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Using the Engineering Unleashed Competition Teams' Skillset to Cultivate Entrepreneurial Mindset in Cocurricular Contexts

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Using the Engineering Unleashed Competition Teams Skillset to Cultivate Entrepreneurial Mindset in Co-Curricular Contexts

Engineering team competitions are a rich educational context in which students can develop an entrepreneurial mindset (EM). In order to support the development of students' EM, we have identified a set of skills that contribute to competition team success while enhancing EM in the competition context. The skillset represents the adaptation of the Engineering Unleashed (EU) Engineering Skills to the competition environment; we believe that the adaptation can help faculty who mentor teams to identify students' skills gap, locate resources that can contribute to students' development, and encourage students to adopt an entrepreneurial mindset.

As a result of our project, we have developed the EU Competition Team Skillset (or "Roadmap"), a visual representation of crucial skills that students need to be successful in engineering competitions. These skills are, we believe, applicable to any competition, whether students participate in the co-curricular space or as members of a class, and no matter the engineering discipline. Used by faculty advisors as a "roadmap," the skillset can provide both students and their advisors a clear picture of the skills necessary to conduct a successful competition project, from the early stages of recruiting and retaining a competition team to the final work of communicating the value of the team's work during the competition event itself. Our goal is to share the roadmap and encourage faculty advisors to employ it with their students.

Student Development and Entrepreneurial Mindset

As we have noted elsewhere, engineering competition team projects provide students with the opportunity to apply learning from the technical classroom to real world, open-ended design projects. [1] Examples of competition team activities include Formula SAE, Human Powered Vehicle, Concrete Canoe, Chem-E-Car, or Design-Build-Fly. Many competitions are sponsored by professional technical societies, such as the American Society of Mechanical Engineers, or by industry, such as the Shell Eco-Marathon. As Bland et al. have observed, based on their research with students who participate on engineering competition teams, "engineering competitions may act as a catalyst for students to learn how to integrate technical and professional skills and knowledge in their development as an engineer." [2] In addition, engineering students' involvement in activities outside of the classroom, such as student competition teams, contributes to their achievement of numerous other outcomes; according to Simmons et al., engagement with these activities enhances students' "career and professional development, communication and leadership development, intellectual development, personal and social development, academic and social engagement, intercultural competence, satisfaction with college experiences, and college belonging and persistence in major and college." [3] Working on a competition team also contributes to the development of students' design and build skills, as well as students' non-technical skills, skills that may or may not be a part of their technical coursework. [4], [5], [6] To date, very little research has been done to evaluate the impact of the competition team experience on the achievement of academic outcomes or the acquisition of an entrepreneurial mindset, but

the competition context is clearly a site for engagement that has been shown to contribute to student development. [7], [8]

KEEN Competition Team Skills Project Context

In our project, we sought to understand the relationship between engineering competition teams and EM by focusing on the Engineering Unleashed Engineering Skillset (EUES) which is part of the EM framework (see Figure 1).

Figure 1: Engineering Unleashed Engineering Skillset [9]

A comparison of the EUES to the competition team context suggests that EUES maps well to competitions in some cases (e.g., the skills listed in the Design category), but maps less well in others (e.g., skills listed in the Impact and Opportunity categories). During an initial focus group with faculty at our home institution who mentor competition teams (Rose-Hulman Institute of Technology, June 2019), there was general agreement that some items in the EUES aligned well with the competition teams context, while there is distinct misalignment with others:

- **Create a business model**—while the faculty interviewed did not see the phrase "business model" with a focus on revenue and cost as appropriate to the engineering competition context, they stated that competition teams generally need to construct an operating model to help them organize and work together effectively;
- **Identify a supply chain—**in order to keep their projects on schedule, student teams need to establish a supply chain or the ability to navigate the university financial systems to procure materials or supplies early in life of the project; supply chain tasks include locating parts, organizing shipping and receiving, and communicating with vendors;
- **Protect intellectual property**—faculty expressed that the underlying spirit/ethos of competitions is generally to share resources and help each other. Without this spirit, teams won't grow and learn. As one faculty mentor stated, "Protecting IP is anathema to many competitions";
- **Assess policy and regulatory issues—**faculty translated this skill into the need for teams to assess the competition rules, then deal professionally with judges/officials;
- **Opportunity generally—**while faculty did not see the competition teams context as a place for students to identify an opportunity to create a business, they agreed that the competition provided the problem to solve, but students needed to assess opportunities to develop and implement innovative solutions and what their "edge" is in the competition;
- **Communicate—**this skill had several applications in the competition teams' context, including inspiring other students to join the team, champion the project, and document what was learned in the previous year in order to sustain the project from year to year.

Our project goal was to explore the connections between the EUES and a potential skillset that reflected the engineering competition team context, with the intention to show that competitions can be an important activity for students' development of an entrepreneurial mindset.

Survey Development and Design

To begin this project, we developed an online survey and identified individuals from faculty and staff within the Engineering Unleashed network (KEEN) who advise/coach student competition teams. We invited 99 individuals to respond to our survey and received 42 responses. The survey instrument listed the 18 EUES, organized into three groups: Design skills, Opportunity skills, and Impact skills. For each skill, respondents were asked two questions: 1) How important is this skill to students' success on a competition team (5=Very Important, 1=Not Important), and 2) how capable are students currently of demonstrating this skill (5=Very Capable, 1=Not Capable). Respondents were asked to use a 5-point Likert scale to rate their responses to the two questions. This two-question format has been applied by Ulwick in Outcome Driven Innovation (ODI) studies to identify important but underserved product needs [10]. In addition, respondents were asked to add additional comments to each skills section. At the end of the survey, we listed all of the EUES and asked respondents to add to the list of EUES by providing important skills that were currently absent: "Please use the comment box to add any skills that you believe are important for student success on competition teams but were not listed above."

Faculty and Student Surveys – Analysis of "Important" and "Capable" Skills

Following the close of the survey, we analyzed the collected data. Results from the faculty survey are shown in Figure 2 with the skill key shown in Figure 3. Each point on the graph shows the 'top 2' fraction of responses (either a 4 or 5 on a 5-point Likert scale) for both importance and capability. An example of these calculations is shown in Figure 4. Points in the lower right-hand corner of the graph are the ones to focus on as very important but where students are perceived to be not very capable at them. Ulwick suggests calculating an "opportunity score" as a combination of importance and capability, and these scores are shown in Figure 3.

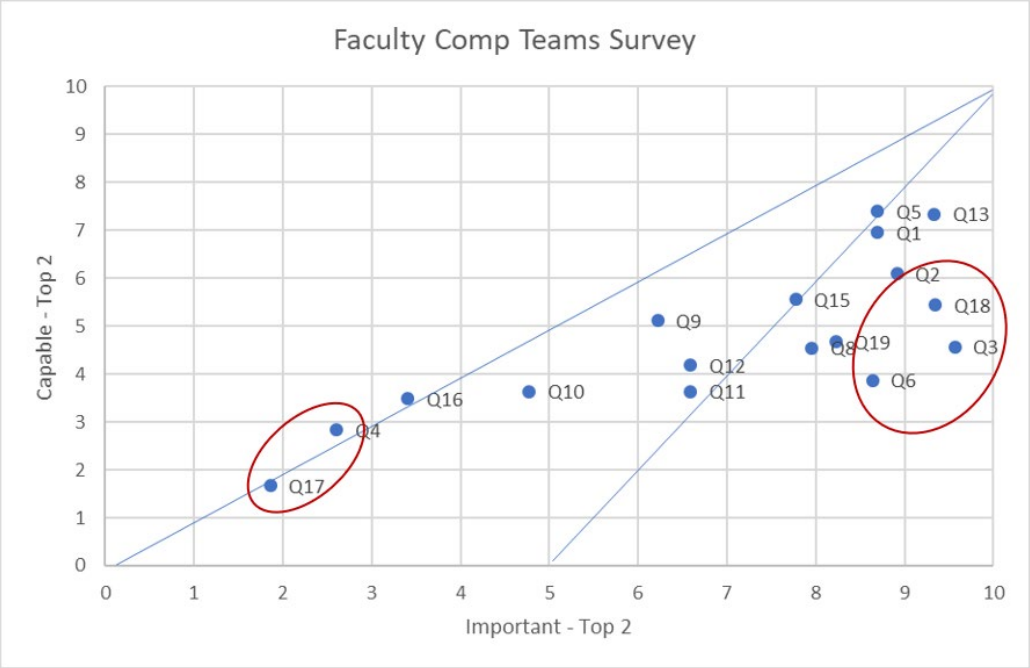

Figure 2: Faculty survey with importance and capability scores

Rank	(I+(I-C)) x 10	Skill
1	14.57	Q3: Analyze solutions
2	13.41	Q6: Validate functions
3	13.26	Q18: Develop partnerships and build a team
4	11.78	Q19: Identify supply chains and distribution methods
5	11.74	Q2: Perform technical design
6	11.36	Q8: Identify an opportunity
7	11.33	Q13: Assess policy and regulatory issues
8	10.43	Q1: Determine design requirements
9	10.00	Q5: Create a model or prototype
10	10.00	Q15: Communicate solution in economic terms
11	9.55	Q11: Evaluate feasible, value, benefit, viable
12	9.00	Q12: Test concepts quickly by customer engagement
13	7.33	Q9: Investigate the market
14	5.91	Q10: Create a preliminary business model
15	3.33	Q16: Communicate solution in societal benefits
16	2.39	Q4: Develop new technologies
17	2.05	Q17: Validate market interest

Figure 3: Faculty survey skill key and opportunity scores (max possible score is 20)

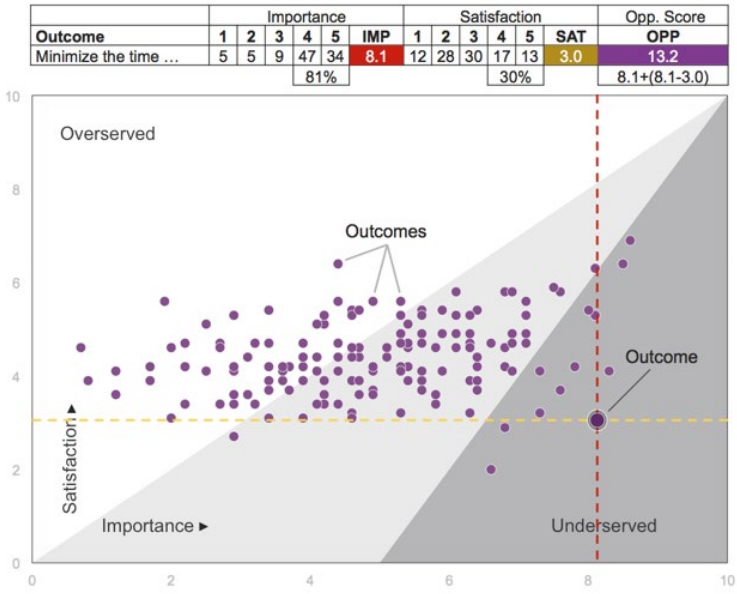

Figure 4: Sample Ulwick ODI plot showing calculation of top 2 scores for a survey question.

This analysis readily highlights the skills in the lower right corner and with the largest opportunity score where additional study or student training might be done to improve the competition experience. The top three skills identified are as follows:

1. analyze solutions,
2. validate functions, and

3. develop partnerships and build team.

The skills with the lower scores indicate that while these might be important in an entrepreneurial venture setting (such as develop new technologies and validate market interest), they may not be directly applicable in a competition team experience.

Like the faculty survey, the student survey was developed using the skills in the Engineering Unleashed Engineering Skills framework and feedback from faculty interviews about important team skills. Questions from the faculty survey were revised, since we were asking students to reflect on their own level of skill, rather than assessing the skills of others. The students surveyed were all competition team participants and team leaders. Results from the student survey are shown in Figure 5 with the skill key shown in Figure 6. Each point on the graph shows the 'top 2' fraction of responses (either a 4 or 5 on a 5-point Likert scale) for both importance and capability. Points in the lower right-hand corner of the graph are the ones to focus on as very important but where students believe their teams are not very capable at them.

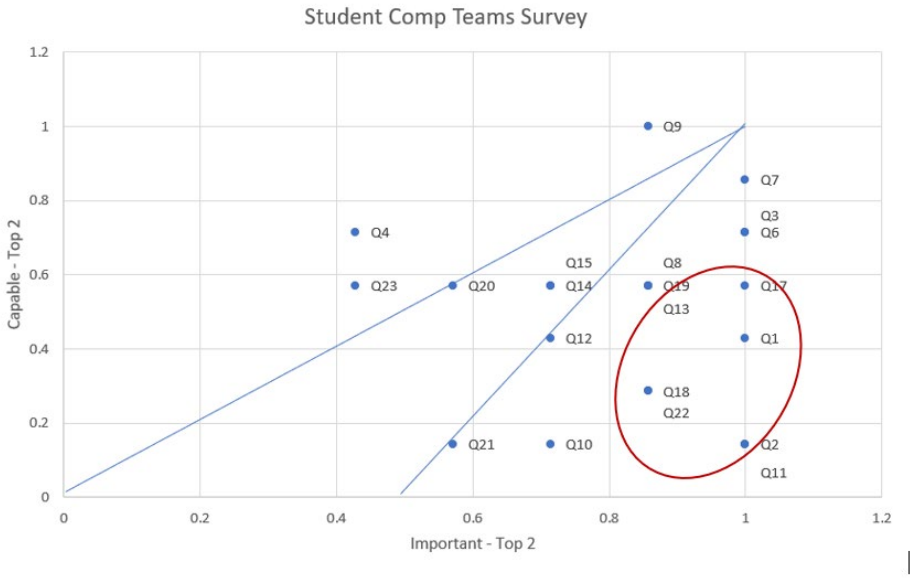

Figure 5: Student survey with importance and capability scores

Rank	(I+(I-C)) x 10	Skill
1	18.6	Q2 Retain team
2	18.6	Q11 Instill perseverence and drive
3	15.7	Q1 Recruit team
4	14.3	Q17 Develop operational plan
5	14.3	Q18 Document work
6	14.3	Q22 Use project mgmt
7	12.9	Q3 Transfer skills between years
8	12.9	Q6 Mentor new members
9	12.9	Q10 Inspire urgency to complete tasks
10	11.4	Q7 Build culture
11	11.4	Q8 Create engagement with project
12	11.4	Q13 Build grow
13	11.4	Q19 Transfer knowledge previous teams
14	10.0	Q12 Support leaders
15	10.0	Q21 Identify partners
16	8.6	Q14 Set goals team development
17	8.6	Q15 Ask help faculty advisor
18	7.1	Q9 Create org structure and op model
19	5.7	Q20 Financial mgmt
20	2.9	Q23 Comm stakeholders
21	1.4	Q4 Tell story of previous team experience

Figure 6: Student survey skill key and opportunity scores (max possible score is 20)

This analysis readily highlights the skills in the lower right corner and with the largest opportunity score where addition study or student training might be done to improve the competition experience. The top six skills identified are as follows:

1. retain the team,
2. instill perseverance and drive,
3. recruit the team,
4. develop an operational plan,
5. document work, and
6. use project management tools.

It is interesting to note that for seven skills, all the students responded with a rating of 5 as very important.

Based on the responses we collected via the survey, we conducted a series of online interviews with 10 faculty from eight institutions who had completed the survey. The purpose of the interviews was to dig deeper into their responses in order to determine the relevance of the EUES to students' work on competition teams. What we heard in the interviews confirmed the survey responses about skills students need that are not currently a part of the EUES, such as project management, leadership, teamwork, and communication. In addition, we heard from faculty that they would appreciate having access to resources that they could share with students to help them develop these skills if they do not come to the competition team with those skills already in their possession. Some respondents indicated that the courses designed to prepare students for

design, such as a junior-level design course, were sometimes not adequate to prepare students for the real-world setting of a competition team and its associated demands. Thus, faculty needed to coach students in order for them to develop these skills.

Engineering Unleashed Competition Teams Skillset ("Roadmap")

As a result of our work on this project, we developed the Engineering Unleashed Competition Teams Skillset, based on the Engineering Skillset, but defining skills that are unique to the engineering competition team context. Figure 7 shows the skillset.

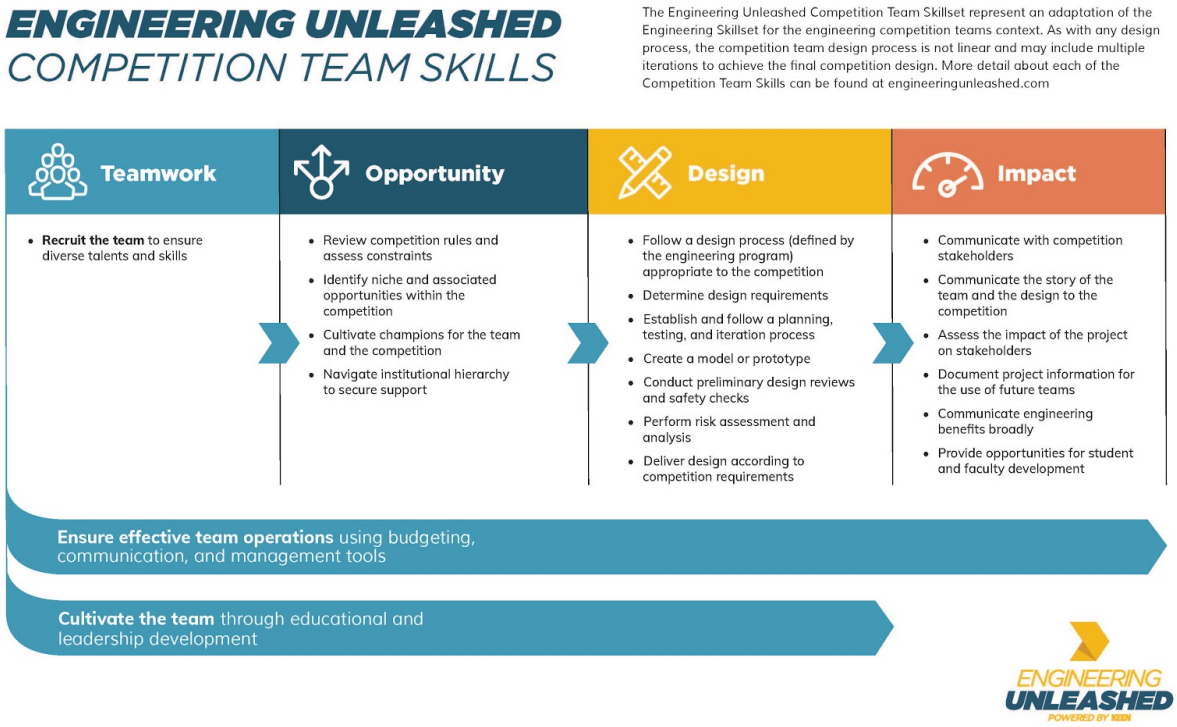

Figure 7: Engineering Unleashed Competition Teams Skillset

Several important aspects of the skillset we developed are important to note. The Opportunity, Design, and Impact categories of skills are retained from the EUES. The skills within these categories have been modified slightly based on the research, but these appear to be universally applicable skills necessary for EM and creating value. Based on input derived from collected survey data and the input of the Advisory Team, we added the Teamwork category of competition skills, comprised at the highest level by the skills of recruitment, team operations, and team cultivation. Next, the high-level skills in Teamwork are further defined by sub-skills that provide more detail about what comprises each high-level skill (the sub-skills are not shown in the Figure 7 graphic). Finally, the visual presented here is a draft of the skillset, and we expect that the visual will undergo revisions as we share the Competition Teams Skillset with members of the Engineering Unleashed community.

The competition team year calendar flows from left to right across the skillset diagram. The activity in a normal year follows a pattern of forming the team and performing design activities in the Fall, followed by building the design in the Winter, then competing and having impact in the Spring.

The addition of the Teamwork category of skills suggests that there are unique aspects and skills needed in the competition team environment. A key question then is, are these skills only applicable to the competition team setting or do they also apply in a more conventional class project? Table 1 below considers several situations and the application of teamwork skills in each situation. The "recruit and retain" aspects of the competition team and class project may be different. Competition team participation is often voluntary, and it is easy to switch to other more attractive opportunities on campus. In the class project, the credit and grade may not be the only driver of participation but are the main student motivator. The engagement aspects of both are similar; both are often led by a student with emerging leadership skills, and students will be highly engaged if it offers exciting project work and an engaging team experience. For comparison, an entrepreneurial venture is included, and these often have professional management as well as employment and compensation motivations.

Situation	Teamwork Skills			
	Join	Engage	Retain	Leadership
Competition Team	Awareness, Perceived value, Exciting opportunity	Interesting project, Engaging team experience.	Exciting work, Easy to switch	Student leader
Class Project	Enroll in class	Interesting project, Engaging team experience	Earn grade, Difficult to switch	Student leader
Entrepreneurial Venture	Exciting opportunity	Exciting work	Employment, compensation. Switch is possible	Professional manager

Table 1: Teamwork Skills in Three Settings

Gap Analysis for Skill Development

In addition to creating the new skillset, we saw this project as an opportunity to identify gaps between what students need and what resources are currently available for faculty and students to use. The EU Competition Skills list serves as a roadmap for faculty advisors to elevate the competition team experience for students from being just an ad-hoc, "build a vehicle" project to a more structured learning experience incorporating entrepreneurially minded learning. Just-in-time training materials could assist students and faculty advisors in these activities.

The roadmap in Figure 7 informs the faculty advisor and student team leaders about the skills and project phases necessary to create a more comprehensive learning environment and to improve the likelihood of team success. In many cases, a team will look to competition scores as the sole measure of success while the matrix suggests that there may be several ways that the

project creates impact, value, and overall success. Most competition teams are organized as co-curricular student clubs and as such, there are typically not for-credit classes that prepare students for or support the competition. Students apply many design and technical skills during the project, but as noted above, there are other skills necessary to build and organize a successful team.

An ideal approach for preparing the faculty advisor and student team leaders to apply the competition team skills is a series of text and graphic materials and training modules that could be used in a "just-in-time" approach. Over the course of the team project, the faculty and students involved could reference these materials as the project moves through various stages.

A brief review of materials supporting the skills in the roadmap suggests that there are many available sources of materials. Several sources were reviewed including LinkedIn Learning, general YouTube videos, and Engineering Unleashed related sources such as the modules produced by the University of New Haven [10]. While resources do exist, we found that the available materials are not ideally suited to the context of student competition teams because of their format or subject treatment. In some cases, the content is hours of material for a course module or standalone workshop. The context of these materials ranges from a general business setting to construction to engineered products. We believe that a collection of training materials with widely different format and context from competition teams would not be well received by faculty advisors or students.

The ideal characteristics of materials to support the competition team and incorporate EM would include the following:

- Brief and to the point: simple graphics, several pages, or 10-minute modules
- Unified format and context
- Materials support key skills in the roadmap, not each item
- Focus on a practical, how-to approach
- Context and examples in the materials is a competition team or closely related
- Materials introduce concepts and templates that can be immediately applied
- Presentation reflects a unified, consistent, and professional approach across all materials

Table 2 below suggests several initial training modules/videos that would be useful for faculty advisors and student leaders.

Training Module Title	Topic
Competition Team EML	Overview of diagram and framework, benefits of adopting this approach to organizing a competition team
Stakeholder Analysis	Identifying relevant stakeholders and their interest is critical to a successful team experience and creating value.

Being an Effective Team Leader	A team leader for a competition team must do several things to create a successful team environment.
Recruit and Retain	Effective approaches for recruiting team members and retaining them are unique skills needed by team leaders.
Design and Build	The heart of the competition team experience is designing and building the vehicle but this must fit in the larger framework of opportunity and impact.
Communication Skills	Student leaders and faculty advisors must develop effective communication skills to engage and all team members and stakeholders.

Table 2: Suggested Training Modules for Competition Team Skills

Conclusion

We see several important next steps for this project. First, we plan to circulate the roadmap to faculty competition team advisors across KEEN. Their feedback could offer us additional revisions to improve the roadmap. Second, we intend to share the roadmap with the professional societies who sponsor student competition teams. These organizations could help disseminate the roadmap and further broaden the reach of this work. Third, by offering the roadmap as a resource to professional societies, we hope to expand the audience for EM to non-KEEN colleges and universities who compete in engineering competition teams.

Acknowledgment

We appreciate the support and encouragement of Engineering Unleashed and the Kern Family Foundation on this project. We also acknowledge the contributions of survey respondents, focus group interviewees, competition team advisers, and student participants who provided input.

Author Note

Dr. William A. Kline passed away unexpectedly on March 20, 2021, before this paper was finalized. As his co-author, I have done my best to revise this paper to reflect the input from the reviewers, as well as Bill's intentions as project collaborator and author. Bill was a tireless advocate for his students and for entrepreneurial mindset, and he will be missed.

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