A Year of IDPro: Lessons Learned

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Empowering Undergraduate Motivation Through Interdisciplinary Project-Based Learning: Insights from Self-Determination Theory

Abstract

This Full Empirical Research Paper aims to showcase the findings from the first year of an interdisciplinary project-based learning course in the Department of Engineering Education at a large mid-Atlantic research university. Both literature and industry have expressed the need for undergraduate students to gain experience in interdisciplinary environments and prepare for their post-graduate careers, whether they aim to continue their education or enter industry after completing their bachelor's degree. Increasingly, all constituent groups cite advantages in beginning experiential learning early – in the first or second year of college.

The Interdisciplinary Projects course IDPro had 80 students enrolled in 2024, which was offered at both the 2000 and 4000 levels for 1-3 credit hours. IDPro was designed to provide students with team-based, interdisciplinary, vertically integrated, project-based learning experience before their degree-specific capstone. Examples of IDPro projects include research projects, industry sponsored projects, and topic-based projects selected by undergraduate students. IDPro functions as a 15-week course with projects expanding across semesters for students to continue developing over time as they hone their academic and professional skills.

End-of-semester student reflections written by 80 students were qualitatively coded in ATLAS.ti to understand the student experience in the course. Categorization of emergent themes was guided by Self-Determination Theory, which consists of basic needs around autonomy, relatedness, competence, and motivation. Self-Determination Theory helped to guide findings emerging from the data which included new soft and technical skills acquired by students, challenges faced, and growth throughout the course. Students described learning skills both independently and from peers, by persevering through challenges, and by working on real-world projects.

Keywords: Interdisciplinary, project-based learning, vertically integrated projects, undergraduate, industry partnerships, career readiness

Introduction

In today's rapidly evolving professional environment, the ability to navigate complex, interdisciplinary challenges has become a vital skill for engineering graduates (Van den Beemt et al. 2020; Lattuca et al. 2017). Incorporating Project-Based Learning (PBL) into educational settings is one way to provide student teams with authentic, engaging, and multifaceted problems that require the design of solutions or artifacts. Through PBL, students actively apply and integrate concepts and procedures while simultaneously developing essential professional skills (Repko et al. 2019). This type of learning environment not only cultivates technical and collaborative skills but also nurtures essential personal qualities such as motivation, self-

determination, and adaptability – qualities that are critical for success in both academic and professional settings (Koch et al. 2017; Palmer & Hall 2011; Prince & Felder 2006; Yusof et al. 2013;). However, while the value of PBL is widely recognized, there remains a need for deeper exploration into how these experiences impact undergraduate students' growth, motivation, and readiness for post-graduate careers.

The Interdisciplinary Projects (IDPro) course at the Department of Engineering Education at Virginia Tech aims to address this gap by providing a vertically integrated PBL experience to students at various stages of their undergraduate journey. Designed to set the stage before their degree-specific capstone projects, IDPro provides an environment where students from diverse disciplines collaborate to solve real-world problems. By engaging in this experiential learning setting, students gain not only technical competencies but also social skills such as communication, teamwork, and perseverance (Koch et al. 2017). These attributes align with Self-Determination Theory (SDT), which posits that the fulfillment of three basic psychological needs – autonomy, competence, and relatedness – is essential for sustained motivation and well-being. Moreover, SDT posits that distinct types of motivation move along a continuum, from completely Non-Self-Determined (amotivation) to Self-Determined (intrinsic regulation) (Ryan & Deci 2017).

Despite the growing body of research on PBL and SDT independently, there is a gap in understanding how early interdisciplinary PBL experiences influence students' motivation, particularly through the lens of SDT. This study seeks to address that gap by examining the pilot year of IDPro, which enrolled 80 students across multiple levels and disciplines. Through a qualitative group instrumental case study design, the purpose of this study is to examine how the IDPro learning environment supports students' psychological needs during the program's first year at Virginia Tech. Through this exploration of how students experience IDPro, this study aims to answer the following research question:

> How do students perceive IDPro's impact on their personal growth, self-determination, and professional readiness, with specific emphasis on autonomy, relatedness, competence, and motivational factors?

This study aims to present the findings from the first year of IDPro, analyzing how students navigated the challenges and opportunities presented by this learning environment. By employing SDT as a theoretical framework, the study highlights how IDPro meets students' psychological needs and enhances their motivation.

Literature Review

Interdisciplinary PBL has emerged as a powerful pedagogical approach that aligns well with the constructs of SDT, a framework that emphasizes the fulfillment of three basic psychological needs: autonomy, competence, and relatedness (Deci & Ryan 1985). In the context of learning environments, autonomy refers to the sense of volition and ownership students feel

over their learning; competence relates to their belief in their ability to achieve desired outcomes; and relatedness reflects their sense of connection with peers, instructors, and the broader learning community (Ryan & Deci 2017). These constructs are particularly relevant in PBL settings, where students engage in collaborative, real-world problem-solving tasks that require them to take initiative, develop skills, and build meaningful relationships within interdisciplinary teams.

Research has consistently highlighted the efficacy of PBL in fostering student motivation and skill development across various educational levels and disciplines. Strobel and van Barneveld (2009) conducted a meta-synthesis of PBL outcomes, finding strong evidence for its impact on long-term knowledge retention and skill acquisition compared to traditional teaching methods. Similarly, Prince and Felder (2006) identified PBL as a high-impact practice that promotes deep learning and intrinsic motivation, particularly when projects are aligned with students' interests and goals – an essential element of autonomy under SDT.

In interdisciplinary contexts, PBL is particularly valuable for preparing students for the complexities of professional practice. Lattuca et al. (2017) argue that interdisciplinary learning fosters cognitive flexibility and problem-solving skills by exposing students to diverse perspectives. These findings are echoed by Donnelly and Fitzmaurice (2005), who note that students engaged in PBL develop not only technical expertise but also the interpersonal and communication skills necessary for effective teamwork. Such experiences contribute to both competence and relatedness, reinforcing the holistic development of students in alignment with SDT.

The motivational benefits of PBL are further supported by research on experiential learning. Kolb (1984) emphasized the importance of active engagement in real-world tasks, a principle echoed by more recent studies such as Choi et al. (2014), who found that students participating in industry-linked PBL projects reported higher levels of self-efficacy and motivation compared to their peers in lecture-based courses. These outcomes are particularly pronounced in vertically integrated projects, where students from different academic levels collaborate, creating opportunities for mentorship and peer learning (Cabrera et al. 2018).

However, challenges remain in implementing PBL, particularly in interdisciplinary settings. For example, Hmelo-Silver (2004) noted that the open-ended nature of PBL can sometimes lead to frustration and cognitive overload, especially for students with limited prior experience. Nonetheless, these challenges can be mitigated through structured guidance and scaffolding, which help students gradually develop the competence needed to succeed. Additionally, Escandell and Chu (2023) highlight the importance of creating a supportive community to foster relatedness, which in turn enhances students’ willingness to engage and persevere in challenging tasks.

Overall, literature underscores the potential of PBL when designed with students' psychological needs in mind. By leveraging SDT as a guiding framework, educators can create

learning environments that not only enhance technical and interpersonal skills but also cultivate motivated, self-determined learners prepared to tackle interdisciplinary challenges.

Methodology

In the Spring of 2024, end-of-semester student reflections were collected from 80 students enrolled in the IDPro class. These reflections consisted of three components, namely a reflection on the project progress and personal growth, artifacts to highlight progress or showcase elements of the project, and a discussion on future steps, both professionally and for the project. Following the collection of these reflections, they were uploaded to ATLAS.ti for *a priori* qualitative coding by three researchers. During this initial round of coding, 81 codes were developed. Interrater agreement was checked by collaboratively coding and discussing findings at weekly meetings for each coding stage. Codes after the initial round of coding were also checked with two instructors of IDPro.

Once the initial coding round was completed, codes were reduced from the initial 81 down to 15. This was completed by the researchers cross-coding, comparing, and then combining codes; expanding code definitions to encompass elements that were missed in the first round; and beginning to align with Self-Determination Theory through discussions guided by selected readings. During the final coding round, the researchers selected the most frequently coded themes - Skills, Collaboration, Challenges, and Professional Development – based on the most prevalent codes, and coded these groups using Ryan & Deci's three "basic psychological needs" for motivation – Autonomy, Competence, and Relatedness. Table 1 lists the top four emergent codes and Table 2 presents an overview matrix of the intersecting themes.

Table 1
Four most frequently coded emergent themes

Code Name	Definition	Frequency
Skills	Applied, technical, soft, or another specific knowledge gained	N = 276
Collaboration	Working with others across disciplines, diverse stakeholders, or interests.	N = 116
Challenges	Any difficulties encountered, including scope changes, lab access issues, team conflicts, or time management.	N = 83
Professional	Discussions of skill transferability or applicability to future careers beyond undergraduate education.	N = 143

Ryan & Deci (2017) described self-determination in terms of necessary components for motivation, or "needs" at the high-level categories of Autonomy, Competence, and Relatedness. As we analyzed the four most frequent codes that emerged from our data - Skills, Challenges,

Collaboration, and Professional Development - we used Ryan & Deci's explanation of the SDT needs as a guide:

Table 2

Matrix of emergent themes (skills, challenges, collaboration, professional development) and SDT motivational needs (autonomy, competence, relatedness)

	Skills	**Challenges**	**Collaboration**	**Professional Development**
Autonomy	Taking responsibility for learning skills needed to advance project	Pride in persevering individually and as team	Recognition of integral need for collaboration	Awareness of growth personally and for career
Competence	Mastery and effectiveness achieved through teams navigating uncertainty	Self-perception in comparison to others and planning	Increases in confidence and self-efficacy in team roles	Seeing value in skills, content that weren't seen before
Relatedness	Skills gain closely related to the needs of the project; also valued for classes and career	Team dynamics strongly impacted feelings of belonging and ability to meet challenges	Value of leaders and team members; overcoming conflicts increased value	Team activity highlighted, less connection to broader society and issues

Autonomy refers to the need to self-regulate one's experiences and actions. In SDT, autonomy is a form of functioning associated with feeling volitional, congruent, and integrated (de Charms, 1968; Friedman 2003; Ryan, 1993; Shapiro, 1981).

Competence is one of the most researched issues in psychology and is widely seen as a core element in motivated actions (Bandura, 1989; Deci, 1975; Harter 2012; White, 1959). In SDT, competence refers to our basic need to feel effectance and mastery. People need to feel able to operate effectively within their important life contexts. The need for competence is evident as an inherent striving, manifested in curiosity, manipulation, and a wide range of epistemic motives (Deci & Moller 2005).

Relatedness (Baumeister & Leary, 1995; Bowlby, 1979; Ryan, 1995) concerns feeling socially connected. People feel relatedness most typically when they feel cared for by others. Yet relatedness is also about belonging and feeling significant among others. Thus, equally important to relatedness is experiencing oneself as giving or contributing to

others (Deci & Ryan 2014a). Relatedness pertains, moreover, to a sense of being integral to social organizations beyond oneself, or what Angyal (1941) so aptly described in his construct of homonomy (Ryan & Deci 2017).

Results

Key points and trends the students discussed during the semester were documented through examples from the end of semester reflections. To present these results, each of the four final categories of Skills, Collaboration, Challenges, and Professional are presented in separate groups with examples that offer deeper understanding of how student behavior evolved in the semester, using the Self Determination Theory constructs of Autonomy, Competence, and Relatedness.

Skills

Instances of students describing skills made up the most frequently coded of our emergent codes. Students mentioned professional skills like collaboration, communication, and time management as much or more than they mentioned technical skills. Many students described their skills attainment in the class as starting from knowing very little to gaining abilities throughout the semester.

Autonomy

Many students described identifying gaps in their skillsets and consequently learning skills through self-teaching and working with peers. For example, a computer science student described both learning technical skills from a peer and contributing their own, and in the process gaining an appreciation for teamwork:

> Moreover, collaborating with my team members, particularly the Team Leader, who had extensive experience in the project, was instrumental in my personal growth. Learning from the Team Leader's expertise and the methods he employed to code a model with 98% accuracy was invaluable. Additionally, my background in machine learning enabled me to contribute to the annotation of the dataset and the development of a model with 93% accuracy. Through these collaborations and contributions, I gained a deeper understanding of the importance of teamwork and leveraging diverse skill sets to achieve common goals – Arsalan

Students also described skills acquisition in ways that are more marginally aligned with SDT framing of autonomy. For example, students characterized the value of the skills they learned in class and how they could transfer this prior knowledge to their (IDPro) project:

> This task has furthered my knowledge in how MATLAB works and what it can be used for. I have taken several courses in MATLAB, and this work has applied to the knowledge obtained in those courses as well as adding to it – Ella

Also, students described changes in their own interests. Jamie reflected that, “Before my involvement, I was uncertain about the direction I wanted to take as a developer. However, this experience has sparked a profound interest in machine learning, helping to clarify my path forward in the tech industry.” Krozen explained, “I enjoyed how I had the freedom to decide on how to approach this end-to-end project of data collection, feature extraction, and creating a predictive model. In terms of my career choices, it really cemented my passion for ML.”

A strong marker of autonomy as authentic engagement was seen in numerous instances of students describing future plans that were either personal, extra-curricular, or intended for optional courses. As Ella stated, “I also plan to conduct my own research over the summer to learn more about conducting data analysis on EEG data and to learn more about the brain and how it works.”

Competence

In their reflections, some students highlighted how accomplishing team goals and overcoming challenges helped build their confidence and self-efficacy.

> My coding skills before this project were very base-level per se, but through this project, I feel that I have developed enough proficiency that I could do something like this by myself with ease” – Jordan.

However, for a student struggling with competence in their team, some challenges were overwhelming:

> Working with the Pi and the coding side of the project was massively complicated and something I did not want to get involved in due to my lack of coding knowledge, but working around the camera module designing a housing for it is something I wish I could have participated in – George.

On a more positive note, most individuals and teams did work through the challenges of not knowing a problem space or the skills required to approach it. Kindred described their meeting difficulty but not so much that motivation was thwarted:

> As we delved into the project, our team transitioned from completely having no idea of the de-palletizing machine to experts well-versed in every aspect of its function. We've become familiar with each component's movement and the various speeds at which they operate in different sections of the machine. We've counted the proximity sensors and motors, gaining a comprehensive understanding of the machine’s intricate workings.

Relatedness

In terms of feeling their own significance as part of a social and/or work group and confidence in their ability to contribute, student reflections about their skills crossed a wide range. For example, AJ described opportunities to grow through interactions with others:

> As a freshman, when I joined the team in IDPro, I did not know anything about socket programming or VPN protocols. I knew about network programming in theory but that

> was about it. Over time, I had the opportunity to learn and grow from people around me. I had never worked in an interdisciplinary setting before where everyone had unique skillsets.

Perhaps the most authentic description of learning and belonging together was Daniel's comment:

> I am also very glad to say I met some awesome people along the way and built good friendships with them. On a side note, I also learned about things outside of my interests like how to properly wire and connect an Arduino to pumps, taking into account the ground wire - Daniel.

As in most courses that include teamwork, not all collaborations went smoothly. A lack of relatedness appears to have negatively impacted skills development:

> Moving forward, I think the team would benefit from weekly meetings being used to update and maybe teach people about certain aspects of the project. I think that way the entire team can be on the same page about expectations, things that are happening, and what they can work on next instead of using the weekly meetings as work time. In recent weeks it has felt like the weekly meetings have changed into group work time and I often find myself with nothing to do – George.

Another student simply stated, "I have had to remind myself many times of what I have to offer my team instead of focusing solely on what I do not know" – Susan. In some teams, student leaders emerged who saw their contributions as both integral to the team and extending beyond the immediate setting with both leadership and project management skills emerging:

> Last semester, I contributed to the project by helping analyze our experimental data with the new team dynamic and give roles to our members. In terms of project contributions, I have managed to take the input of the team and design a general outline for the future of this project from a previous team. For this semester, my administrative contributions include having helped recruit and interview new members, establish a new team dynamic, and give roles to our members. In terms of project contributions, I have managed to take the input of the team and design a general outline for the future of this project and am now in the process of further defining the immediate steps for our upcoming experiment – Esteban.

Finally, students also described both increased confidence in reaching out to others for support in learning skills as well as contributing their work toward a project beyond the current phase:

> I am currently taking the route of reaching out to other teams and people more experienced than me in this specific topic. I did not take this approach earlier and tried to complete this task myself, which is one of the biggest things I have learned through my time in this project. Reaching out to others is essential in research, especially since the work we are doing is something not many have completed yet. We are currently in talks with another group also working with OpenBCI to learn their methods and hopefully collaborate further – Hailey.

This shows the beginnings of students being able to see their own relatedness to a larger context.

Collaboration

Autonomy

Students' reflections illustrated how they actively shaped their roles and took ownership of tasks, sometimes taking responsibility as leaders. "I also feel that the process of starting up this project has given me a lot of experience in a leadership role, communicating with my teammates and helping them to help our team" – Alex.

This included students having the courage and empowerment to adapt to a new context and take the initiative in leveraging team members' strengths.

> I think that this experience led to some personal growth I wouldn't have experienced otherwise. I learned how to work with an interdisciplinary team, which I hadn't done before, and leverage everyone's individual strengths" – Jamie.

Multiple students mentioned continuing their work during the summer, showing a self-regulated approach to their own growth and development and demonstrating ownership of their learning journe: "Over the course of the summer, I plan to make a few projects of my own to help improve my skills, and I feel this project was a great steppingstone for that" – Nina.

Competence

In their reflections, some students reflected on how increasing their collaborative skills fostered a growing desire to understand and apply their new knowledge of a topic in other projects beyond the current context.

> Our project has been an enriching learning experience over the semester. It has taught me valuable skills in conducting research, working in a large team, and gaining insights into current and future accessibility solutions. – Casey.

Other students looked at how the processes involved in successful projects must be done collaboratively, even if they do not always seem like grand movements towards completion:

> A valuable lesson that I got out of this project is to implement super small process as part of a more intricate system. We cannot rely on broad strokes to achieve desired outcomes. It's the finer details within each process that are important, especially when optimizing facilities and eliminating waste and bottlenecks to enhance efficiency – Kindred.

Relatedness

Students emphasized how working in interdisciplinary teams enriched their experiences and provided opportunities for belongingness and shared purpose.

> Our project could not have come far without a unique balance of individual roles and strong-suits, as well as a huge emphasis on communication, collaboration, and enjoying each other as not only professionals, but people – Taylor.

Other students emphasized the role of strong leadership within their teams, highlighting how it encouraged a sense of community: "I realized the importance of leadership and how a group of complete strangers can become comrades in a few short weeks thanks to the tireless efforts of a motivated leader" – Susan.

When challenges arose, such as team turnover or miscommunication, students recognized that threats to relatedness have big impacts. They also highlighted the learning opportunities these moments provided, further deepening their sense of connection and understanding of group dynamics.

> However, we slowly began to lose members of our team, including our only electrical engineer… This threw a wrench into things, in my opinion, which led us to a period of stagnation since we really weren't sure what to do. From this point onwards, we had to learn a bunch of stuff outside of our skill sets to achieve our goals that we set for ourselves at the beginning of the semester. This was tough, as there was a lot of trial and error, but towards the last couple weeks we began making progress again and were able to get stuff done. I think that this experience led to some personal growth I wouldn't have experienced otherwise. – Andres

Connections among students extended to interactions with external partners and mentors, especially where mentors looked to the students as collaborators, which students described as crucial for their growth from being a student to being a professional: "Being able to navigate team issues also allowed me to grow closer with my supervisors as I had to collaborate with and look towards them for advice" – Evan. This shows that students were beginning to realize that they could be valuable as collaborators not only to their team members but also to their supervisors.

Challenges

Students described a wide array of challenges they faced as part of the IDPro class. These challenges ranged across team conflicts, time management, and learning, with a strong pattern of students being proud of meeting challenges both individually and with their team members.

Autonomy

In relation to the challenges they faced during the semester, students described a lot of growth and development driven from an intrinsic desire to learn more and to be a better member of the team.

> I learned to adapt and communicate as best as I can to still provide and contribute to my team's weekly goals. This experience has profoundly impacted my personal development by fostering resilience and adaptability—qualities essential for any successful engineer – Abe.

Students also did not shy away from understanding that the first design is not necessarily the best or only design.

> As I continued to research and further understand submerged root hydroponic systems, I finally realized how wrong I was and how flawed my initial design was. Of course, this was very frustrating, but I did not let it stop me – Daniel.

Students also were quick to acknowledge forces beyond their control, including parts of their own life, and the impact they had on their progress in the semester.

> I hit a lot of challenges this semester, personally and academically, that minimized my progress towards our project. Nonetheless, I feel that I did a lot with what life has thrown at me, and I am proud to showcase that – Yumi.

These challenges were integral to both their academic and personal lives, and they described their project work as integral too.

Competence

Student self-perceptions of their competence, especially in comparing themselves to others, was a frequently mentioned challenge. Susan described her perspective, "I enjoy working with knowledgeable people who share my passion, it can be very difficult to not compare myself to them". There were also frustrations caused by the lack of one's own interest and enthusiasm to contribute to the project they are a part of:

> "I would have been happy to work more than this, but there wasn't anything that I felt was exciting to work on. Almost all of the design work had already been done by [team member], and I felt like the RPI was about ready for flight apart from connecting it to the flight controller which was a headache to work on" – Donald

Students also felt project progress was hindered at times due to not having back up plans ready to go or properly considering risk mitigation, which Emad identified: "Our team ended up placing all eggs in a single basket, and once we were not able to achieve this goal, our group got stranded and not sure where to head".

This was further exacerbated when the teams relied heavily on other groups to make progress, as Andy explained, Some obstacles that I feel like I faced included the reliance on other groups outside of the research group to make progress this semester. Most things ended up working out, but it was a bit slower.

Relatedness

A significant challenge faced was a lack of a sense of belonging on some of the project teams. As George explained, "Coming into the team at the beginning of the semester left me feeling somewhat lost as I did not have to interview like others on the team did." Other students, however, appreciated the multiple layers of involvement that team experiences brought them:

> The program has been more than rewarding; not only have I been able to work on a project that is interesting, yet challenging, but I also get to work within a group of like-minded peers from different academic backgrounds – Susan.

Students also began to identify approaches to managing their productivity. Catherine described a particular strategy that enhanced her productivity:

> A way that helped me complete my project tasks was doing them during or immediately after the team meetings. However, I didn't do this every time. This understanding of how I work would translate well into the workplace because I can try to complete tasks as soon as possible after meetings are completed – Catherine.

Mitch described ways that the team persevered by working outside its bounds:

> Despite the inherent difficulties posed by external competition, our team remained resilient and adaptable in our recruitment approach. By showcasing the significance and relevance of our project, we were able to secure commitments from interested participants successfully – Mitch.

Professional

Autonomy

Several students either reaffirmed their original intentions to apply skills to a certain career path, or clarified how they envision applying some of these skills to a newly identified future profession. For example, Maggie notes, "I still want to work in the aerospace industry, but I want to work to make it more sustainable by reducing its dependence on fossil fuels." Maggie started their academic career with a desire to pursue aerospace engineering, generally. However, after engaging in a project to develop sustainable materials, Maggie recognizes that some of the skills gleaned from the program, and the overall theme of the program, will empower them to engage with the aerospace field through a sustainability lens.

Similarly, Emad discussed their plans to pursue a graduate degree in nuclear engineering, as the exposure to knowledge and applications of heavy elements encountered in the program, "My graduate school plans are to go towards nuclear engineering and even possibly the study of the properties of heavy elements because of this project". Jamie notes "However, this experience has sparked a profound interest in machine learning, helping to clarify my path forward in the tech industry."

Esteban calls out specific transferable skills that they would like to or are now able to apply by moving into a career space:

> As for my career choices, I have landed a role as a project manager intern, and I know that I will be able to transfer the skills learned here to that role. I know my skills in communication and planning will serve me well in my other pursuits, and I have already been able to use these.

Competence

In terms of competencies, students noted the refinement of specific professional skill competencies, with Kindred noting that:

> Professionally, this project has been instrumental in honing my client interaction skills, particularly during our weekly meetings. Learning to ask the right questions and engage with clients courteously is vital. These skills are not only prepping me for my senior design project but are also laying the groundwork for future interactions with superiors and colleagues, positioning me to become a more effective communicator.

Students also highlighted that the interdisciplinary aspect of the projects helped them to focus on some of the professional skills due to the fact that some of the technical aspects were beyond their competencies, allowing them to see value in places not seen before, likely as part of learning and growing from one stage to another. Erik states, "I may not be able to do everything that the rest of the team can in terms of technological proficiency, but I think it will be a great strength going forward to understand everything I can about what goes into developing devices like this"

Many students spoke of the fact the participation in the program itself served as an effective means to translate competencies to future employers. Debby was one of several to note anecdotes such as "My involvement in the NLP project played an important role in getting me a summer internship, where the company was impressed with my hands-on experience with NLP techniques."

Relatedness

With respect to relatedness, many students spoke of the development of professional networks, and an understanding of the inherent value associated with professional networks. Audrey notes:

> This project has helped me to make connections with other industry leaders in meat processing equipment like Provisur and CCI which could lead to potentially beneficial relationships in a future professional career.

Similarly, Katie notes, "I now have an internship this summer with Boeing which I believe will become a catalyst in my career development." She continues, stating that these professional networks have bolstered her confidence in a professional career, as awareness of her own transition/growth: "Now, I have much more confidence to apply to the internships and research that I felt like I was not qualified for"

Abe also speaks of inclusion in a potential professional network and the associate benefits to a career:

> Moreover, the project has significantly broadened my professional network, connecting me with industry leaders and innovators who can provide insights and opportunities that may have been previously out of reach. These connections are not merely professional contacts; they are potential collaborators who can help drive forward my ideas and projects in aerospace.

Here, the student views themself as a participant in a network of professionals connected through the work they have done for their IDPro project.

Discussion

Originally, the results were coded into four discrete categories. These categories were driven by the most frequent themes that appeared in open coding. However, these categories do not operate separately; the axes of self-determination interact.

Autonomy exists as a critical component of IDPro; motivation realized through agency brings passion and direction. Through IDPro, autonomy can be seen in two ways. First, students are able to choose their path to find their interest, delineating their path forward to find exactly what they want to do. Second, student motivation drives their ability to apply skills, which lays a foundation of transferability of professional and technical skills to future careers. That autonomy then leads to competence and relatedness; students deepen their understanding of their field and skills, while the ability to apply those skills helps them identify with their field.

Some of the skills and competencies that students develop can be difficult to name, particularly those that do not result in a tangible deliverable, such as systems-level perspectives, developing team dynamics, and professional communication. Despite the fact that a sense of belonging and relatedness are intrinsic to the learning portion of the program, students understand that they benefit from the network of skills and knowledge that surrounds them, but it's not always clear to them how their peers and mentors benefit from their role within such a network. The class itself offers a space to strengthen the student's sense of self: how their work contributes to their peers and teammates, as well as how they fit into a larger, societal mosaic that holds the power to shape their world. This founds an empathetic view of society where students are involved in their own story.

Community relatedness helps students overcome challenges. Social capital allows students to handle the cognitive workload, a key characteristic of team projects. The interdisciplinary nature of the projects provides opportunities for belongingness, as students are encouraged to contribute and highlight their own skills; practices in the course structure call attention to how each student contributes. The interaction of technical competency and interpersonal competency creates a unique environment where students must display competency vulnerabilities: things they admit they do not know. The ability to be open with competency vulnerabilities can be encouraged by instructors and mentors, but ultimately, it relies on the relatedness and community of the students. Navigating competency vulnerabilities creates a new learning outcome for students: navigating uncertainty. The basis for displaying competence is not necessarily measured in the precise skills that are gained, given the diverse skills that students may develop over the course of their project progress. Instead, students should be encouraged to become competent in learning, fostering an attitude of lifelong learning.

In looking at the interpersonal relationships of students, it is clear that having a strong leader influences the team's attitude towards continual learning, how individuals feel on the team, and how resilient students are to challenges. One key example is that an individual student will feel more confident in exploring their competency vulnerabilities and psychological safety with the example and encouragement of leaders. The leader also facilitates the ways in which

students understand their relationship with their teammates and mentors. This leadership role can be facilitated to a certain extent in the class; however, in allowing a team the collective and individual autonomy to define their relationships and interpersonal dynamics, it is important for mentors and instructors to predefine and specify how leader roles should look on teams, instead allowing the students to explore the role and its responsibilities.

As a student steps into the leadership role, it falls to the students to delegate tasks and develop a roadmap. Ownership is a demonstration of autonomy; when students are not prescribed a singular, concrete path, they must instead develop their own path and their role relative to it. The autonomy to develop and apply skills further grants the confidence that students need to pursue careers and propels them towards future learning by showcasing their competence and ability to work professionally. While this autonomy can result in even greater contributions to a student's own learning journey, the role of the leader can sometimes result in externally driven ownership (i.e. a student may feel ownership over a task because it was explicitly given to them, rather than feeling ownership because of their own autonomously driven motivation to engage with the task).

During every semester of IDPro, continual adjustments are made to reflect the needs of students, both as individuals and in teams. As the structure of IDPro continues to develop and change, it is necessary to preserve the open space wherein students are allowed to make their own transitions between identities and roles, facilitated through project-based learning environments.

Conclusion/Future Work

In learning spaces such as higher education, transitions are common. Students graduate and transition into professionals; many undergraduate students transition to become graduate students. In this space, IDPro becomes an environment where students can become aware of such transitions and explore the skills they will need to make their own transition in the future. By working in vertically integrated interdisciplinary projects, students are able to learn from the perspectives of other disciplines while deepening their own disciplinary identity. The transdisciplinary nature of an environment such as IDPro mean that students are able to explore their research interests and skills while continuing to learn through the project—ultimately allowing them to take forward a depth of skills and knowledge, not only from the project content but also from engaging in research and developing their interpersonal skills. As students gain skills, they bring them back to IDPro, which in turn serves as a lens through which students are able to understand that their skills can contribute to the problem, identifying value in places where it may not have been seen previously. IDPro invites students to transition into collaborators and partners: continual learners who can navigate uncertainty and explore interdisciplinary spaces with confidence in their skills and contributions.

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