

(Multi-disciplinary) Teamwork Makes the (Real) Dream Work: Pragmatic Recommendations from Industry for Engineering Classrooms

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Abstract

Many students choose to major in engineering to join the community of professional engineers and gain exposure to the field through their college experience [1]. However, research suggests that engineering graduates may not be adequately prepared for the workplace due to the complexities of engineering work [2]. Engineering work involves complexity, ambiguity, and contradictions [3], and developing innovation skills requires analyzing real-world problems that are often ill-defined and multifaceted [4]. Therefore, it is essential for engineering students to have opportunities to work in multi-disciplinary teams to develop their skills in problem-solving and innovation. This emphasis on the need for exposure to multi-disciplinary problem solving holds true not only for undergraduate engineers in training, but also for graduate students focused on engineering education.

This paper draws from experiences of a multi-disciplinary team (including engineers, scientists, UX researchers, Industrial-Organization (I-O) psychologists, economists, and program and product managers) studying talent management in the tech industry, to present lessons learned from leading with science to understand, inform, and improve employee experiences at a large private technology company. Our paper exemplifies how projects in industry leverage multi-disciplinary expertise and presents recommendations for new graduates and engineering professionals. Ultimately, this paper affords an opportunity for educators to expand on examples of how multiple disciplines come together to study engineers in the workforce.

Introduction

The prevalence and importance of collaboration in engineering research and development cannot be overstated. Real-world problems are complex and multi-dimensional, thus requiring expertise from across multiple domains to problem-solve effectively, calling for training in multi-disciplinary skills as essential for engineering graduates [5]. Outcome-based curriculum development followed by most universities is aimed at developing engineers better prepared for the workplace. Several engineering educators [6] - [8] have also strongly advocated for teaching students more real-world engineering team operations. However, many students entering the workforce over the last many decades persistently remain underprepared for and unfamiliar with the opportunities or challenges that multi-disciplinary collaborations may present [9] - [12].

Teaching multidisciplinary skills in the engineering classroom, though important, can be challenging due to a variety of reasons. First, engineering students traditionally find themselves restricted by a narrow disciplinary focus [13]. Though multidisciplinary courses can better prepare students for real world contexts [14], for learning to become more multi-disciplinary, instructors themselves need to be trained to break disciplinary silos and successfully teach students how to function on multi-disciplinary teams [15]. Second, the engineering curriculum is already packed [16], often leaving little room for integrating multidisciplinary courses. Further, classroom settings can be limiting in terms of resources and time, making it hard to replicate the complex, real-world

problems that require multidisciplinary approaches [17], [18]. Third, assessing student learning in a multidisciplinary context can be challenging due to the complexity of the skills and knowledge being taught [19]. These challenges, among others, make it difficult to effectively integrate teaching multidisciplinary skills in the engineering classroom.

A successful way that several STEM researchers have integrated teaching their students multi-disciplinary skills is through project-based, active learning approaches [20] - [22]. However, such approaches may be challenging for instructors to implement and engineering students to learn from as they struggle to connect the project to their technical skills and fail to understand how and when the different disciplines on a team interact in the product development lifecycle. This paper addresses this gap by providing an example from industry on how a multi-disciplinary team works on problem-solving and delivering a solution to a customer.

The purpose of our paper is two-fold. We aim to 1) provide a diagrammatic representation of the various steps in developing (primarily, software-based) products, within the context of talent management research, to explain how multiple roles come together in industry to problem-solve, and 2) elaborate on pragmatic recommendations for engineers in training, engineers in industry, and educators drawn from auto-ethnographic reflections of members from a multi-disciplinary team. Even though the focus of this particular group is software based, the take-aways for multi-disciplinary collaboration will apply across non-software teams as well. Ultimately, this paper affords an opportunity for educators to expand on examples of how multiple disciplines come together in the tech/engineering workforce. Additionally, the paper implores engineers to engage in lifelong learning as they interact with increasingly multi-disciplinary teams in the workplace.

Background

Most students who choose to major in engineering do so to become a part of the community of practice of professional engineers [1], meaning that they want their college experience to include adequate exposure to what a career as a professional engineer might be. However, according to Jonassen [2], engineering graduates are not well trained to contribute to the workplace due to the complexities associated with engineering work. Stevens et. al [3] described engineering work as that which involves complexity, ambiguity, and contradictions.

Developing the skills for innovation involves analysis of complex, ambiguous, ill-defined, real-world problems [4], thus, students training to partake in industry must have an opportunity to, at the very least, be exposed to multi-disciplinary teams. This emphasis on the need for exposure to multi-disciplinary, team-based, problem-solving holds true not only for undergraduate and graduate engineers in training, but also professional engineers practicing in industry.

Multi-disciplinary Team

Teamwork, as Scarnati [23] describes, is a cooperative process allowing ordinary people to achieve extraordinary results. Teams usually work collaboratively towards a common goal, and multiple roles on the team contribute towards this purpose [24], [25]. A multidisciplinary team in industry, extends this definition of team by referring to a group of individuals with diverse backgrounds, skills, and expertise working together to achieve a common goal or project objective. These teams

typically integrate multiple disciplines, such as engineering, design, research, marketing, and sales, to develop and deliver a product or service.

By combining their expertise, team members can share unique perspectives and insights, leading to more innovative and comprehensive solutions. This collaborative approach fosters creativity, accelerates development cycles, and enhances product quality. Moreover, multidisciplinary teams make better decisions by considering multiple viewpoints, increasing their competitiveness and success within the industry. The key benefits of multidisciplinary teams include comprehensive problem-solving capabilities, innovative solutions, enhanced creativity, faster development cycles, improved product quality, better decision-making processes, and increased collaboration and communication. By leveraging the diverse perspectives and expertise of individuals from various disciplines, multidisciplinary teams can achieve superior outcomes compared to individual contributors working in silos, driving success and advancement across various industries.

Context: A Talent Management Science and Engineering Team

Our multi-disciplinary team sits within a larger talent management organization. Talent management focuses on how organizations engage and manage employees in order to achieve organizational outcomes [26]. There are many talent management processes including recruiting, hiring [27], compensation, onboarding [28], training, career development, performance evaluation [29], that impact the employee experience, organizational commitment [30], engagement [31], performance [31], and likelihood of an employee leaving the organization [33,34]. Organizations engaging in talent management research are often doing so to identify how best to attract, select, engage, motivate employees to maximize employee performance in order to drive organizational success. It is in this context that our team collaborates.

Demystifying various job roles on multi-disciplinary (software) teams

In industry, such as in software focused tech organizations, multiple roles come together to work towards improving processes and developing products. Projects represented on such teams range from traditional software product development efforts to, more recently, the use of generative artificial intelligence (Gen AI) such as large language modeling (LLM). The various roles within such a multidisciplinary team interact and collaborate in a dynamic and iterative manner. There are five well documented stages of team development (forming-storming-norming-performing-adjourning) as illustrated in Figure 1 per Tuckman [35] who indicated these phases are all necessary and inevitable in order for a team to grow, face up to challenges, tackle problems, find solutions, plan work, and deliver results. Over time team effectiveness increases as the team begins to norm. We have found that integrated (where different roles are specialized but the members of the team interact in planned and controlled ways), diverse, and complementary teams (where team members are not just integrated but also complement each other) [36] are the most effective and can achieve the performing stage more quickly. Many sources discuss the typical roles associated with development projects [37] - [40].

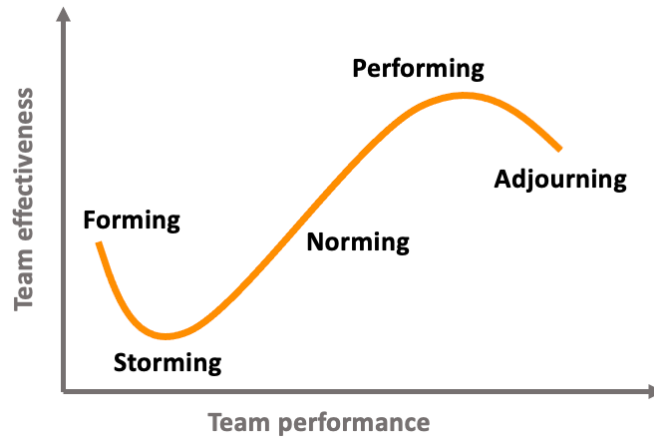


Figure 1: Tuckman's model of team development

In the talent management space within our organization, the Product Manager (PM) works closely with the UX Researcher to understand user needs and validate product decisions, while also partnering with the UX Designer to ensure design aligns with the product vision. The UX Designer, in turn, collaborates with Software Engineers to ensure design implementation and address usability issues. Meanwhile, the Research and Applied Scientist or Economist consults with the Product Manager and Software Engineers to apply scientific expertise and extend or develop new technologies. Software and Data Engineers then implement the required data pipelines or features and fix bugs based on the Product Manager's priorities. Business Intelligence Engineers analyze data to track key metrics, collaborating with Data Scientists to validate research findings. Often, Project and Program Managers oversee overall project timelines, resources, and risks, facilitating communication and decision-making among team members. Through this collaborative effort, the team delivers as well as continuously iterates upon, a well-designed, technically sound, and user-centered product or service. It should be noted that different organizations and project needs may necessitate slightly different roles and team composition.


Figure 2 diagrammatically elaborates on the various roles typical to a multi-disciplinary team and explains how they interact through the development process in an iterative manner. A typical project begins with the identification of some need from a stakeholder or team member which is assessed and prioritized. Once the decision has been made to pursue a project, the need is further defined and scoped to include goals and objectives, risks and constraints, requirements, project timelines, and the UX and user research approach and compiled into a business requirements document (BRD) which is provided to the software engineering (SDE) team. The Product Manager owns the BRD but all team members contribute to this document. The designs are developed (design workshops may be utilized) and iterated upon and implemented into a functioning product.

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Product Manager (PM) – Responsible for the development of products for an organization and owns the product strategy behind a product, specify its functional requirements, and manage feature releases.

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User Experience Researcher (UXR) – Have specialized knowledge in at least one user research discipline, such as human-computer interaction (HCI), cognitive psychology, sociology, human factors, ethnography, etc. They understand user research methodologies (e.g., usability study, survey design, field study protocols) and determine the best methodology to answer research questions and deliver insights to enhance the design of products, services, or software.

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Research Scientist (RS) – Are trained in disciplines including STEM [e.g., computer science, machine learning, engineering (electrical, mechanical, industrial, etc.)], operations research, math and statistics, physics, biology and chemistry, or another related technical field. They provide strategic direction to the team where new solutions need to be invented to address business problems or where building upon old functionality to optimize the effectiveness, health and well-being of individuals and organizations.

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User Experience Designer (UXD) – Defines the experience a user would go through when interacting with a company, its services, and its products.

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Software Development Engineer (SDE) – Applies the engineering design process to design, develop, test, maintain, and evaluate computer software.

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Applied Scientist (AS) – Conducts scientific research with a focus on applying the results of their studies to solve a wide range of business challenges.

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Business Intelligence Engineer (BIE) – Researches and analyzes company data to tailor the product experience per customer behaviors.

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Economist (E) – Economist have a strong technical proficiency in and deep knowledge of economic/ econometric techniques. They identify where improvements in modelling and data manipulation can be made and take strategic action to drive efficiencies to scale these solutions.

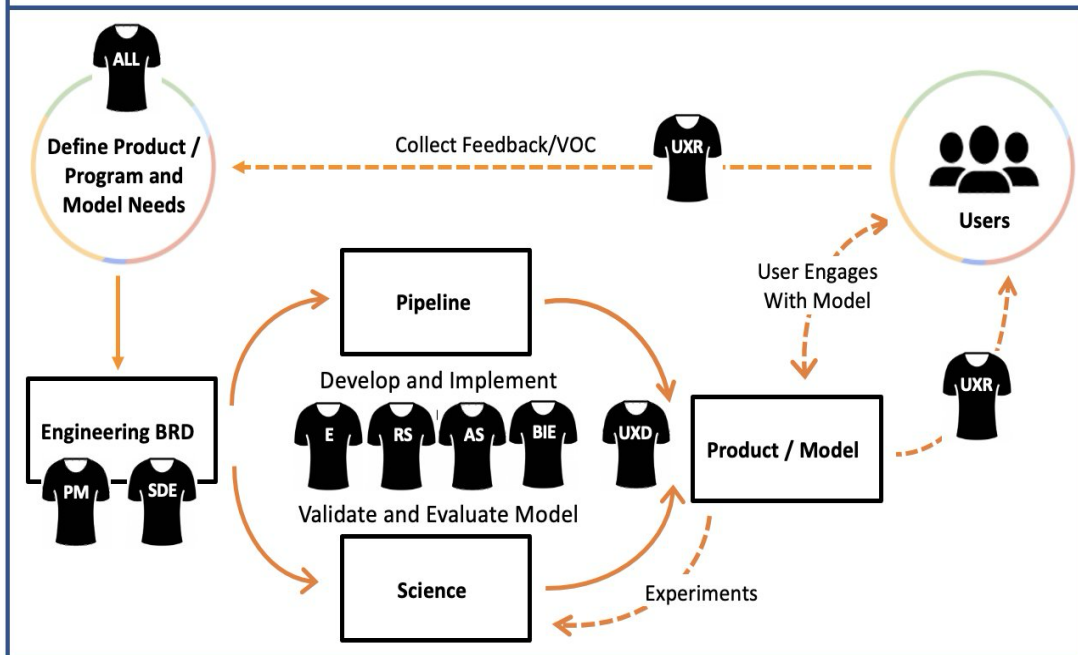


Figure 2: The Dream Team and Their Role in the Process

In parallel, as development proceeds, plans for validating and evaluating the product or model are created and a variety of experiments are conducted to optimize the product or model. A/B experimentation, often led by Economists, is also likely to be utilized to test alternative approaches. Concurrently, research with users occurs where users engage with the product or model to identify and address usage issues prior to releasing the product or model for widescale use. Research and science collect and assess customer feedback and impact using both qualitative and quantitative data to improve and enhance the product or model.

Pragmatic recommendations for successful collaborations on multidisciplinary teams

We employed the use of an auto-ethnographic reflective method to come up with a list of pragmatic recommendations for students and new industry professionals looking to contribute to multidisciplinary teams in industry. Creswell and Creswell [41] describe auto-ethnography as a research methodology that analyzes a phenomenon using self-narratives, which would otherwise remain private or buried. Auto-ethnographic reflections have been used in engineering education to provide authors an opportunity to shift from being an outsider to an insider in the research, which further enables their voices to be better heard within the community, thus promoting convergence and inclusion [42], [43]. Like Matusovich et al. [44] we undertook an analytical auto-ethnography approach, borrowing from Anderson [45] and focused on pragmatic reflections and takeaways.

At a project level, our collective reflections found that successful teams work on the following recommendations:

1. Work backward from a common goal

Each discipline may approach a problem from its unique perspective, emphasizing different aspects and factors. Without a shared understanding of the problem, the proposed solutions may not adequately address all the relevant dimensions [46]. This challenge highlights the need for a holistic and integrative approach that considers diverse viewpoints. Working backward from a common goal is a crucial aspect of multidisciplinary teamwork. This involves setting a clear and shared objective, then breaking it down into smaller, manageable tasks that each team member can work on. By doing so, team members can align their individual efforts towards achieving the same goal, ensuring a unified and focused approach. Creating platforms and spaces for regular communication, such as collaborative workshops, team meetings, and digital collaboration tools, enhances cross-disciplinary dialogue and fosters a shared understanding of the problem and solution [47].

2. Get entire team involved early and have frequent check-ins

Getting the entire team involved early and having frequent check-ins is essential for multidisciplinary teams. This practice helps to prevent internal disciplinary silos and ensures that all perspectives are considered throughout the project, at various phases. By encouraging cross-functional participation from the start, team members can build relationships and trust, leading to better communication and collaboration. Research has shown that teams that engage in frequent check-ins (i.e., daily stand-up meetings) and feedback, have higher levels of satisfaction and performance. The factors that contributed the most to a positive attitude towards the daily stand-up meeting were information sharing with the team and the opportunity to discuss and solve

problems [48]. Pinto and Pinto [49] discuss how high cooperation teams differ from low cooperation teams both in terms of their increased use of informal methods for communication as well as their reasons for communicating. A comparison centering the agile lens is provided by Vinekar et al. [50] who explain that “agile development and traditional development have different views on teamwork. *Agile development* is characterized by collaborative work, which requires multidisciplinary skills, pluralist decision making, high customer involvement, and small teams, while *traditional development* focuses on individual work, specialized skills, managerial decision making, low customer involvement, and larger teams.”

3. Recognize that all voices are important

In multidisciplinary teams, it is important to recognize and be intentional about ensuring that all voices are important. Each team member brings unique expertise and perspectives, and creating a safe and respectful space for diverse opinions and ideas allows for richer discussions and better decision-making. Gallo [51] defines team psychological safety as “a shared belief held by members of a team that it’s OK to take risks, to express their ideas and concerns, to speak up with questions, and to admit mistakes— all without fear of negative consequences”, and as Edmondson [52], [53] suggests, “it is felt permission for candor.” Furthermore, Gallo [51] presents three reasons why psychological safety is important: 1) it leads to team members feeling more engaged and motivated, because they feel that their contributions matter and that they’re able to speak up without fear of retribution, 2) it can lead to better decision-making, as people feel more comfortable voicing their opinions and concerns, which often leads to a more diverse range of perspectives being heard and considered, and 3) it can foster a culture of continuous learning and improvement, as team members feel comfortable sharing their mistakes and learning from them. By actively seeking input from all team members and valuing their contributions equally, teams can foster a safe, open, collaborative, and trusting environment that encourages creativity and innovation.

4. Continuously experiment and iterate

Experimentation and iteration are essential for multidisciplinary teams to develop innovative solutions. By encouraging team members to try new approaches and embrace failure as an opportunity to learn and improve, teams can foster a growth mindset and culture of experimentation. By embracing fast failure, experimentation, and constant iteration, multidisciplinary teams can deliver exceptional results and push the boundaries of what's possible. Numerous web articles [54], [55] discuss the value and benefits of rapid and iterative design. As Syafrony [56] states “the iterative nature of design thinking allows for continuous refinement and improvement throughout the process. It encourages designers to revisit previous stages, incorporate new insights, and iterate on their ideas based on user feedback. This iterative approach enables designers to develop innovative and user-centered solutions to complex problems”. Plattner et. al [57] adds “design thinking is an iterative process that embraces experimentation, learning, and iteration. Adopting agile methods, such as rapid prototyping and testing, allows for quick validation and refinement of ideas and enables multidisciplinary teams to make incremental progress and learn from failures, leading to more effective and innovative solutions”.

Next, at an individual level, individuals on multi-disciplinary teams can work towards the following:

1. Develop written and verbal communication skills

Sageev and Romanowski [58] observed, “*Technical abilities are a given, communication and leadership differentiate*”. As a member of a multidisciplinary team, it is essential to develop strong written and verbal communication skills to effectively collaborate with team members from different disciplines. This includes being able to articulate complex ideas in a clear and concise manner, actively listening to others, and being open to feedback and constructive criticism. By honing these skills, individuals can ensure that their ideas and perspectives are heard and valued, and that they are able to contribute meaningfully to the team's work.

2. Be intentional about understanding the bigger picture towards career development

Prior research has highlighted that students often overestimate their preparedness to acquire their first position after graduation, because they lack an accurate understanding of the career development process in industry [59]. In addition to technical skills, it is important for individuals looking to join multidisciplinary teams in industry to understand the career development process through also understanding the business and economic aspects of their industry of interest. This includes being aware of market trends, regulatory frameworks, and financial considerations that may impact the team's work as well as career development opportunities and potential. By being intentional about understanding these aspects, individuals can make fully informed decisions that not only align with a specific organization's goals and objectives, but are better able to translate their development across organizations within and across industries.

3. Engage in lifelong learning

To stay current and relevant in a rapidly changing world, individuals on multidisciplinary teams should engage in lifelong learning. This includes seeking out new knowledge and skills, attending conferences and workshops, building on competencies, and reading industry publications. Passow [60] found that graduates of 11 engineering majors consistently rated developing competencies such as teamwork, communication, and problem solving to be significantly more important than designing experiments. By continuously learning and expanding on one's knowledge base, individuals can bring fresh perspectives and innovative ideas to their team.

4. Explore outside disciplinary silos

Students and fresh graduates often have limited capability to make connections between their own disciplinary background and the knowledge of their team members from other disciplines. Richter and Paretti [61] describe this effect as negative relatedness, and it reflects the tendency to narrowly train engineers to be experts in their disciplinary topics with little emphasis on topics outside their discipline. Thus, it is important for individuals on multidisciplinary teams to explore outside their disciplinary silos and engage with others from different backgrounds and perspectives [62]. This includes being open to new ideas and approaches, seeking out collaborations with others, and leaving room for reflection and introspection. Additionally, students often perceive learning inside and outside the classrooms differently [63]. Helping students engage in multi-disciplinary pursuits in their learning outside of the classroom, such as through hobbies, can help them tie those learnings back to their discipline of interest. By doing so, individuals can broaden their understanding of the team's work and contribute to a more dynamic and innovative team culture.

Closing Thoughts

In today's industry, multidisciplinary teams are the norm, bringing together individuals from various disciplinary backgrounds and expertise to tackle complex projects. Universities have long been dedicated to the mission of helping their graduates succeed in industry [64-65], however, there continues to exist a gap in student perceptions of the workforce and subsequently, their preparedness for their first job post-graduation [59]. By bridging this gap between industry and academia, educators can better prepare students for the dynamic work environments they will encounter in their careers. Consequently, understanding how industry works, and how to effectively navigate dynamic multidisciplinary teams is crucial for success – the earlier these skills are built, the better. This paper contributes towards demystifying the various titles on typical multidisciplinary software teams in tech industry, by describing their roles in the product development and research cycle, as well as their interactions with other members on the team. The paper also provides valuable insights and recommendations for engineering students, recent graduates, and even tenured professionals as they navigate dynamic multi-disciplinary teams in the workplace. Additionally, the paper emphasizes the need for engineering educators to integrate more real-world industry examples into their teaching, providing students with early and frequent exposure to multidisciplinary problem-solving.

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