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WIP: Implementing Backward Design Approach in Integrated Business and Engineering Capstone Project: A NASA Tech Transfer Case Study

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Implementing Backward Design Approach in Integrated Business and Engineering (IBE) Capstone Project: A NASA Tech Transfer Case Study

The 21^{st} century presents engineering students with complex, interdisciplinary challenges that require a combination of technical and business skills. This case study examines the implementation of a backward design approach within a joint business and engineering program at a large Midwestern university. The program provides students the opportunity to explore patented advanced technologies and then identify new real-world applications for these technologies. This initiative supports interdisciplinary learning to better prepare students for modern industry challenges.

The purpose of this study is to investigate how backward design fosters critical thinking, entrepreneurial abilities, and collaboration among engineering and business undergraduate students. Leveraging novel technologies from a global aerospace agency, students develop problem-solving skills applicable to 21^{st} century engineering and business challenges.

The four-semester program begins with a feasibility study phase, which includes a business alignment exploration component feeding into a senior capstone project. And it is supported by partnerships with a government technology transfer office, research institutions, and industry leaders. In the early phase, technologies are pre-vetted and aligned with trends in non-competitive industries. Using a structured technology push methodology, potential applications of the technology's attributes are explored.

This work-in-progress case study highlights the potential of backward design as a pedagogical tool in engineering education. The backward design approach emphasizes interdisciplinary learning and public-private collaboration by tasking students with identifying problems that can be addressed using off-the-shelf technologies applied to non-competitive fields of use. Feedback from key stakeholders including industry, business, educational, and commercial mentors, technology providers, and student participants, will be used to assess the effectiveness of this approach. Reflections and insights gathered from these stakeholders will inform potential future iterations of the program with additional student teams. The preliminary findings from this study will also guide the development of future full-scale studies and curriculum improvements, with a focus on assessing the generalizability of the approach.

Additionally, this study contributes to workforce development by equipping students with the interdisciplinary skills and problem-solving capabilities that align with the expectations of private and public sector partners supporting real-world problem solving through technology transfer.

Introduction

This study explores a novel approach to capstone projects that begins with a solution (patented technology) and focuses on identifying viable applications, narrowing them to specific use cases that address real-world problems. The process progresses to prototyping, verification and validation, marketing, and other essential steps to transform these applications into potential startup ventures. The purpose of this research is to examine how a backward design approach fosters critical thinking, entrepreneurial skills, and collaboration among undergraduate engineering and business students. By leveraging patented technologies from a global aerospace agency, the study investigates how students identify practical applications through a structured four-semester program, starting with feasibility analysis and culminating in senior capstone projects. Partnerships with a government technology transfer office, research institutions, and industry leaders enhance the program's impact by providing mentorship and aligning projects with emerging, non-competitive industry trends.

This work-in-progress case study aims to generate insights that inform future curriculum development and decision-making in engineering and business education. By examining the outcomes, challenges, and advantages of this distinctive capstone project structure, the study seeks to identify practical improvements and scalable strategies. Two central research questions guide this investigation: (1) How can the findings from this case study inform the design of interdisciplinary curricula that incorporate this specific backward design approach and entrepreneurial thinking? (2) What key challenges, benefits, and lessons from this project can influence the successful implementation of similar programs in the future?

The following sections explore the key components of this study, offering a brief background on each element. These components collectively shape the study's focus and lay the groundwork for understanding the impact of incorporating innovative practices into curriculum development to inform future decision-making and educational strategies.

Capstone project

Capstone projects were introduced in engineering education in the mid-20th century as a way to bridge the gap between theoretical knowledge and practical application. The primary goal was to provide students with hands-on experience in solving real-world engineering problems, thereby preparing them for professional practice [1].

Evolution over time

- Integration with industry: Initially, capstone projects were largely academic exercises. However, over time, many universities began partnering with industries to provide students with real-world challenges. This collaboration has been beneficial for both students and companies, often leading to innovative solutions and potential employment opportunities [1].
- Technological advancements: With the advent of new technologies, the nature of capstone projects has evolved. Modern projects often involve cutting-edge technologies such as robotics, renewable energy systems, and advanced manufacturing techniques [2].
- Pedagogical approaches: The approach to capstone projects has also changed. There is now a greater emphasis on interdisciplinary projects that integrate knowledge from various fields of engineering. Additionally, peer review and collaborative learning have become more common, enhancing the learning experience and better preparing students for teamwork in their professional careers [2].
- Global trends: The globalization of engineering education has led to the adoption of capstone projects in universities worldwide. This has resulted in a diverse range of projects that address global engineering challenges, fostering a more comprehensive educational experience [3].

Current trends and future directions

Today, capstone projects are seen as a critical component of engineering education. They not only help students apply their knowledge but also develop essential soft skills such as teamwork, communication, and project management. As engineering education continues to evolve, capstone projects are likely to incorporate even more advanced technologies and interdisciplinary approaches, further enhancing their value in preparing students for the engineering profession [3].

Backward design approach

To address the complex, interdisciplinary challenges of 21st-century engineering education, educators can leverage established frameworks such as backward design. Originating from the work of Wiggins and McTighe [4], backward design offers a structured and intentional approach to course development that prioritizes the alignment of learning outcomes, assessments, and instructional activities. This approach has proven invaluable in addressing the growing demand for enhanced teaching practices and improved student learning outcomes in fields like engineering and business education [5].

Backward design emphasizes starting with the end in mind, focusing first on the desired outcomes before determining the means to achieve them. Fink [6] elaborates on its transformative potential, noting that it encourages educators to consider not just knowledge acquisition but also the development of skills, attitudes, and long-term competencies. Similarly, McTighe and Thomas [7] highlight that backward design fosters coherence across curriculum components, ensuring that learning activities and assessments are meaningfully aligned with the intended outcomes. These principles resonate strongly with interdisciplinary and applied contexts, such as capstone projects in engineering and business programs.

The Backward design framework comprises three interconnected stages:

- Identifying desired results: In this initial phase, educators define the overarching goals and specific learning outcomes they wish students to achieve by the end of the course or program. This process ensures clarity in what students are expected to know, understand, and be able to do, fostering a goal-oriented approach to curriculum design.
- Determining acceptable evidence: This stage involves designing an assessment plan that includes both formative and summative assessments. These assessments are explicitly linked to the learning outcomes, providing evidence of student progress and mastery. By emphasizing measurable outcomes, this phase ensures that instructional goals are met effectively.
- Planning learning experiences and instruction: Finally, educators design activities and instructional strategies that support students in achieving the desired outcomes. This stage emphasizes active learning, scaffolding, and alignment between instruction and assessment, ensuring a cohesive and impactful learning experience.

Applying backward design to the context of integrated business and engineering capstone projects, as explored in this case study, underscores the framework's relevance in fostering interdisciplinary learning and addressing real-world challenges. The approach is particularly well-suited for the capstone model described in the abstract, which tasks students with starting from advanced technologies and identifying practical problems they can solve. This aligns with the principles of backward design by beginning with a clear vision of the desired competencies—

critical thinking, entrepreneurial skills, and collaborative problem-solving, and working backward to design instructional and assessment strategies that cultivate these outcomes.

In the described four-semester program, backward design is operationalized as follows:

- Identifying desired results: The program's goals include equipping students with interdisciplinary skills and the ability to identify innovative applications for pre-vetted technologies in non-competitive industries.
- Determining acceptable evidence: Students' capabilities are assessed through feasibility studies, business alignment explorations, and the development of capstone projects that demonstrate practical applications of the technologies.
- Planning learning experiences and instruction: Students engage in structured learning activities, such as exploring the attributes of novel technologies, receiving mentorship from industry and academic partners, and collaborating with peers from diverse disciplines.

This structured approach ensures that students not only acquire technical knowledge but also develop the entrepreneurial mindset and collaborative skills necessary for tackling complex industry demands. By starting with the solution, advanced technologies from a global aerospace agency, and working backward to uncover real-world problem application, the program exemplifies how backward design can drive innovation and interdisciplinary integration in capstone projects. Furthermore, the feedback loop from stakeholders ensures continuous refinement, enhancing the program's impact and scalability.

Ultimately, this implementation of backward design highlights its potential as a transformative tool in engineering and business education, preparing students to excel in an increasingly interconnected and technology-driven world.

Integrated Business and Engineering (IBE) Honors Program

The Integrated Business and Engineering (IBE) Honors Program is a rigorous four-year program designed to develop the next generation of leaders who can seamlessly operate across business and technical domains. This program emphasizes an interdisciplinary approach to problem-solving, equipping students with the skills needed to address real-world challenges.

The need

In an increasingly interconnected global economy, U.S. companies face both collaborative opportunities and competitive pressures. This creates a demand for broadly educated professionals with a strong foundation in both engineering and business disciplines. The IBE program at The Mid-western addresses this need by preparing graduates to meet these challenges head-on.

The approach

Offered jointly by a Midwestern University's College of Engineering and College of Business, the multidisciplinary IBE honors program integrates engineering and business education. Students take classes, tackle real-world problems, and network with industry leaders throughout their undergraduate experience. The program supplements the standard engineering or business curriculum with core courses from the opposite discipline and includes a sequence of dedicated IBE courses and seminars focused on experiential, entrepreneurial, and multidisciplinary learning. In class, IBE students work in teams to solve problems and create solutions, applying classroom theory to practical scenarios.

Students served
The IBE program selectively recruits a small cohort of 72 students each year. Invitations to apply are sent in February to students accepted into university's engineering honors or business honors programs.

Community
Beyond academics, a peer-elected student leadership board organizes extracurricular events, including welcome week activities, recruitment events, executive keynotes, social retreats, and alumni networking.

Graduation results
Upon successful completion of the program, students receive a Bachelor of Science in business or engineering, a minor in the opposite field, and an "Honors in Integrated Business and Engineering" diploma distinction. IBE graduates are highly sought after, with a resume attractive to numerous hiring companies.

Employment outcomes
IBE students are recruited for internships and full-time positions by top employers. Impressively, 100% of students accepted an employment offer within three months of graduation. Graduates have also joined prestigious graduate programs at institutions such as the University of California-Berkeley, The University of Chicago, Harvard University, Stanford University, and the Stockholm School of Economics.

It is also noteworthy that several universities offer integrated undergraduate programs that combine business and engineering disciplines, often within honors frameworks. Some notable examples include:

- The Ohio State University: Offers the Integrated Business and Engineering Honors Program, a four-year curriculum designed to prepare students for leadership roles by providing interdisciplinary education in both business and engineering [8].
- Purdue University: Features the Integrated Business and Engineering (IBE) program, which bridges the gap between business and engineering, preparing graduates to make informed business decisions with a strong understanding of engineering principles [9].
- University of California, Berkeley: Offers the Management, Entrepreneurship, & Technology (M.E.T.) program, a highly selective dual-degree track that allows students to earn degrees in both engineering and business, fostering a blend of technical and entrepreneurial skills [10].
- Lehigh University: Provides the Integrated Business and Engineering (IBE) Honors Program, an interdisciplinary course of study culminating in a Bachelor of Science degree that integrates business and engineering principles[11].
- Carnegie Mellon University: Through its Tepper School of Business and College of Engineering, Carnegie Mellon offers interdisciplinary programs that allow students to pursue studies in both business and engineering, fostering a comprehensive understanding of both fields [12].

- University of Texas at Austin: Provides the Texas Honors Electrical and Computer Engineering and Business program, an integrated degree path that enables students to earn degrees in Electrical and Computer Engineering and Business, emphasizing interdisciplinary expertise[13].

On-Ramp program

The On-Ramp program at the Midwestern University serves as a corporate innovation accelerator, designed to equip students with foundational innovation skills while addressing real-world challenges through collaboration with industry sponsors. This unique initiative offers students the opportunity to engage in paid internships with the university's Center for Innovation Strategies, where they gain hands-on experience in exploring and de-risking new ideas, identifying unmet customer needs, and proposing viable solutions informed by customer validation and innovation techniques [14].

Through On-Ramp, students work in interdisciplinary teams to address challenge hypotheses posed by corporate sponsors, applying lean startup methodologies and other structured innovation approaches. Each semester, participants focus on a distinct innovation challenge, collaborating with industry leaders and leveraging diverse perspectives to drive impactful outcomes. This structure not only enhances students' understanding of the innovation process but also fosters their ability to work effectively within industry settings.

Key benefits of the program include:

- Industry collaboration: Students develop a deep understanding of working in professional environments while creating meaningful connections with corporate leaders.
- Innovation training: Participants learn and apply lean startup methodologies and other innovation processes to address sponsor-generated concepts.
- Flexibility: The program is designed to accommodate students' academic and personal commitments, ensuring a balance between school, work, and life.
- Paid experience: Students engage in a paid analyst role, contributing to their professional growth while supporting their financial needs.

The program's focus on interdisciplinary collaboration and customer-focused problem-solving makes it accessible to students of all majors and academic years.

NASA Tech transfer, On-Ramp, and IBE integration

This OSU capstone project was designed as a collaborative effort that leveraged partnerships with key organizations to enhance student learning and support technology commercialization. This initiative was made possible through partnerships with NASA Glenn's Technology Transfer Office, with financial support provided by the Ohio Space Grant Consortium (OSGC), managed by the Ohio Aerospace Institute (OAI) & Parallax Advanced Research (Parallax). Additionally, program management support was provided by the Technology-Based Economic Development (TBED) practice group at OAI & Parallax, which played a critical role in facilitating the project.

By leveraging cutting-edge technologies from NASA Glenn Research Center, the program seamlessly integrates business acumen and engineering expertise to address real-world challenges.

Program overview

The initiative spans four semesters, starting in Spring 2024 and continuing through Summer 2024, Fall 2024, and Spring 2025. It involves a structured, phased approach designed to guide students from understanding NASA's patented technologies to developing and validating real-world applications. The key stages include:

1. Tech Push Innovation Sprint (Spring 2024):
    - Students analyze NASA technologies to identify target industries and align attributes with potential applications.
    - The phase focuses on proposing innovative use cases, laying the groundwork for deeper research and development.

2. Center for Innovation Strategies (CIS) OnRamp Innovation Cohort (Summer 2024):
    - A 10-week accelerator program facilitated by the university's Center for Innovation Strategies (CIS) in collaboration with NASA Glenn Research Center.
    - Participants refine business models, conduct user interviews, and validate industry trends through structured sessions.
    - Outcomes include a narrowed selection of use cases, which are reviewed for further development in the IBE capstone course.

3. IBE Capstone Integration (Fall 2024 – Spring 2025):
    - Students transition to the capstone course, focusing on validating technical and business use cases.
    - This stage involves mentorship from NASA Glenn experts to refine applications, align solutions with industry partners, and explore commercialization pathways.

Outcomes and Impact

The initial phases of the program have shown promising outcomes, providing students with valuable hands-on experience in technology commercialization and aligning with the broader goals of the Integrated Business and Engineering (IBE) program. Key early outcomes include the development of interdisciplinary problem-solving skills and entrepreneurial thinking, along with the integration of NASA's technologies into the academic curriculum, offering students real-world applications. Additionally, public-private collaborations have begun to address industrial challenges and support workforce development.

However, the full impact of the program, particularly in the latter stages of the capstone project during semesters 3 and 4, remains to be fully understood. As students transition into these phases, the case study will reveal deeper insights into the continued development of their skills and the ultimate effectiveness of the program. The ongoing synergy between industry mentors, academic structures, and real-world applications will be crucial in determining how well students can bridge the gap between academia and industry, and ultimately lead in the commercialization of advanced technologies.

The Role of Industry Mentorship in Capstone Design Projects

Industry mentorship plays a critical role in guiding students through capstone design projects, bridging the gap between academic learning and professional practice. Through collaboration with industry professionals, students gain valuable insights into real-world challenges, aligning their projects with practical applications and current market demands. Mentors provide guidance on technological trends, design standards, and project management, fostering an environment where students can develop critical thinking, entrepreneurial skills, and effective collaboration. In the context of this study, which examines the integration of backward design in fostering interdisciplinary learning, industry mentorship significantly enriches the educational experience. Industry mentors offer a unique perspective by challenging assumptions, sharing professional expertise, and supporting students through the design process [15].

Previous research has also highlighted the benefits of industry engagement in capstone courses, including enhanced student outcomes such as improved problem-solving skills, critical thinking, and readiness for industry challenges [16]. Open-ended problem-solving tasks guided by mentors stimulate innovation and encourage students to explore interdisciplinary approaches, making industry mentorship particularly valuable in a backward design framework.

However, this mentorship dynamic is not without its challenges. In some cases, mentors—intentionally or unintentionally—may steer students toward pre-existing solutions or narrowly defined approaches that align with industry norms. This influence can limit students' creative freedom and discourage the exploration of unconventional or disruptive ideas. When mentors prioritize their preferences or agendas over fostering open ideation, it risks undermining the very essence of entrepreneurial thinking: curiosity, experimentation, and out-of-the-box problem-solving.

Theoretical framework and Methodology

Case Study Methodology

The case study methodology is widely utilized in higher education and student affairs research due to the nature of the environments and scenarios that represent “cases.” Researchers often identify a group on campus—such as a student organization, residential community, or service-learning class—and design a case study around it. This qualitative research methodology enables an in-depth examination of a bounded system, such as a program, process, or group, within its real-life context [17]. Case studies are particularly effective for investigating complex, context-dependent phenomena where the boundaries between the phenomenon and its environment are not clearly defined.

In this study, the unique structure of the capstone program serves as the bounded system for examination. This program tasked students with applying a NASA-patented technology to potential markets, making it an ideal subject for a case study design. By focusing on this single case, the study facilitates a detailed exploration of students' learning experiences, challenges, and outcomes as they navigated the entrepreneurial process. The methodology incorporates diverse data sources, such as mid-semester reflection responses, project artifacts, and potential follow-up interviews, to support triangulation and enhance the study’s validity and depth [18].

The case study approach is particularly suitable for this research because it emphasizes contextual understanding and provides a nuanced exploration of the interplay between program structure, mentorship, and student outcomes. This study qualifies as an exploratory case study, as it aims to examine how students develop entrepreneurial thinking and approach technology commercialization in an innovative educational setting. According to Yin, exploratory case studies are valuable for generating insights into phenomena with limited prior research [17]. Similarly, Stake highlights the interpretive and context-driven nature of case studies, making this methodology ideal for uncovering the impacts of the program's unique features [19].

Case Study- Capstone Project Description:
During the On-Ramp Program, NASA issued patent number 10,005,558, which was studied to explore its applications as a solution for various industries. The research focused on three key applications of Hexagonal Boron Nitride Nanotubes (BNNTs); a NASA-developed technology known for its exceptional properties. These include thermal stability, high thermal conductivity, electrical insulation, and neutron absorption capabilities. The following three applications were explored during the On-Ramp Program:

1. ***Li-Ion Battery Enhancement for Electric Vehicles (EVs)***
   BNNTs were evaluated for their ability to improve Li-Ion batteries, particularly in heat dissipation and energy efficiency, offering potential advancements in the EV industry.
2. ***NanoFresh, Advanced Food Packaging Technology***
   The NanoFresh project investigated BNNTs' integration into packaging materials to extend shelf life, enhance food quality, and improve safety by leveraging their thermal and antimicrobial properties.
3. ***BNNTs as Radiation Shielding Material for Aviation Clothing***
   BNNTs were explored for use in aviation clothing to shield against cosmic radiation, leveraging their neutron absorption capabilities, high-temperature stability, and lightweight nature for effective protection.

When the IBE-Capstone project began, the team initially focused on the Li-Ion Battery Enhancement application, guided by their industry mentor. After seven weeks of work, the team decided to pivot to the third application, BNNTs as Radiation Shielding Material for Aviation Clothing. This shift was driven by factors such as better alignment with the team's dynamics, stronger consensus, and greater feasibility for prototype development and testing.

Why Case Study is an Appropriate Methodology:
The case study methodology is particularly suitable for this research due to its ability to address the bounded nature of the case, focusing on a single cohort of students within a specific capstone program and timeframe. It facilitates an in-depth exploration of complex processes, such as how students approach entrepreneurial challenges and mentorship, while leveraging multiple data sources like reflection responses, project artifacts, and follow-up interviews to ensure comprehensive triangulation. Moreover, it emphasizes the contextual understanding of the program's unique features, including the integration of NASA technology and industry mentorship, providing valuable insights into the interplay between program structure and student outcomes.

Method

Data Collection

The study leverages a longitudinal qualitative design to investigate how a student team adapts and progresses through entrepreneurial challenges. Reflections are collected at three phases to track the evolution of their learning and problem-solving approaches:

1. Mid-Fall Semester: Focused on initial challenges, team dynamics, and early milestones.
2. End of Fall Semester: Captures comprehensive insights on key accomplishments, challenges, and goals for the prototyping phase.
3. Spring Semester (Planned): Will examine prototyping execution, team strategies, and commercialization readiness.

The end-of-semester reflections provide critical data points that highlight the team's learning curve, technical pivots, and aspirations for prototyping.

Preliminary Findings

The reflections from mid-semester and end-of-semester stages provide valuable insights into the progress, challenges, and learning outcomes of the team working on this NASA-related project. As a work-in-progress study, these findings reflect the ongoing nature of the project, with further results anticipated during the prototype phase, expected to conclude by the end of Spring 2025.

Positive Aspects

- Excitement and Motivation: Team members expressed enthusiasm for engaging with a NASA-related project, viewing it as an opportunity to address innovative technical challenges and apply NASA-developed technologies across diverse industries. The project fostered exploration beyond comfort zones, serving as a strong motivational driver.
- Learning and Development: Significant personal and professional growth was reported, including enhanced skills in research, communication, teamwork, and problem-solving. Notably, some participants discovered new interests in specialized fields such as materials science and aviation, highlighting the project's role in sparking intellectual curiosity.
- Team Collaboration: Strong team dynamics were maintained, supported by effective communication and collaborative problem-solving. Members demonstrated leadership in specialized areas, such as radiation shielding technology, while differing perspectives were resolved through open dialogue.
- Anticipation of Prototype Testing: The team expressed optimism for the prototyping phase, particularly the opportunity to conduct real-world testing, which could validate the practical application of their work.

Challenges

- Knowledge Transfer and Team Buy-In: The technical lead carried the burden of transferring knowledge from prior work, which strained resources and time. Additionally, initial resistance to the chosen technology and application resulted in a slower onboarding process, as team members lacked early investment in the direction of the project.
- Limited Guidance and Communication: The absence of consistent engagement from NASA personnel created a gap in technical guidance. Feedback was primarily provided by a third-party entity as NASA industry partner, which limited direct access to critical

expertise. This lack of interaction compounded the difficulty of navigating the project's complex requirements.

- Pivot and Resource Constraints: A mid-project pivot from the original Li-Ion battery concept to radiation shielding required the team to refocus efforts entirely. This introduced additional workload, steep learning curves in radiation technology, and logistical challenges, such as identifying new subject matter experts and adjusting timelines.
- Technology Accessibility: The high technological barrier of the project posed a significant challenge, particularly the lack of access to sample materials and uncertainty regarding testing procedures. These hurdles highlighted the difficulties of working with advanced, high-tech solutions in a constrained environment.

Looking Ahead

As a work-in-progress initiative, the team is actively preparing for the prototype testing phase, which represents a critical milestone for the project. Results from this phase, anticipated by the end of Spring 2025, are expected to provide valuable data on the feasibility and practicality of the proposed solution. Key priorities include securing access to necessary materials, refining testing methodologies, and addressing market viability concerns for the developed technology. Persistent challenges include the potential for further pivots, the need for enhanced technical guidance, and improved team cohesion. Nevertheless, the team remains motivated to advance the project, building on lessons learned in adaptability and collaborative resilience.

Discussion and Lessons Learned

The preliminary findings from this case study highlight important pedagogical insights into implementing industry-focused, student-led projects in higher education. While the project facilitated significant learning opportunities and personal growth, it also revealed critical areas for improvement if similar approaches are to be attempted in the future.

Agency and Ownership in Student-Led Projects

One of the key lessons learned pertains to the dynamics between industry mentors and student teams. This study underscores the importance of fostering student agency and ownership over their work. When students are empowered to make key decisions, they develop a deeper connection to the project and are more likely to engage critically with challenges, fostering creativity and problem-solving. Conversely, a mentor-centric approach that overly directs or dictates the decision-making process risks undermining students' confidence, autonomy, and sense of accountability.

To maximize the pedagogical benefits of such projects, it is essential that industry mentors adopt a facilitative rather than authoritative role. Specifically, mentors should:

- Encourage inquiry and exploration by posing open-ended questions rather than providing prescriptive solutions.
- Validate student-driven decisions, even when they diverge from the mentor's initial expectations.
- Act as a resource for technical expertise while respecting the team's autonomy in project direction.

This balance not only reinforces the students' capacity to think independently but also mirrors real-world professional scenarios where collaboration and negotiation are critical.

Clarity in Objectives and Stakeholder Communication

The necessity of a mid-project pivot revealed the challenges associated with ambiguous project goals and limited communication with sponsors. When attempting this approach again, clearly defined objectives and frequent, direct communication with all stakeholders must be prioritized from the outset. Establishing a shared understanding of the project's scope, deliverables, and timeline between the student team, mentors, and sponsors can mitigate the risk of misalignment and reduce the likelihood of disruptive pivots.

Scaffolding Knowledge Transfer and Technical Complexity

Another significant challenge was the steep learning curve associated with transitioning to a highly specialized technology. Knowledge transfer mechanisms, such as providing detailed documentation, structured training sessions, and opportunities for hands-on experimentation early in the project, could alleviate the pressure on technical leads and expedite the team's adaptation process. Additionally, assigning faculty advisors or graduate mentors to provide consistent technical guidance may bridge gaps in expertise and facilitate smoother progress.

Balancing Innovation with Feasibility

The shift from an exploratory research concept (Li-Ion batteries) to a more testable and feasible application (radiation shielding) demonstrated the need for a balanced approach to innovation. While pushing boundaries is important, it should be tempered with an understanding of the resources, timelines, and skill levels available within a student project. Future iterations should involve a structured feasibility assessment during the project's initial stages, ensuring that the chosen direction aligns with both educational goals and achievable outcomes.

Implications for Pedagogical Design

From a pedagogical standpoint, the following recommendations emerge for structuring student-industry collaboration projects:

- Empower Students with Agency: Integrate reflective practices and decision-making autonomy into the project framework, emphasizing the role of students as active participants rather than passive executors.
- Foster Collaborative Mentorship: Train industry mentors to act as facilitators, encouraging critical thinking and respecting the unique educational objectives of student projects.
- Enhance Communication Protocols: Establish clear channels for regular communication between all stakeholders, ensuring alignment and transparency throughout the project lifecycle.
- Support Technical Learning: Provide resources and support structures, such as access to subject matter experts, modular training, and incremental task scaffolding, to manage the complexity of technical challenges.
- Incorporate Feasibility Analysis: Design the project to include early-stage evaluations of scope, resource availability, and technical feasibility to guide realistic and actionable project goals.

Conclusion

This case study highlights the potential of industry-mentored, student-led projects to foster transformative learning experiences. The project description, which explores the application of NASA's patented technology, provides insight into how students tackled real-world problems, collaborated, and applied critical thinking. The team's pivot from the first to the third application revealed key lessons about mentorship, team dynamics, and prototype development challenges.

These experiences emphasize the importance of creating an environment where students are empowered and aligned with clear objectives. The team's decision to pivot, influenced by mentor guidance and evolving consensus, demonstrates the need for flexibility and adaptive leadership. As this is a work-in-progress, further analysis will be conducted by the end of the spring semester, allowing for a more refined conclusion on this approach. This will inform its potential implementation in future projects, aiming to better balance education and innovation for the next academic year.

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