data reveals compelling insights into how users navigate the DE framework. Spring 2025 data demonstrates a strong preference for sequential progression, with users consistently advancing through multiple consecutive steps rather than jumping between disparate framework elements. This linear navigation pattern not only illuminates how students operationalize entrepreneurial methodologies but also highlights how Orbit's interface effectively structures the complex journey from idea to implementation.

Through analyzing the step sequences performed by the users, the research finds that during Spring 2025, users primarily engaged with Orbit through sustained, sequential work

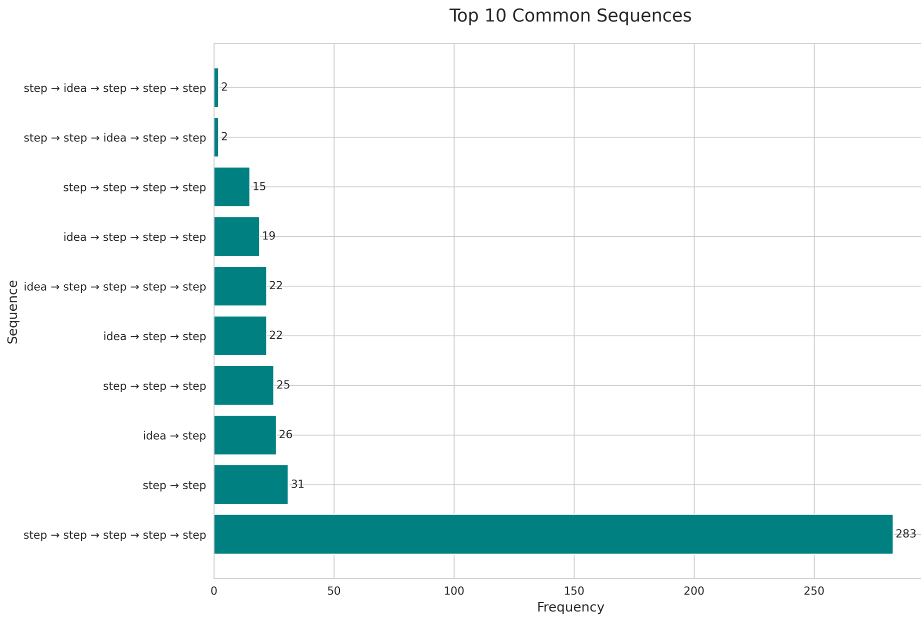

Figure 4.8: Enter Caption

on DE steps. The high frequency of five-step sequences demonstrates users' ability and tendency to work through multiple related entrepreneurial tasks consecutively. Idea creation or selection consistently serves as the common entry point before users delve into DE steps. The relative frequencies indicate that a step-to-step progression dominates the typical user journey. The prevalence of sequential step progressions suggests users commonly adopt a linear approach to navigating the DE framework, at least for process segments. While the DE framework is designed with a logical flow, Orbit effectively supports users in following this intended pathway for multiple consecutive steps. The data does not indicate frequent jumping between disparate, non-consecutive steps as a primary usage pattern, though more detailed analysis would be needed to fully characterize all navigation behaviors.

While detailed comparative navigation data between Orbit v1 (Spring 2024) and v2 (Fall 2024, Spring 2025) is limited by data logging implementation timing, the increased overall engagement and step completion depth observed with v2 suggests its interface facilitated smoother, more sustained navigation. The higher frequency of longer step sequences in v2 periods indicates users found it easier to maintain momentum through the process. The higher observed linear navigations also show that the interface between the Orbit system and the Student/Team system through the tool's UI effectively supports moving directly from one step to the next. Quick access to the subsequent DE steps, and the ability to transition smoothly from an idea to its related tasks, likely underpins these workflows, demonstrating the effective transfer between the Orbit and DE Framework systems. Orbit's presentation of the DE framework, presumably as a sequential or easily navigable list, aligns with and enables the observed linear engagement patterns. The tool successfully translates the structured nature of the DE framework into an actionable pathway for users.

4.2.4 Depth of Framework Completion per Idea

Beyond observing aggregate engagement and iteration on specific DE steps, it is crucial to understand the extent to which individual entrepreneurial ideas are developed within the Orbit tool. To accomplish this, the research looked into the depth of framework completion per idea, revealing how far typical ventures progress through the 24 steps and highlighting any evolution in this depth across semesters.

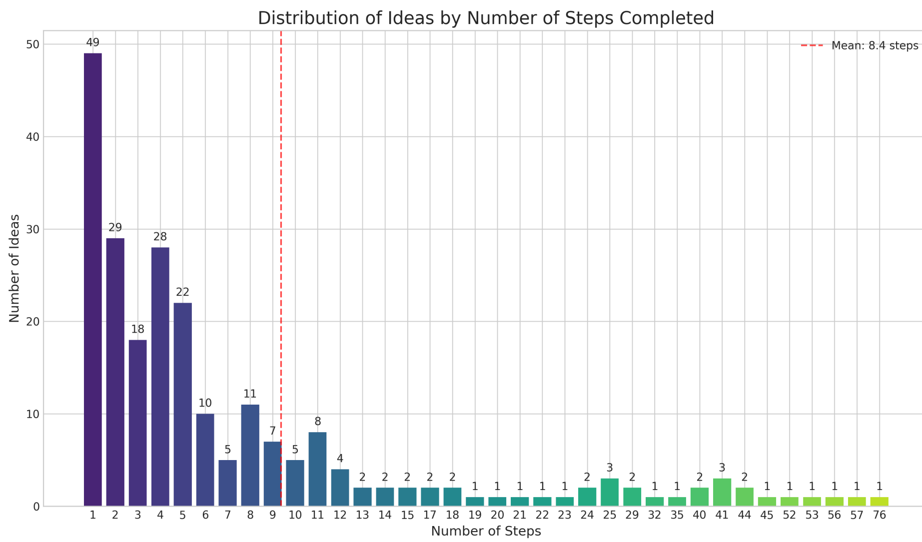

Figure 4.9: Distribution of ideas by the number of completed steps for Fall 2024

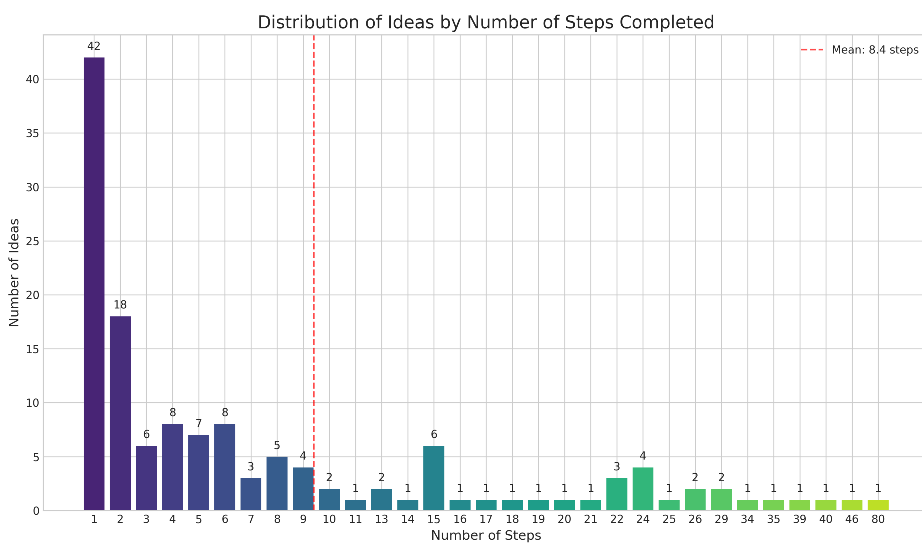

Figure 4.10: Distribution of ideas by the number of completed steps for Spring 2025

Analysis of step completion data across consecutive Orbit v2 semesters reveals consistent patterns in how users engage with the Disciplined Entrepreneurship framework, while also highlighting important evolution in tool usage. Both Fall 2024 and Spring 2025 semesters show strongly right-skewed distributions, with most ideas completing only a few steps. In both periods, single-step ideas were most frequent with the Fall 2024 semester showing 49 and the Spring 2025 semester showing 76. This is followed by a sharp decline for users' ideas engaging with two steps,42 for Fall 2024 and 29 for Sring 2025, and then three steps; 18 and 23 for the Fall and Spring. Interestingly, for both semesters there is a small upswing for ideas completing 8 steps. The steps were not all the same for the ideas with 8 steps, and the reasoning behind this and the significance is unclear. Despite these similarities, meaningful differences emerged between semesters. The mean steps completed per idea increased substantially from 8.4 in Fall 2024 to 11.3 in Spring 2025. Spring 2025 also showed more ideas reaching advanced stages, with the maximum steps and step versions for a single idea increasing from 76 to 119.

These patterns suggest Orbit primarily serves early-stage exploration for most ideas, while simultaneously supporting deeper engagement for a subset of ventures. The increase in mean step completion and higher maximum values in Spring 2025 indicates evolving usage patterns as users gained familiarity with the tool or received enhanced pedagogical support. This progression in engagement depth, even within the v2 implementation period, demonstrates how the tool accommodates diverse usage patterns while encouraging increased framework engagement over time.

4.3 Course-Level Outcomes

To assess the overall performance and student perception of the Entrepreneurial Learning system, aggregated course evaluation data was attained for the 15.390 entrepreneurship course. These evaluations, submitted anonymously and voluntarily by students who attended each iteration of the course, provide a valuable longitudinal perspective on how the learning experience was perceived over time, particularly in relation to the introduction and evolution of significant educational resources like the Orbit AI tool. The data and outcomes from the course evaluations contribute the primary qualitative dimension to the mixed-methods approach employed in this research.

While course evaluations offer a broad view rather than granular metrics of specific learning objectives, they serve as a significant indicator of student satisfaction, perceived value, and the overall effectiveness of the educational environment. For an established course like 15.390, tracking these evaluations across semesters, specifically from Fall 2021 through Fall 2024 (the Spring 2025 evaluations were not available at the time of this report), allows for a comparative analysis. The data collected spans from the Fall 2021 semester to the Fall 2024 semester. This historical data provides a reference point to which the the impact of the Orbit implementation can be compared and an allows for the assessment of potential shifts in the student experience with more reliability.

The course evaluations encompass a range of questions designed to capture different facets of the learning experience. These questions and their respective scoring scales are outlined below:

1. Core Subject Assessment (1-7 Scale: 1=Strongly Disagree, 4=Neutral, 7=Strongly Agree; Optimal Score: 7)

a. Subject expectations were clearly defined (Measures clarity in course objectives and requirements)
b. Subject's learning objectives were met (Assesses student perception of achieving the stated educational goals)
c. Assignments contributed to my learning (Evaluates the perceived value of coursework in the learning process)
d. Grading thus far has been fair (Gauges fairness in assessment)

2. Course Pace (1-7 Scale: 1=Too Slow, 4=Just Right, 7=Too Fast; Optimal Score: 4)
   a. The pace of the class (content and assignments) was: (Assesses if the course progression suited student learning needs)
3. Time Commitment (User-inputted numerical value representing hours per week)
   a. Average hours you spent per week on this subject in the classroom.
   b. Average hours you spent per week on this subject outside of the classroom.
   c. (These questions quantify the student workload)
4. Overall Subject Evaluation (1-7 Scale: 1=Very Poor, 7=Excellent; Optimal Score: 7)
   a. Overall rating of the subject (Provides a holistic measure of student satisfaction)
5. 5. Recommendation (1-5 Scale: 1=Strongly Disagree, 3=Mixed, 5=Strongly Agree; Optimal Score: 5)
   a. Recommend Subject (Indicates the likelihood of a student endorsing the course to their peers, serving as a strong proxy for perceived value and positive experience)

The results from the collected course evaluations are shown in 4.11

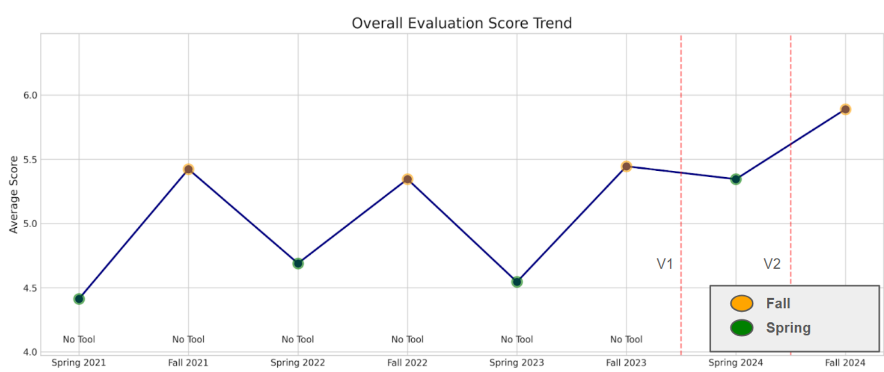

Figure 4.11: Course evaluation trend from Spring 2021 to Fall 2024

Since the course evaluations are anonymous, they may provide a candid reflection of the student experience across these multiple dimensions. The analysis of the results from the collected evaluations illuminates trends in these metrics, particularly focusing on noticeable shifts that correlate with the introduction and evolution of the Orbit AI tool within the 15.390 learning system-of-systems.

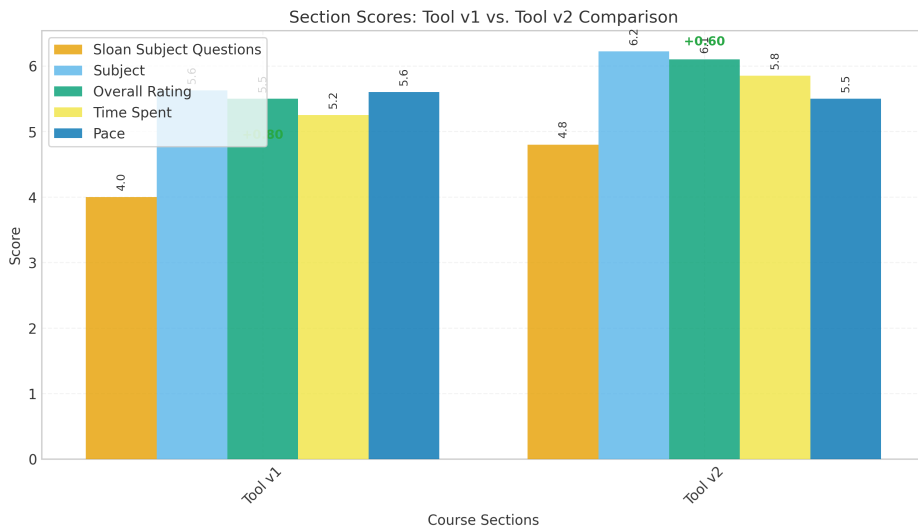

Figure 4.12: Course evaluations broken down by question, compared between Orbit v1 and Orbit v2

Comparing course evaluations from semesters prior to Orbit's implementation with those from semesters where the tool was utilized provides valuable insight into its potential effect on the Educational Environment system. Historically, ratings for the 15.390 entrepreneurship course, while generally stable, tended to show Fall semesters rated slightly higher on average than Spring semesters. The introduction and evolution of Orbit, however, appear to coincide with notable positive shifts in these established patterns. Comparing course evaluations from semesters prior to Orbit's implementation with those from semesters where the tool was utilized provides valuable insight into its potential effect on the Educational Environment system. Historically, ratings for the 15.390 course, while generally stable, tended to show Fall semesters rated slightly higher on average than Spring semesters. The introduction and evolution of Orbit, however, appear to coincide with positive shifts in these established patterns.

Arguably one of the most interesting findings emerges when examining the Spring 2024 semester, which saw the introduction of Orbit v1. While Spring semesters for 15.390 from the past evaluations tended to be rated on average lower than Fall semesters (which had a historical average overall rating of 5.8), the Spring 2024 semester achieved an overall rating of 5.9. This score not only surpassed typical Spring performance but also slightly exceeded the Fall 202 average, representing a significant departure from the established trend.

Combined with the overall rating for pre-Orbit Fall semesters, which averaged 5.5. The data shows an overall increase in rating to 5.9 with the introduction of Orbit v2 in Fall 2024. When focusing on a composite of core questions directly relevant to Orbit's potential impact, namely, "Subject's learning objectives were met," "Assignments contributed to my learning," and "Subject expectations were clearly defined," the average for Fall 2024 rose further to 6.1. These specific questions were given particular attention in this analysis as they directly reflect core aspects of the learning experience potentially enhanced by an AI educational tool: the achievement of learning objectives is paramount, and positive contributions to learning

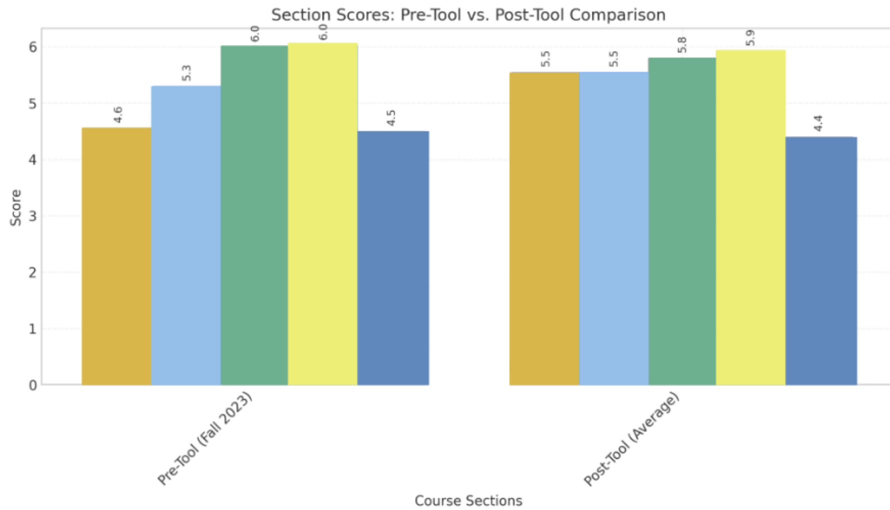

Figure 4.13: Course evaluations broken down by question, compared between pre-Orbit and post-Orbit introduction

signify an enriched educational atmosphere.

Another interesting finding from the course evaluation data is that students showed a positive increase in scores for “Assignments contributed to my learning,” with this metric rising from a pre-Orbit average of 5.6 to 6.1 in semesters with Orbit. With Orbit v2 being fully integrated into the curriculum and indicated as a tool for assignments, this suggests that students not only used the tool for their coursework but also perceived it as a valuable and trusted component of their learning activities within the educational environment. This increased perceived value is consistent with the higher user counts and enrollment observed by the Spring 2025 semester (though formal Spring 2025 evaluations are pending).

Further analysis of the average number of hours spent on course material outside of the classroom reveals an increase from 5.3 hours per week in Fall 2023 (pre-tool) to 5.5 hours in Spring 2024 (Orbit v1). There was also a further increase between Orbit versions, from 5.5 hours with v1 to 6.2 hours with v2 (Fall 2024). Combining this with the improved scores for learning objectives being met and increased overall satisfaction, this rise in time spent suggests students were experiencing deeper learning through more intensive engagement with the Orbit system and the broader learning system, facilitated by tool interactions and assignment resources. Students may have been leveraging Orbit v2 to delve deeper into the entrepreneurial concepts within the Disciplined Entrepreneurship framework, potentially contributing to the higher average number of ideas and steps generated within the tool in later semesters, like Spring 2025.

This positive shift, particularly the notable performance of the Spring 2024 (Orbit v1) semester and the strong ratings in Fall 2024 (Orbit v2), suggests that students perceived the course as highly effective in achieving its stated pedagogical objectives during periods of Orbit use. The Orbit system’s potential function as an "external enabler" for engaging with the Disciplined Entrepreneurship framework, its capacity to alleviate "cognitive load" for certain challenging tasks, and its support for deeper iteration (as evidenced by increased steps per idea in later Orbit v2 semesters, detailed in Section 4.3) may have collectively contributed to this enhanced sense of learning and satisfaction within the system. Furthermore, preliminary indicators such as an observed increase in student enrollment or attendance from previous offerings to the Spring 2025 semester (Orbit v2) could also suggest a growing perceived value of the 15.390 course, potentially influenced by the positive experiences with and capabilities of the Orbit tool. However, formal course evaluation data for Spring 2025, when available, will need to be gathered in order to support (or maybe disprove) this observation.

4.4 Student/Team-Level Engagement

Having examined the broader patterns of tool adoption, the intricacies of engagement with the Disciplined Entrepreneurship framework, and overall course-level outcomes, the focus of the research pivots to a more granular analysis of user interaction at the student and team level. The Orbit AI tool and the entrepreneurial learning process are not experienced uniformly by all participants, so therefore the research aims to understand the variability in engagement based on individual student characteristics and team dynamics. The granular student and team-level interactions that will be explored relate to how student and team attributes mediate the effectiveness and utilization of the Orbit tool within the System-of-Systems. The important aspects of engagement patterns were found by analyzing the impact of self-reported user personas, quantitatively defined engagement segments, aspects of team composition such as size, and collaborative dynamics within teams. The influence of other available demographic factors, like student interests, were analyzed as well. The primary aim here is to identify how these different attributes correlate with varying levels and styles of interaction with both the Orbit tool and the DE framework it supports. By uncovering these nuanced patterns, we can gain deeper insights into who benefits most from the current iteration of the AI-enhanced learning environment and identify potential areas for more tailored support or tool development.

4.4.1 Student Engagement by Persona

Looking at users through analysis of their of self-reported user personas provides two key visualizations provide insights. The first insight details the aggregate number of ideas and DE framework steps generated by each persona group, shown in 4.14, and the second insight illustrates the average number of DE steps completed per user within each persona category (<FIGURE>). Together, these analyses help to understand both the overall contribution of different persona groups and the typical depth of individual engagement within those groups.

In both charts, the "Not Specified" category (users who did not select a persona) accounts for the highest aggregate number of both ideas (460) and steps (4,340). This large volume from unspecified users highlights a significant portion of tool usage comes from individuals who either chose not to identify with a predefined persona or for whom persona data was not captured. While this is a significant portion of users, the analysis on the users who elected to input this information can still lead to valuable insight. Following "Not Specified," "Founder with an Idea" and "Explorer" are the next largest contributors to idea generation. "Joiner" and "Founder without an Idea" show somewhat influential idea output. Other personas

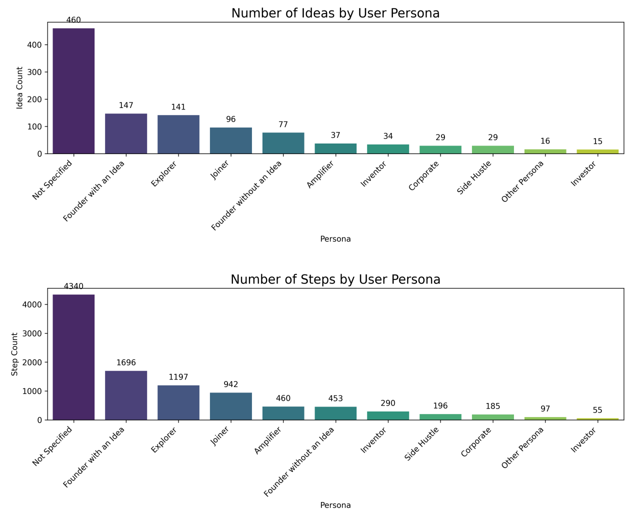

Figure 4.14: Enter Caption

like "Amplifier," "Inventor," "Corporate," "Side Hustle," "Other Persona," and "Investor" contribute a smaller volume of total ideas. For total steps processed, after "Not Specified," "Founder with an Idea" is the leading identified persona, contributing 1,696 steps. "Explorer" and "Joiner" also demonstrate high aggregate step engagement. "Amplifier" (460 steps) and "Founder without an Idea" (453 steps) follow, with other personas showing progressively lower total step counts. The aggregate data shows the overall footprint of each persona group within the Orbit ecosystem. While the "Not Specified" group is largest, among the identified personas, "Founder with an Idea" and "Explorer" are major drivers of both idea creation and step processing in terms of sheer volume.

The average steps per user by persona metric offers a normalized view of engagement depth, revealing how intensively individuals within each persona category interact with the Disciplined Entrepreneurship framework through Orbit. This analysis uncovers distinct patterns of tool utilization across different entrepreneurial identities. Users identifying as "Amplifiers" demonstrate exceptional engagement depth, averaging 46 steps created per user. This suggests that individuals in this role, focused on expanding and enhancing existing concepts, engage most thoroughly with the DE framework when using the tool. "Founders with an Idea" show the second-highest average engagement (37.7 steps per user), indicating substantial individual commitment to developing their pre-existing concepts. "Joiners" also exhibit strong individual engagement at 33.6 steps per user, likely reflecting their dedication to understanding ventures they aim to contribute to. Three personas demonstrate moderate engagement levels: "Explorers" (29.9 steps), "Inventors" (26.4 steps), and "Founders without an Idea" (25.2 steps). This middle tier suggests a pattern of methodical but less intensive framework navigation. At the lowest end, "Investors" average only 6.9 steps per user, showing significantly more selective engagement with the DE process. When analyzing both aggregate contributions and per-user averages together, a more sophisticated understanding emerges of how personas shape tool interaction patterns:

Intensity vs. Volume: While the "Not Specified" category dominates in aggregate contributions due to its size, personas like "Amplifier" and "Founder with an Idea" demonstrate the most intensive individual engagement. This distinction reveals how a smaller group with high individual engagement can show different usage patterns than a larger group with moderate engagement.

Purposeful Engagement: The substantial difference between "Founders with an Idea" (37.7 steps per user) and "Founders without an Idea" (25.2 steps) provides compelling evidence that having a pre-existing concept drives significantly deeper initial engagement with the DE framework, suggesting that Orbit serves different functions based on a user's starting point.

Role-Aligned Utilization: "Explorers" and "Joiners" show balanced profiles with significant activity both in aggregate and average engagement, reflecting their exploratory and collaborative entrepreneurial roles. Meanwhile, "Investors'" limited engagement likely reflects their distinctive goals possibly in evaluating rather than developing ventures as well as different expectations from the DE process.

These findings strongly support the hypothesis that user personas significantly mediate interaction patterns with both Orbit and the DE framework, with each persona exhibiting a distinctive engagement profile aligned with their entrepreneurial identity and objectives.

4.4.2 Team-Level Engagement Dynamics

The collaborative nature of MIT's 15.390 course makes team-level analysis essential for understanding how Orbit facilitates group entrepreneurial work. This section examines the progression of team engagement across the Spring 2024 (Orbit v1), Fall 2024 (Orbit v2), and Spring 2025 (Orbit v2) semesters, revealing significant shifts in collaborative tool utilization patterns. By analyzing team outputs (ideas generated and DE steps completed), work session characteristics, and interaction patterns, the research revealed a marked evolution in how teams leverage Orbit's capabilities. The data demonstrates a compelling correlation between tool development from v1 to v2 and increasingly sophisticated team engagement over time. Teams progressively moved from basic tool exploration to deeper, more strategic utilization of Orbit's features, suggesting an enhanced integration of AI assistance into their collaborative entrepreneurial process. This transformation in team engagement patterns not only reflects the technical improvements in Orbit v2 but also indicates an evolving understanding among students of how to effectively incorporate AI tools into complex collaborative work. The following analysis details these shifts in team behavior and their implications for AI-enhanced entrepreneurial education.

Figure 4.15 illustrates team activity by semester, displaying the number of ideas and steps created by each team. A consistent pattern across all semesters is that teams generated substantially more DE steps than distinct ideas, underscoring that the primary use of Orbit by teams is to work through the detailed stages of the DE framework for their selected ventures. A marked increase in the volume of steps processed per team is evident, particularly with the transition to and continued use of Orbit v2. The most active team generated approximately 150 steps. Overall step counts per team were generally lower during this Orbit v1 period. The top team ("Atelier V") processed around 200 steps, with several other teams demonstrating similarly high engagement. The leading team created over 450 steps, with other top teams also showing exceptionally high output, exceeding previous semesters. This clear progression in the sheer volume of DE steps handled by teams, especially the pronounced increase in Spring 2025, points to Orbit v2 facilitating more extensive and in-depth team engagement

Figure 4.15: Team activity for all semesters

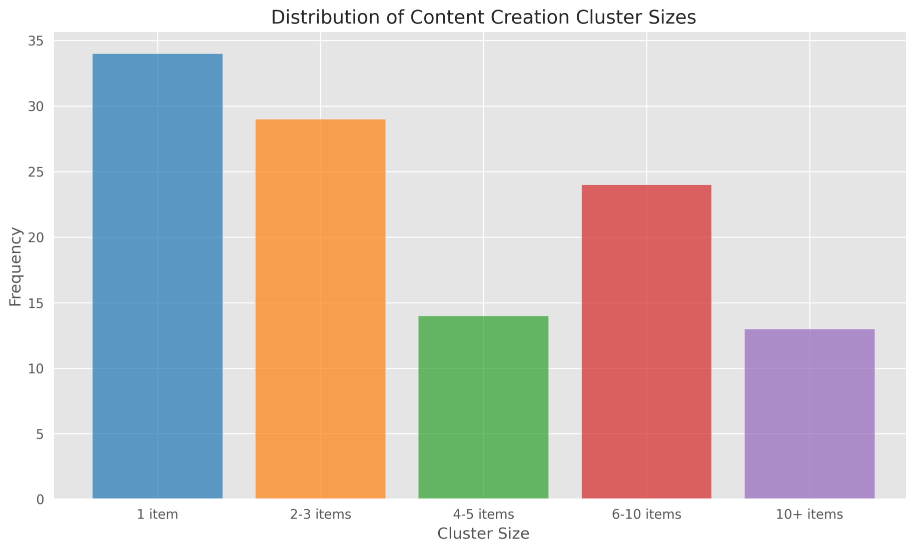

Figure 4.16: Team content cluster sizes for Spring 2024

with the DE framework. This illustrates an evolution in engagement patterns coinciding with Orbit's development.

To add to the analysis from the team total output, the research looked at how the intensity or "burstiness" of team work sessions evolved. The clusters in figures 4.16, 4.17, and 4.18 represent the number of items (ideas or steps) created by a team within a concentrated timeframe, indicating the volume of output during focused periods of activity. The first chart relates to the Spring 2024 semester, the second chart relates to the Fall 2024 semester, and the third chart relates to the Spring 2025 semester.

In 4.16, representing the content distribution in the Spring 2024 semester, the high frequency of lower item creation clusters, and decrease in frequency of the lower item clusters suggests that many work sessions in Orbit v1 were characterized by lower intensity output. In the Fall semester, a swing in team behavior occurred, with clusters of 10 items becoming the dominant team behavior. This coincides with the rollout and integration of Orbit v2, and shows the beginning of a trend towards teams engaging in more intensive work sessions, producing a larger volume of content in concentrated periods. This trend towards higher-intensity work sessions intensified. Bursts of activity yielding 10 or more items in a timeframe were overwhelmingly dominant. Not only did the larger clusters remain dominant through the evolution of Orvit v2, but the frequency of the smaller cluster sizes collectively shrank. This indicates that there is an overall movement toward more interactions in single sessions with the evolution of the Orbit tool.

By examining both team activity volume and work session intensity, we observe a clear shift from v1 to v2 toward deeper, more concentrated engagement with Orbit. In the later semesters, teams not only completed substantially more DE steps but also organized their efforts into focused bursts of activity. This pattern suggests that enhancements in Orbit v2, whether through new features, a smoother interface, or tighter curriculum integration, made it a more powerful platform for collaborative entrepreneurial work. These findings show how Orbit's evolution altered team engagement patterns, and demonstrate how the Student/Team

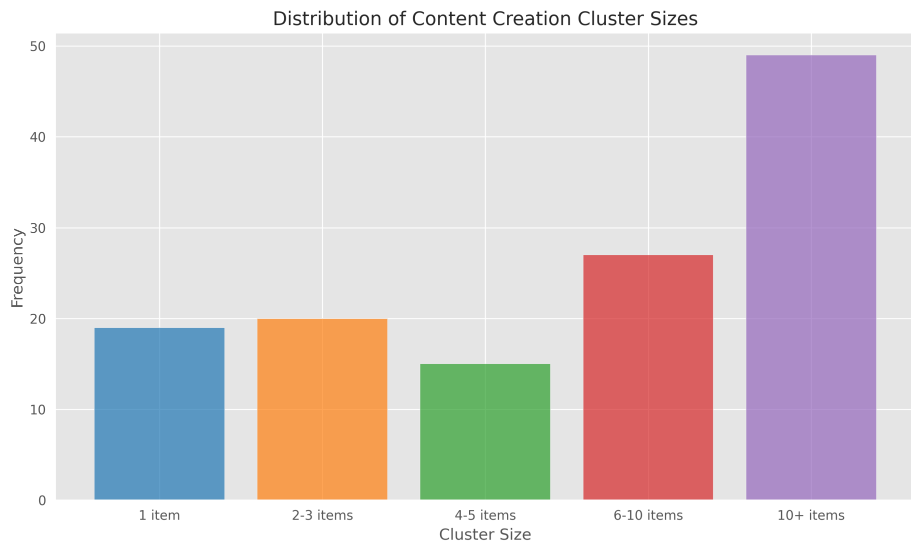

Figure 4.17: Team content cluster sizes for Fall 2024

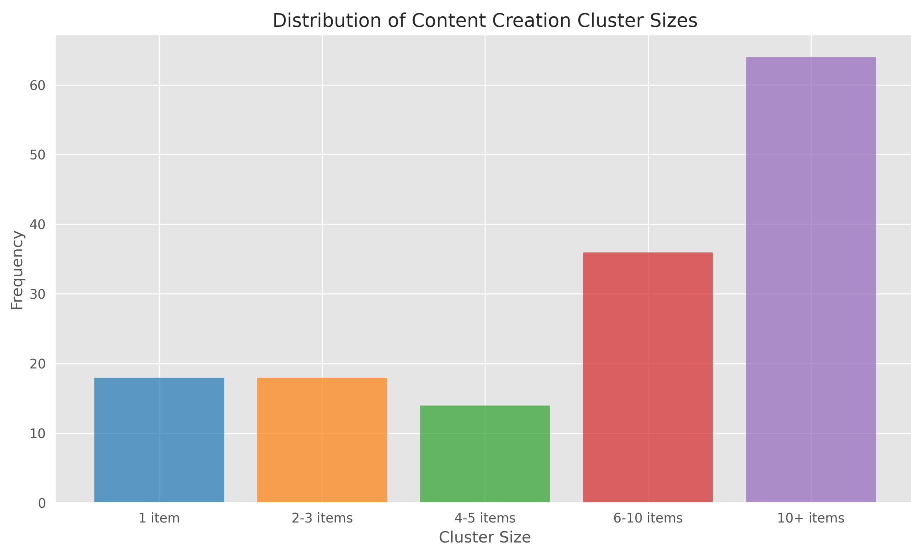

Figure 4.18: Team content cluster sizes for Spring 2025

system and Orbit system interface supported richer, more focused collaboration. While individual teams varied in their intensity, the overall trend further reinforces Orbit's growing role in enabling intensive, in-depth exploration and execution of the DE framework.

To understand how teams engaged with the Disciplined Entrepreneurship (DE) framework through Orbit as well as how that engagement evolved as the tool matured, the research conducted a comparative analysis of three key dimensions across Spring 2024 (v1), Fall 2024 (v2), and Spring 2025 (v2). By examining the number of ideas each team generated, the average number of iterative versions per idea, and the equity of contribution within teams (measured via the Gini coefficient), we capture both the breadth and depth of collaborative work, as well as how evenly that work was shared. First, it is important to look at the Spring 2024 semester as a baseline for comparison, since this is when Orbit was first deployed. Then the analysis will be able to trace how engagement patterns shifted with the v2 interface in Fall 2024 and Spring 2025. Through this layered comparison, the analysis aims to show not only whether teams generated more ideas or refined them more deeply, but also whether Orbit's evolution fostered more balanced, sustained collaboration. Ultimately, these findings speak directly to how team engagement patterns change over time and how interface enhancements influence collaborative dynamics

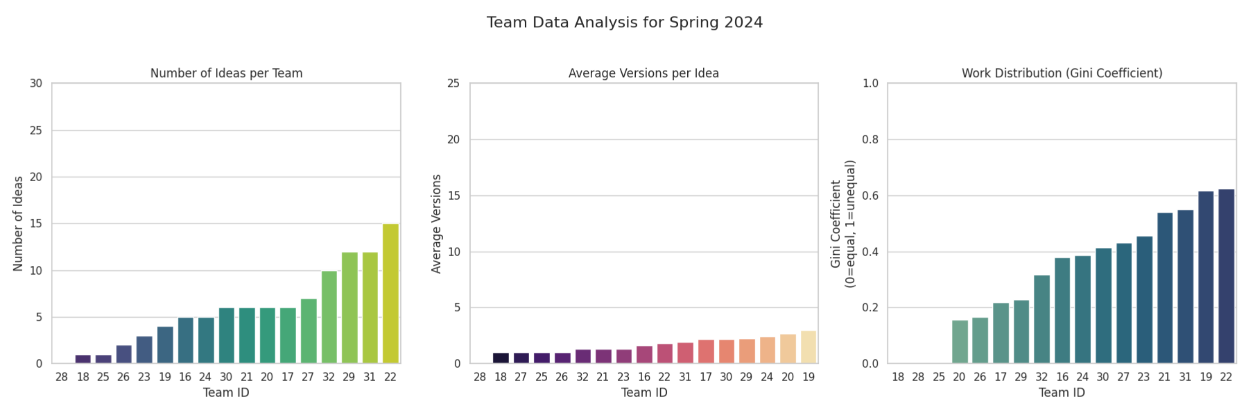

Figure 4.19: Engagement depth analysis for Spring 2024

The Spring 2024 semester established our baseline for how teams engaged with Orbit. Most teams generated only 1–6 ideas, with just a few pushing into double digits. This narrow ideation range suggests that Orbit v1 either didn't encourage broader concept exploration or that teams used it with a very targeted focus—consistent with early AI-adoption behavior at the "jagged technological frontier." Iteration on those ideas was also minimal: teams averaged only 1–3 versions per concept, implying they treated Orbit primarily as a place to document initial drafts rather than refine them over time. Finally, contributions were uneven: Gini coefficients clustered between 0.3 and 0.6 for many teams, indicating one or two members did most of the work. From a system-of-systems standpoint, this uneven workload points to a suboptimal interaction between the Student/Team system and the Orbit Tool system.

With the transition to Orbit v2 in Fall 2024, all three engagement metrics shifted noticeably. Ideation breadth expanded with several teams creating more than 10 ideas, and the top performers reaching 20–25 (a roughly 67% increase in maximum ideas compared to Spring 2024). This jump aligns with Davidsson's external enabler theory, suggesting

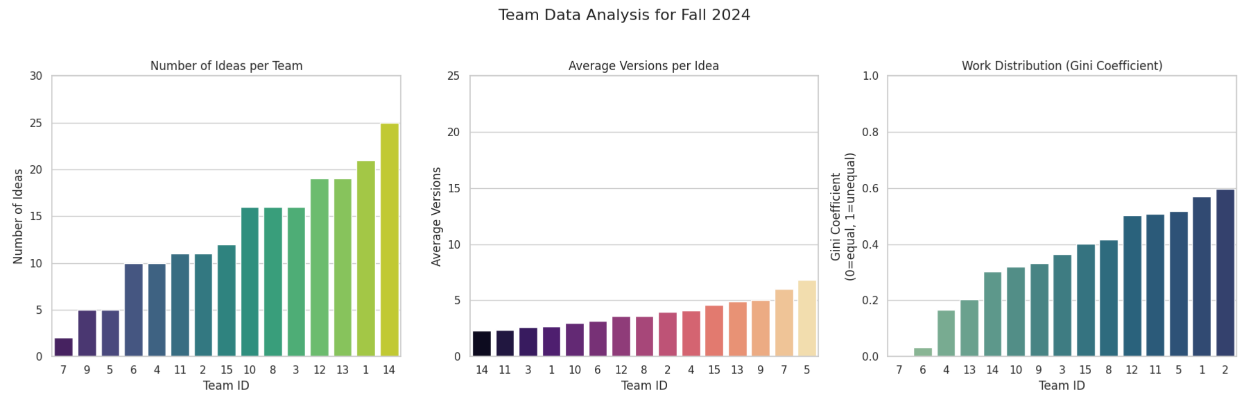

Figure 4.20: Engagement depth analysis for Fall 2024

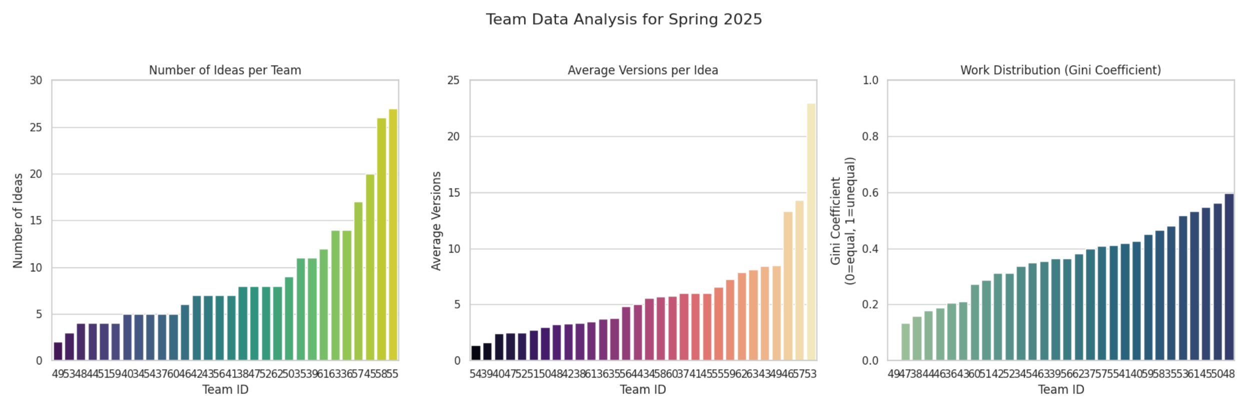

Figure 4.21: Engagement depth analysis for Spring 2025

the v2 enhancements lowered barriers to creative exploration. Collaboration also became more equitable: although Gini scores still varied, the average coefficient fell from 0.231 to 0.052, reflecting a large improvement in workload balance. Enhanced interface design, deeper curriculum integration, and fewer technical hurdles likely helped more students participate evenly.

By Spring 2025, teams were tapping Orbit v2 even more deeply. Ideation breadth held steady beyond Fall 2024 levels, while iteration depth doubled. These patterns show that, as the tool matured, students leveraged Orbit's full capabilities to explore and refine a wider array of concepts. Overall, the Spring 2025 data demonstrate that Orbit v2 did more than speed up existing workflows; it fundamentally transformed team engagement by fostering richer exploration, more sophisticated development, and fairer collaboration than was possible with v1.

4.5 Emergent Patterns and System-Level Observations

The preceding sections have detailed the specific patterns of tool adoption, engagement with the Disciplined Entrepreneurship (DE) framework, course-level outcomes, and the influence of student and team characteristics within the 15.390 learning environment. The goal now is to see what system-of-systems emergence patterns can be observed. The research will synthesize the findings to identify emergent patterns and system-level observations that arise from the complex interplay of the constituent systems: the Student/Team, the Orbit AI tool, the DE Framework, and the Educational Environment. Emergence, in the context of a System-of-Systems (SoS), refers to novel properties, behaviors, or outcomes that are not inherent in any single component system but arise from their dynamic interactions. Identifying such emergence is crucial for understanding the holistic impact of introducing an AI tool like Orbit into an established educational setting. This analysis explores shifts in learning engagement, collaborative dynamics, and overall system performance that suggest more than simple additive effects of the tool. These observations will be pivotal in informing the discussion around design principles for future AI-enhanced entrepreneurial learning environments.

4.5.1 Emergence of Deeper Learning Engagement

One of the most significant emergent patterns observed is a shift towards deeper and more iterative learning engagement, particularly evident with the maturation and integration of Orbit v2. This goes beyond mere acceleration of tasks, suggesting a qualitative change in how students approached the entrepreneurial learning process.

This pattern is supported by several converging lines of evidence. Firstly, there was a dramatic increase in the number of versions created per DE step and per idea, especially in the Spring 2025 (Orbit v2) semester. Next, the nature of work sessions evolved, with a clear shift from smaller "content creation cluster sizes" (representing items created in a concentrated timeframe) in Orbit v1 to significantly larger and more intensive clusters in Orbit v2 . Additionally, the average number of DE steps completed per idea showed an upward trend within the Orbit v2 period (Fall 2024 vs. Spring 2025. And finally, this increased tool-based engagement occurred alongside an increase in "average hours spent outside of the classroom" which, importantly, was coupled with improved overall course satisfaction and students' perception that learning objectives were met.

The SoS, particularly with Orbit v2 as a central component, appears to foster a more transformative learning experience. Students were not just completing more steps; they were engaging in more profound iterative cycles, dedicating more focused time, and developing their ideas to a greater depth. This suggests that the interplay between a more capable AI tool (Orbit System), its integration into course assignments (Educational Environment System), the structured DE Framework, and student adaptation (Student/Team System) created an environment conducive to deeper critical thinking and refinement, rather than just faster output.

4.5.2 Enhanced Learning System Performance and Perceived Value

Along with more learning engagement, the data points towards an emergent property of enhanced overall learning system performance and an increase in the perceived value of the 15.390 course. This was shown in the positive shifts in key course evaluation metrics during the Orbit v1 and particularly Orbit v2 periods. Improvements in "overall rating of the subject," student agreement that "subject's learning objectives were met," and that "assignments contributed to my learning" are significant. These occurred alongside increased Monthly Active Users (MAU) and larger, more concentrated user creation spikes during Orbit v2 semesters, indicating higher adoption and sustained engagement. Furthermore, the substantial increase in overall output by teams (total ideas and especially total steps processed) in Orbit v2 semesters points to a more productive learning environment.

The synergy between an improved Orbit tool (Tool System), its effective integration into the curriculum (Educational Environment System), and the resulting higher and deeper student engagement (Student/Team System) appears to have led to an emergent outcome of improved overall system performance and heightened perceived course value. The learning environment, as an integrated whole, became more effective and satisfying for students. This is not solely attributable to Orbit being a "better tool" by itself, but rather to how its enhanced capabilities interacted with and positively influenced the other constituent systems.

4.5.3 Evolution of Team Dynamics and Engagement

The team-based nature of the 15.390 course provides a fertile ground for observing emergent collaborative patterns facilitated by Orbit. Analysis of team-level data revealed several key trends. There was a notable increase in team output, including more ideas explored per team, significantly more DE steps processed, and dramatically higher average versions per idea, especially in Orbit v2 semesters. This was coupled with the shift to larger "content creation cluster sizes," indicating more intensive and focused team work sessions. Furthermore, while individual team collaboration varied, the trend in average Gini coefficients suggested an improvement towards more equitable work distribution within teams during the Orbit v2 period.

The introduction and evolution of Orbit within the 15.390 course structure appears to have fostered an emergent shift towards more intensive, iterative, and potentially more equitable team collaboration. Teams were not just producing more; they were engaging in deeper refinement and working in more concentrated bursts of activity. Orbit v2 may have acted as a shared cognitive tool, enhancing communication, transparency, and co-creation, leading to the improved collaborative outcomes. This emergence comes from the dynamic interaction of the Student/Team system with the Orbit tool, all within the specific context of the Educational Environment's team-based assignments, with guidance from the DE Framework

A specific pattern of deep engagement emerged around the foundational elements of the DE framework. Across all semesters, data showed consistently high engagement (step progression) and exceptionally high iteration (version counts) on early DE steps like "Market Segmentation," "Beachhead Market," and "Beachhead TAM Size". Importantly, the temporal analysis of iteration indicated that these iteration peaks for foundational steps became even more pronounced and temporally concentrated during Orbit v2 semesters.

The SoS, with Orbit as a key enabler, created an environment where the most critical and often challenging early-stage entrepreneurial concepts received intense and sustained, tool-supported scrutiny. Orbit, particularly v2, appears to have amplified this focus, leading to an emergent pattern of deep, iterative wrestling with core concepts. This intensive, iterative engagement at the early stages, facilitated by the entire system (Student/Team grappling with DE Framework via Orbit within the Educational Environment), is likely a big factor for building a stronger foundation for subsequent entrepreneurial development and decision-making.

The introduction and evolution of the Orbit AI tool within the 15.390 learning environment did more than just introduce a new technology, it positively affected a series of interconnected changes. The emergent patterns of deeper learning engagement, enhanced system performance, evolved team dynamics, and intensified focus on foundational concepts give rise to the complex, positive, and systemic impact of this AI-enhanced approach to entrepreneurship education.

Chapter 5

Discussion - Emergent Behaviors and Transformations in the Learning SoS

Empirical findings on student interaction with the Orbit AI tool in MIT's 15.390 entrepreneurship course are synthesized through a System-of-Systems lens to reveal three central themes: the ways in which AI reshapes the learning experience, the nuanced challenges of navigating AI's "jagged frontier," and Orbit's role as an external enabler within the educational ecosystem. By examining how the Orbit tool system, the student/team learning system, the Disciplined Entrepreneurship process system, and the broader educational environment interconnect, this analysis uncovers the mechanisms driving observed learning outcomes, engagement patterns, and the emergent behaviors that together signal a meaningful shift in entrepreneurial education.

5.1 Orbit as an Enabler, Learning Transformer, and Navigating the Frontier

The integration of Orbit into the 15.390 course did not merely introduce a new technology; it acted as a catalyst within the learning SoS. The primary narrative that emerges is one where Orbit, functioning as an External Enabler [22], facilitated a Transformation of Learning processes and outcomes. Students engaged more deeply and iteratively with the DE framework where data allowed such observation, and overall system performance saw improvements. However, this transformation was not uniform. It was consistently mediated by the "Jagged Frontier" [23] of AI's capabilities and the diverse ways students interacted with the Orbit system, leading to uneven impacts and highlighting areas for future development.

5.1.1 Orbit as an External Enabler: Reducing Opacity and Shaping Engagement

Davidsson et al.'s [22] framework posits that External Enablers (EEs) can significantly alter the conditions for entrepreneurship by reducing "opacity" and "agency-intensity." The findings suggest Orbit fulfilled this role. The DE process, while structured, can be opaque to novices. Orbit, by breaking down steps and generating initial content, helped clarify the path, particularly for complex early DE tasks [36,37]. This was especially evident as Orbit evolved to v2, with its improved UI enhancing Perceived Ease of Use (PEOU) and, consequently, Perceived Usefulness (PU) [15], leading to increased engagement. This enhanced PEOU and the tool's DE-specific grounding by being explicitly integrated into the curriculum likely reduced the "transparency issues" sometimes associated with general AI [38], fostering greater trust (PT) and a sense of Perceived Social Presence (PSP) [17]. When students trust and feel a connection with the tool, as indicated by the increased idea generation and, within v2 semesters[1], deeper iteration, they are more willing to leverage it. This allowed Orbit to effectively "trigger" broader idea exploration, "shape" their approach to the DE framework through its structured guidance, and "enhance" their learning process through iterative refinement where versioning data was available [8,22]. The significant increase in average ideas per team and, within v2, steps per team [31] underscores Orbit's enhanced enabling role over time.

5.1.2 Transformation of Learning: Deeper Engagement, Shifting Behaviors, and Self-Efficacy

The data strongly indicates that Orbit facilitated a transformation of learning that went beyond simple acceleration, fostering deeper and more iterative engagement where data collection permitted such observation. This is a key emergent property of the SoS. Shunk's [28] work on self-efficacy is relevant to this point: the improved tool experience with Orbit v2, leading to more successful navigation of DE steps, likely bolstered students' self-efficacy [16], explaining the increased willingness to tackle more DE work and iterate more thoroughly in v2. The significant rise in the idea progress metric in Fall 2024 (0.72) versus Spring 2024 (0.41) directly supports this link between improved technology perception (and likely PEOU/PU [15,35]) and heightened engagement [16].

This transformation is also evident in changed learning behaviors [8]. The dramatic increase in average DE steps completed per team during the v2 period (Fall 2024 & Spring 2025 averaging 126.8 steps per team, a notable increase from v1's 48.3) [31] signifies a profound shift in engagement depth. Orbit, by implementing and supporting the DE process, appeared to manage cognitive load [14], allowing students to engage more deeply and critically, as suggested by the increased time spent outside the classroom coupled with higher course satisfaction in v2 semesters [39]. Students were not just completing tasks, but "exploring and validating their entrepreneurial ideas" [38] through a more interactive and personalized environment. The prevalence of "Highly collaborative" teams (34 of 61) suggests Orbit was used as an "augmentation" tool [40], enhancing human capabilities rather than merely automating tasks, which is crucial for genuine skill development [36]. This aligns with Awad et al.'s [12] findings, suggesting Orbit's blend of structured guidance and AI flexibility fosters sustained engagement and competency development. This transformative process echoes Banathy's [5] call for "future-creating" education, where tools like Orbit help students "LEAP-OUT" from traditional learning frames and learn through the "design" of their ventures. However, achieving holistic transformation requires ongoing attention to ethical dimensions

[1] Step data for Orbit v1 is insufficient for analysis due to the data collection beginning in May 2024

and broader ecosystem development [41].

5.1.3 Navigating the "Jagged Frontier": Uneven Impacts and Critical Considerations

While Orbit enabled significant learning transformations, its impact was shaped by the "jagged technological frontier" [23] of AI's uneven capabilities, which manifested in several ways:

Differential Engagement and Skill-Leveling

Engagement varied across DE steps, with analytical early steps like "Market Segmentation" seeing intense activity and, within v2, high iteration (542 versions), while later, potentially more creative or synthesis-heavy steps, showed drop-offs. This suggests students leveraged Orbit where its AI capabilities strongly aligned with the task, a core aspect of the "jagged frontier." While overall course ratings improved, suggesting broad benefits, whether Orbit acted as a true skill-leveler as seen by Dell'Acqua et al. [23] (benefiting lower performers more) is unclear without more granular performance data. The varying engagement by persona and the potential for AI to exacerbate performance differences if not carefully managed [26] indicate that benefits were not uniform. Factors like AI self-efficacy [16,28] and technical background [41] likely influenced students' ability to navigate this frontier.

Risk of Overreliance and Homogenization

The "jagged frontier" also encompasses the risk of students over-relying on AI, especially where it might seem proficient but lacks true understanding [23,42]. The course's emphasis on using Orbit as a guide (Educational Environment System intervention) is crucial. While many teams used Orbit collaboratively, the potential for uncritically accepting AI outputs, leading to "shallow" understanding [40] or "homogenized outputs" [23,38], remains a concern that the SoS must actively manage. The high volume of ideas (694 total) and initial step engagement is positive, but the Educational Environment must ensure this breadth doesn't come at the cost of creative diversity.

Cognitive Load and Collaboration

Orbit's role in managing cognitive load [14] is also nuanced by the "jagged frontier." It may effectively reduce extraneous load for well-defined analytical tasks but might be less helpful, or even add load, if its suggestions are off-target for more ambiguous creative tasks. The improved Gini coefficients in Fall 2024, suggesting more equitable work distribution, might indicate that Orbit v2 helped teams better navigate the "jagged frontier" collectively, perhaps by making it easier for more members to contribute to tasks where the AI provided a solid starting point. However, the persistence of varied collaboration patterns suggests that effectively leveraging AI as a team across its "jagged frontier" is itself a skill that develops unevenly.

5.1.4 Synthesizing Key System Interactions and Emergence

The observed transformations and challenges are emergent properties of the entire SoS [2]. The improved Orbit v2 (Orbit System) with better PEOU [15,16] and deeper curriculum integration (Educational Environment System) fostered greater trust [24] and self-efficacy [28] within the Student/Team System. This, in turn, led to increased engagement with the DE Framework System, particularly for early analytical steps where Orbit's AI likely reduced cognitive load [14] and agency-intensity [22]. This created a more effective Socio-Technical Interaction Network (STIN) [9]. However, the "jagged frontier" [23] of the Orbit System meant that its ability to reduce cognitive load or act as an effective enabler was not uniform across all DE steps or for all students. This led to uneven engagement patterns and highlights the need for the Educational Environment System (instructors, curriculum design) to actively guide students in critically engaging with AI and developing strategies to compensate for AI's limitations. The overall SoS, as described by Lock et al. [3], demonstrated an ability to adapt and evolve (e.g., improvements from v1 to v2), but vulnerabilities remain, particularly around ensuring deep critical thinking and creative exploration across all aspects of the entrepreneurial process. The transformation of the learning experience [4,7] is thus an ongoing process of co-evolution between all constituent systems.

5.2 System Design of Orbit: Facilitating or Hindering SoS Interactions

The "form and function" of Orbit's system architecture is a critical component of the SoS, and its design directly influences interactions with other systems and the overall learning experience [9]. The evolution from v1 to v2 provides clear evidence of how design changes can impact engagement and perceived value.

5.2.1 Ease of Use, Usefulness, and Adoption: The Impact of v2 Enhancements

The significant increase in overall engagement metrics, such as higher monthly active users and more concentrated user creation spikes in v2 semesters, and a greater average volume of ideas generated per team in v2 compared to v1, strongly aligns with theories of technology acceptance. Shao et al. [16] found perceived ease of use (PEOU) to be a more influential driver of AI adoption than perceived usefulness (PU) initially. The UI improvements in Orbit v2, including more accessible editing tools and a more intuitive layout, directly targeted PEOU. This enhancement likely contributed to the increased adoption and deeper engagement observed. Davis's [15] Technology Acceptance Model (TAM) posits that PEOU positively influences PU; as Orbit v2 became easier to use, its perceived usefulness for tackling the DE framework likely increased. This is supported by the rise in overall course rating from an average of 5.34 in Spring 2024 (v1) to 5.89 in Fall 2024 (v2), suggesting that an easier-to-use and therefore more useful tool contributed to greater student satisfaction. Farrow's [6] assertion that Explainable AI (XAI) is a "necessary precondition for meaningful discourse about our possible futures" can be extended to usability; the design improvements in v2, making the tool's functions more transparent and usable, coincided with measurable engagement improvements. For instance, the average number of ideas per team increased, and within v2 semesters, the depth of iteration (versions per step) became a significant factor. This iterative design process, ideally involving collaboration between educators and AI developers as Baker [43] suggests, is crucial for creating effective AIEd tools.

5.2.2 Addressing Challenges and Guiding Future Evolution

While Orbit v2 marked a significant improvement, insights from researchers like Otis et al. [26] regarding challenges in AI tool adoption highlight the need for continuous evolution. The "jagged frontier" means that Orbit's design must continually adapt to better support tasks where AI currently underperforms or where student needs are most diverse. For example, providing more nuanced support for creative DE steps, or developing more sophisticated feedback mechanisms for complex analytical tasks, could be areas for future design focus. Davidsson et al. [22] note that EEs themselves evolve; Orbit's design must continue to adapt to maintain and enhance its enabling value over time, ensuring it effectively supports diverse student learning styles and needs within the SoS. The current architecture, with its deep DE framework integration, clearly facilitates structured learning. However, optimizing its interfaces with the Student/Team system (focusing on usability, trust, and fostering critical engagement) and the Educational Environment system (ensuring alignment with pedagogical goals and assignment structures) remains an ongoing design imperative for Orbit to maximize its positive impact as a transformative component of the entrepreneurial learning SoS.

5.3 Limitations

It is important to acknowledge the limitations inherent in this research, which primarily stem from data availability and the evolving nature of the Orbit tool and its implementation. The partial DE step data collection for the Spring 2024 semester restricts a full longitudinal understanding of framework navigation during the Orbit v1 period. While end-of-semester data provides some comparative points, and idea generation data is consistent, a complete picture of early v1 usage for step progression and iteration is unavailable. Therefore, direct comparisons of step-related metrics (like number of steps completed per team or versions per step) between v1 and v2 have been avoided or carefully qualified. Similarly, the absence of step versioning data in v1 limits insights into iterative processes during that initial phase. The reliance on aggregated course evaluation data, while useful for trend analysis, does not permit a direct correlation between individual student tool usage and their specific course perceptions or learning outcomes. The varying number of students across semesters also means that absolute content generation figures must be interpreted with caution, with a preference for per-user or per-team averages where appropriate for comparison.

From an SoS perspective, directly observing and measuring the nuances of all inter-system interfaces in a real-world educational setting is inherently complex. While tool logs provide data on Student-Orbit and Orbit-DE Framework interactions, and course evaluations shed light on Student-Educational Environment dynamics, the more subtle aspects of how these interfaces influence each other (e.g., how specific pedagogical approaches in the Educational

Environment shape Student-Orbit trust) are inferred rather than directly measured. Future research could benefit from more granular qualitative data, such as student interviews or direct observation, to further illuminate these complex interdependencies and the full spectrum of emergent behaviors within the SoS.

Chapter 6

Conclusions and Recommendations

At the intersection of artificial intelligence and entrepreneurship education lies a complex, evolving landscape—one where innovative tools like Orbit are reshaping how students engage with entrepreneurial frameworks. This research examined the integration of the Orbit AI tool within MIT's 15.390 entrepreneurship course through the sophisticated lens of System of Systems (SoS) theory. Rather than viewing Orbit as an isolated technological intervention, we explored how it dynamically interacted with three other critical systems: the student/team ecosystem, the structured Disciplined Entrepreneurship (DE) framework, and the broader educational environment. This multi-dimensional analysis revealed a rich tapestry of interactions, where the tool functioned not merely as a passive resource but as an active component in transforming entrepreneurial learning.

The preceding discussion wove together empirical findings from multiple semesters, interpreting them through three theoretical anchors: Orbit's emergence as a Davidsonian External Enabler that reduced barriers to entrepreneurial learning, the resulting Transformation of Learning that transcended mere acceleration, and the mediating influence of AI's "Jagged Frontier" that shaped where and how students benefited from this technology. As we now synthesize the primary conclusions of this investigation, we move beyond descriptive analysis to extract meaningful insights for both theory and practice. This chapter crystallizes the key contributions of this research, articulates implications for entrepreneurial education, and charts a path forward through targeted recommendations for pedagogical approaches, tool refinement, and future scholarly inquiry in this rapidly evolving domain.

6.0.1 Summary of Key Conclusions

The integration of Orbit into MIT's 15.390 Disciplined Entrepreneurship course reveals profound impacts across the entrepreneurial learning system-of-systems. Our analysis demonstrates that Orbit v2, the more refined iteration, functioned as a powerful External Enabler within this educational ecosystem. By significantly reducing both the opacity and agency-intensity inherent in the complex DE framework, the tool made entrepreneurial concepts more approachable and actionable for students. This enabling function manifested through increased tool adoption rates, enhanced idea generation, and—where comparative data was available within v2 semesters—deeper iterative engagement with DE steps, signaling the tool's effectiveness in triggering, shaping, and amplifying student learning activities.

Rather than merely accelerating existing processes, Orbit catalyzed a genuine Transformation of Learning within the course environment. Students developed distinctly different engagement patterns, particularly when working through the foundational stages of the DE framework. This transformation became evident through increased iterative behavior, greater willingness to tackle complex entrepreneurial challenges (reflected in the significantly higher number of ideas and steps completed per team), and an enhanced overall learning experience as indicated by improved course evaluations alongside increased time investment in coursework. These shifts highlight AI's potential to fundamentally alter not just the efficiency but the qualitative nature of student engagement with challenging entrepreneurial concepts.

The transformative impact of Orbit, however, was consistently moderated by the "Jagged Frontier" of current AI capabilities, leading to uneven outcomes across the DE process. While the tool provided robust scaffolding for analytical, early-stage DE tasks, where student engagement was highest, its support for later-stage, potentially more creative or synthesis-dependent tasks showed less pronounced tool-supported iteration. Moreover, Orbit's benefits weren't uniformly experienced across all student segments; individual characteristics such as AI self-efficacy and prior entrepreneurial experience (suggested by persona data) appeared to influence how effectively students could navigate and leverage the tool. This finding underscores that even specialized AI tools do not represent universal solutions, and their impact remains contextually nuanced.

The evolution from Orbit v1 to v2 highlighted another critical insight: effective System Design coupled with thoughtful Curriculum Integration is essential for the success of AI-enhanced educational tools. Orbit v2's more intuitive interface design, combined with its deliberate incorporation into the course structure, substantially increased adoption rates, deepened student engagement, and enhanced the perceived value of the entire course. This emphasizes that an AI tool's effectiveness depends not merely on its underlying technology but fundamentally on how well it aligns with user needs and integrates within the broader pedagogical framework.

Viewing these findings through the SoS lens reveals that these outcomes represent Emergent Properties arising from the dynamic interplay between all constituent systems rather than isolated effects. For instance, improvements in student self-efficacy likely emerged from the convergence of positive interactions with the redesigned Orbit interface, a supportive course structure validating tool use, and the guiding DE framework. Similarly, the observed shifts in team collaboration patterns reflect the combined influences of Orbit's capabilities, course assignments, and students' adaptive strategies in leveraging AI collaboratively.

Together, these conclusions illustrate the promising yet complex nature of integrating AI into entrepreneurship education. Orbit has demonstrated clear potential to positively transform learning experiences, but fully realizing this potential requires ongoing attention to tool design, pedagogical integration strategies, and a sophisticated understanding of AI's current capabilities and limitations within the entrepreneurial learning system-of-systems.

6.1 Recommendations

The insights gleaned from the preceding system-of-systems analysis of Orbit reveal opportunities to enhance not only the tool itself but also the broader educational ecosystem in which it operates. These recommendations aim to amplify Orbit's impact as an external enabler, deepen the transformation of entrepreneurial learning, and equip students to navigate more effectively through AI's "jagged frontier." The proposals fall into three interconnected domains: technological enhancements to the Orbit platform, pedagogical strategies for the educational environment, and directions for future scholarly inquiry.

To maximize Orbit's potential as a catalyst for entrepreneurial learning, the following design and functionality improvements are proposed that directly address the patterns observed in the empirical analysis:

Enhance Exportability and Workflow Integration

Improve Orbit's ability to export information into common document formats and explore integrations that allow its outputs to be seamlessly incorporated into students' existing business planning documents. This would enhance its utility as a practical enabler in the entrepreneurial process.

Refine Idea Prompting and Initiation

Augment the initial idea input interface. Instead of a simple open text box, consider offering structured templates, guiding questions, or examples to help users articulate their initial concepts more effectively, thereby reducing early-stage agency-intensity.

Improve DE Step Process Guidance and In-Tool Support

Implement clearer visual indicators of progress within the DE framework, such as what steps have been completed, what remains, and context-aware suggestions for logical next steps. Incorporate dynamic tooltips or brief tutorials that offer guidance on how to interact most effectively with Orbit's features for specific DE tasks.

Enable Granular Content Recomputation and Iteration

Allow users more fine-grained control over AI-generated content, such as the ability to selectively recompute or refine only specific portions of a DE step's output (e.g., analyzing an additional market segment without regenerating the entire market segmentation analysis). This supports more focused and efficient iteration

Explore Advanced AI Capabilities for Accuracy and Diversity

Investigate the integration of mechanisms to enhance the perceived and actual accuracy of AI-generated content. This could involve allowing users to select from different underlying LLMs for certain tasks or incorporating features that encourage critical review and cross-referencing of AI suggestions, helping to address the "jagged frontier."

Support for Broader Contexts and Existing Ventures

Consider allowing users to input more detailed information about existing ventures or more complex pre-existing contexts as the starting point for their work in Orbit. This could cater to a wider range of entrepreneurial learning scenarios.

Strengthen Team Collaboration Features

Develop and integrate features specifically designed to support team-based work, such as shared idea repositories, collaborative editing tools for DE steps, or team-specific dashboards. This can help transform Orbit from a primarily individual tool into a more robust platform for collaborative entrepreneurship.

Prioritize Continuous UI/UX Refinement for Ease of Use

Maintain a strong focus on user-centered design, continually refining the UI and UX to ensure Perceived Ease of Use remains high. This is fundamental to sustained adoption and effective tool utilization.

Reinforce Ethical Use and Data Security

Clearly communicate guidelines for the ethical use of AI-generated content and provide transparent information about data handling and security measures to build and maintain user trust. Robust anonymity of user data used for research or analytics should be standard.

These tool-specific recommendations aim to build upon Orbit's successes, particularly the positive impacts observed with v2, by further reducing barriers to use, supporting deeper and more nuanced engagement with the DE framework, and empowering students to navigate the complexities of AI in their entrepreneurial journey.

References

[1] *ChatGPT was used in this thesis for editing and grammar for clarity. Anthropic Claude was used selectively for python code generation.*

[2] J. Boardman and B. Sauser. *System of Systems-the meaning of of*. Tech. rep. IEEE, Apr. 2006.

[3] R. Lock and I. Sommerville. "Modelling and analysis of socio-technical system of systems." In: *Proceedings of the IEEE International Conference on Engineering of Complex Computer Systems, ICECCS*. Institute of Electrical and Electronics Engineers Inc., 2010, pp. 224–232. ISBN: 9780769540153. DOI: 10.1109/ICECCS.2010.31.

[4] A. V. Dhukaram, C. Sgouropoulou, G. Feldman, and A. Ardavan. "Higher Education Provision Using Systems Thinking Approach-Case Studies." *European Journal of Engineering Education*, **43**(), 1, Aug. 2016, pp. 3–25.

[5] B. H. Banathy. *Designing Educational Systems: Creating Our Future in a Changing World*. Tech. rep. 1992, pp. 41–46.

[6] R. Farrow. "The possibilities and limits of XAI in education: a socio-technical perspective." *Learning, Media and Technology*, **48**(), 2, 2023, pp. 266–279. ISSN: 17439892. DOI: 10.1080/17439884.2023.2185630.

[7] M. London, R. Rahdar, Y. Lin, H. Jiang, R. Rahdar, M. London, Y. Lin, and bibinitperiod Jiang. *Systems Thinking Applied to Higher Education Curricula*. Tech. rep. Applicatble to defining the educational environment as a system and the importance of that. 2023. URL: https://commons.erau.edu/publication.

[8] S. Bulathwela, M. Pérez-Ortiz, C. Holloway, and J. Shawe-Taylor. "Could AI Democratise Education? Socio-Technical Imaginaries of an EdTech Revolution." (), Dec. 2021. URL: http://arxiv.org/abs/2112.02034.

[9] W. Scacchi and W. S. Bainbridge. *Socio-Technical Design*. Tech. rep. 2004. URL: http://www.ics.uci.edu/~wscacchi.

[10] S. F. Pamungkas, I. Widiastuti, and S. Suharno. "Kolb's Experiential Learning As An Effective Learning Model In Creative Product And Entrepreneurship Subjects." *Journal of Mechanical Engineering and Vocational Education (JoMEVE)*, **2**(), 1, July 2019, p. 27. DOI: 10.20961/jomeve.v2i1.28352.

[11] G. M. Sekli and M. Portuguez-Castro. “Fostering entrepreneurial success from the classroom: unleashing the potential of generative AI through technology-to-performance chain. A multi-case study approach.” *Education and Information Technologies*, (), 2025. ISSN: 15737608. DOI: 10.1007/s10639-025-13316-y.

[12] A. Awad, E. Abdelaziz, A. Al-Saadi, J. Alnaqbi, and S. Alnaqbi. “Integrating Artificial Intelligence in Entrepreneurship Education: A Study of Higher Education Institutions in the Middle East.” Aug. 2024. DOI: 10.20944/preprints202408.1140.v1. URL: https://www.preprints.org/manuscript/202408.1140/v1.

[13] J. Garzón, Kinshuk, S. Baldiris, J. Gutiérrez, and J. Pavón. *How do pedagogical approaches affect the impact of augmented reality on education? A meta-analysis and research synthesis*. Nov. 2020. DOI: 10.1016/j.edurev.2020.100334.

[14] J. Sweller. “Cognitive load theory and educational technology.” *Educational Technology Research and Development*, **68**(), 1, Feb. 2020, pp. 1–16. ISSN: 15566501. DOI: 10.1007/s11423-019-09701-3.

[15] F. D. Davis. *Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information*. Tech. rep. 1989, pp. 319–340.

[16] C. Shao, S. Nah, H. Makady, and J. McNealy. “Understanding User Attitudes Towards AI-Enabled Technologies: An Integrated Model of Self-Efficacy, TAM, and AI Ethics.” *International Journal of Human-Computer Interaction*, (), 10, 2024. ISSN: 15327590. DOI: 10.1080/10447318.2024.2331858.

[17] S. Choi, Y. Jang, and H. Kim. “Exploring factors influencing students’ intention to use intelligent personal assistants for learning.” *Interactive Learning Environments*, (), 2023. ISSN: 17445191. DOI: 10.1080/10494820.2023.2194927.

[18] B. Aulet. *Disciplined Entrepreneurship: 24 Steps to a Successful Startup: Expanded and Updated*. Wiley & Sons, 2024. ISBN: 978-1-394-22251-3.

[19] YEC. *Are Successful Entrepreneurs Born Or Made?* Mar. 2019. URL: https://www.forbes.com/councils/theyec/2019/03/21/are-successful-entrepreneurs-born-or-made/.

[20] H. M. Neck and P. G. Greene. “Entrepreneurship Education: Known Worlds and New Frontiers.” *Journal of Small Business Management*, **49**(), 1, Jan. 2011, pp. 55–70. ISSN: 00472778. DOI: 10.1111/j.1540-627X.2010.00314.x.

[21] B. H. Banathy. *Developing a Systems View of Education*. Tech. rep. 1995, pp. 53–57.

[22] P. Davidsson and M. Sufyan. “What does AI think of AI as an external enabler (EE) of entrepreneurship? An assessment through and of the EE framework.” *Journal of Business Venturing Insights*, **20**(), Nov. 2023. ISSN: 23526734. DOI: 10.1016/j.jbvi.2023.e00413.

[23] F. Dell’Acqua. *Navigating the Jagged Technological Frontier: Field Experimental Evidence of the Effects of AI on Knowledge Worker Productivity and Quality*. Tech. rep. Sept. 2023. DOI: https://dx.doi.org/10.2139/ssrn.4573321.

[24] J. Cassell and T. Bickmore. *Negotiated Collusion: Modeling Social Language and its Relationship Effects in Intelligent Agents*. Tech. rep. Feb. 2003. DOI: https://doi.org/10.1023/A:1024026532471.

[25] C. Winkler, B. Hammoda, E. Noyes, and M. V. Gelderen. *Entrepreneurship Education at the Dawn of Generative Artificial Intelligence*. Oct. 2023. DOI: 10.1177/25151274231198799.

[26] N. G. Otis, B. Haas, R. Clarke, H. Business, S. Soì, E. Delecourt, D. Holtz, and R. Koning. *The Uneven Impact of Generative AI on Entrepreneurial Performance*. Tech. rep. July 2024.

[27] Y. K. Dwivedi. "Generative Artificial Intelligence (GenAI) in entrepreneurial education and practice: emerging insights, the GAIN Framework, and research agenda." *International Entrepreneurship and Management Journal*, **21**(), 1, Dec. 2025. ISSN: 15551938. DOI: 10.1007/s11365-025-01089-2.

[28] D. H. Schunk and M. K. Dibenedetto. *Self-Regulation, Self-Efficacy, and Learning Disabilities*. Tech. rep. Sept. 2021. DOI: 10.5772/intechopen.99570. URL: www.intechopen.com.

[29] J. C. Castilla, L. Naldi, and M. Ots. "External enablers in existing organizations: Emergence, novelty, and persistence of entrepreneurial initiatives." *Strategic Entrepreneurship Journal*, **17**(), 2, June 2023, pp. 335–371. ISSN: 1932443X. DOI: 10.1002/sej.1458.

[30] M. Csikszentmihalyi. *Flow and the Foundations of Positive Psychology*. Springer, 2014. ISBN: 978-94-017-9083-3. DOI: 10.1007/978-94-017-9088-8_1.

[31] A. Kusetogullari, H. Kusetogullari, M. Andersson, and T. Gorschek. *GenAI in Entrepreneurship a systematic review of generative artificial intelligence in entrepreneurship research: current issues and future directions*. Tech. rep. 2025.

[32] S. Rizvi, J. Waite, and S. Sentance. "Artificial Intelligence teaching and learning in K-12 from 2019 to 2022: A systematic literature review." *Computers and Education: Artificial Intelligence*, **4**(), Jan. 2023. ISSN: 2666920X. DOI: 10.1016/j.caeai.2023.100145.

[33] S. Z. Salas-Pilco and Y. Yang. *Artificial intelligence applications in Latin American higher education: a systematic review*. Dec. 2022. DOI: 10.1186/s41239-022-00326-w.

[34] V. Venkatesh and F. D. Davis. "Theoretical extension of the Technology Acceptance Model: Four longitudinal field studies." *Management Science*, **46**(), 2, 2000, pp. 186–204. ISSN: 00251909. DOI: 10.1287/mnsc.46.2.186.11926.

[35] V. Gupta. "An Empirical Evaluation of a Generative Artificial Intelligence Technology Adoption Model from Entrepreneurs' Perspectives." *Systems*, **12**(), 3, Mar. 2024. ISSN: 20798954. DOI: 10.3390/systems12030103.

[36] L. Chen, D. Ifenthaler, J. Y. K. Yau, and W. Sun. "Artificial intelligence in entrepreneurship education: a scoping review." *Education and Training*, (), Oct. 2024. ISSN: 00400912. DOI: 10.1108/ET-05-2023-0169.

[37] H. Etemad. "Transformative potentials of generative artificial intelligence: Should international entrepreneurial enterprises adopt GEN.AI?" *Journal of International Entrepreneurship*, (), June 2024. ISSN: 15737349. DOI: 10.1007/s10843-024-00363-8.

[38] M. Vecchiarini and T. Somi. "Redefining entrepreneurship education in the age of artificial intelligence: An explorative analysis." *International Journal of Management Education*, **21**(), 3, Nov. 2023. ISSN: 14728117. DOI: 10.1016/j.ijme.2023.100879.

[39] R. Bell and H. Bell. “Entrepreneurship education in the era of generative artificial intelligence.” *Entrepreneurship Education*, **6**(), 3, Sept. 2023, pp. 229–244. ISSN: 25208152. DOI: 10.1007/s41959-023-00099-x.

[40] D. Chalmers, N. G. Mackenzie, and S. Carter. “Artificial Intelligence and Entrepreneurship: Implications for Venture Creation in the Fourth Industrial Revolution.” *Entrepreneurship Theory and Practice (ETP)*, (), 2021, pp. 1028–1053. DOI: 10.1177/1042258720934581.

[41] Q. Mu and Y. Zhao. “Transforming entrepreneurship education in the age of artificial intelligence.” *Resources Data Journal ONLINE ISSN*, **3**(), 3, Jan. 2024, pp. 2–20. ISSN: 2758-1438. DOI: 10.50908/rdj.3.0_2.

[42] E. Mollick. *Co-Intelligence: Living and Working with AI*. Penguin, 2024. ISBN: 9780593716717.

[43] T. Baker et al. *Educ-AI-tion Rebooted? Exploring the future of artificial intelligence in schools and colleges*. Tech. rep. Nestsa, 2019. URL: www.nesta.org.uk.