

Innovative Professional Master's Capstone to Bridge the Gap Between Academia and Industry

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Abstract

This paper is to introduce a new approach to bridge the gap between the academic higher education and the industry practice. The conventional engineering senior design capstone project has provided a good foundation for our future engineers. However, the industry corporation is actively seeking more experiential learning from the academic curriculum. At the graduate college of engineering, it is limited to offer any Professional Master's Program capstone project during the regular semesters in an academic calendar. From the prospective of industry applications, it has a successful story to develop and implement an innovative professional master's capstone program to bridge the gap between academia and industry. It is intended to share the best practice and create a new standard to enhance the experiential learning from the top U.S. engineering schools.

Key words: PMP Capstone, executive sponsors, business impact, real-time response

1. Introduction

In the 21st century global industry, corporate recruiting managers recognize the gap in workforce development skills from the recent engineering graduates. Fortune 500 companies continue to spend millions of dollars for on-job training and rotational development program on their newly hires. At the university level, there is always a challenge to implement the engineering knowledge into industry practice and the real-life product and process applications.

Traditionally, higher education institution in engineering introduced the experiential learning curriculum via Senior Design Capstone Project with the local corporate partnership and the industrial alumni network [1,2,3,4]. Industries value higher education institutions as the ideal partners to outsource their research and development activities and increase their competitiveness via the exchange of knowledge and technology. Meanwhile, their industry partnerships represent a value-added source of funding for performing university research.

Nevertheless, some researchers disputed that the higher education institution always lags behind the development of the industry. To an extent, there may be a disconnection between the university training and the corporate expectation [5,6]. Hiring managers feel that the graduating engineers often lack of sufficient practical training to relate their knowledge into their workplace. In order to bridge the gap between academia and industry [6,7,8,17,18], corporate sponsors will partner with universities to offer summer internship and co-op opportunities to the engineering students. Often, they would assign their own engineers to mentor and develop student skills for

their senior capstone projects. The concept is good, however, implementing the industrial capstone project effectively within 16 weeks is always a challenge to all the parties involved. Studies showed that students with internship and co-op experiences would further develop their interpersonal and communication skills than those without the experience [14,15,16].

Moreover, industry expects recent graduates with the capability of proposing innovative, quick, sustainable, and cost-effectively solutions. Universities must offer the experiential learning to allow their students to achieve advanced engineering knowledge and hands-on practical experience. We need to understand the motivation and the perception of capstone project benefits for the industry sponsors [9]. Benefits may include but not limited to making business impact to the industry sponsors, exchange of research technology, brand marketing, and talent acquisition. The professional formation of recent graduates and their aptitude to perform relies on their technical knowledge and professional competencies [10,11]. Maintaining a healthy relationship between the industry executive sponsors and the academic advisor is often the key to the success of the capstone program [12]. If the conventional 4th year senior design project model does not provide a win-win situation between the corporate partners and the students, there may be an alternative business model that can fill this gap [19,21].

In the past three years, Purdue School of Industrial Engineering had developed an innovative Professional Master's Program (PMP) Capstone to close this gap significantly. This MSIE-PMP degree program offers the selection of advanced industrial engineering courses and the required 9-credit hours of industry sponsored capstone projects.

For the rest of this paper, we will evaluate the overall effectiveness of the conventional 4th year, senior design project in Industrial and Systems Engineering curriculum. We will focus on four common areas for evaluation:

- A. Industry Partnership
- B. Capstone Project
- C. Benefits of Project
- D. Roles and Responsibilities of People

Each key area will further breakdown into multiple sub-sections for assessment. We will then introduce the transformative Engineering OpEx Consulting Model from Purdue to enrich the workforce development training in graduate engineering education to prepare our next generation industry leaders.

This paper is written from the viewpoint of the global industrial practice, with 30 years of diverse experience (20+ sectors, 80+ global manufacturing facilities) in R&D, IoT product strategy, Lean Six Sigma enterprise transformation, and commercial growth. Lastly, the author was able to connect and benchmark multiple disciplinary engineering faculty and staff whom had the first-hand experience to mentor the Engineering Capstone Projects [19,20,21,22].

2. Conventional Senior Design Project Model

In this section, we will go through a step-by-step approach to evaluate four common areas that have the biggest impact to the conventional 4th year senior design project model as shown in Figure 1.

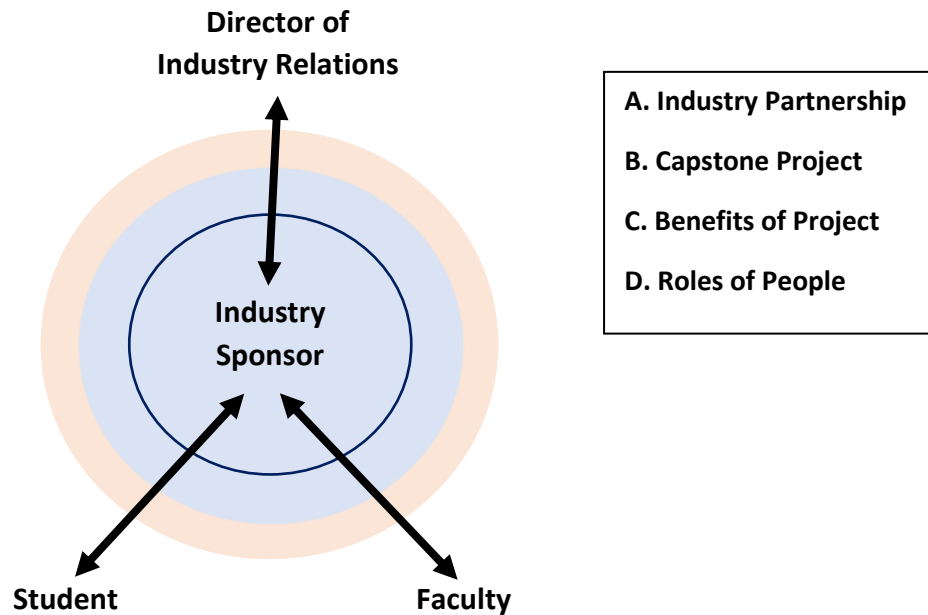


Fig. 1: Relationship Among Team for Senior Design Project

2-A. Industry Partnership

The first step is to establish a business relationship or a partnership with your target industry sponsors. The entire business development process may take 1-3 years, depending on many factors. Once the connection has built, the industry sponsor will help to identify a capstone project for the students. Meanwhile, there are legal documents, like Non-Disclosure Agreement form and Project Sponsor Acknowledgment Form, to be signed. Depending on the school policy, some may request a small project donation of \$5,000-\$7,000 per semester to cover the travel and administrative expenses. The three phases of Forming, Sustaining, and Expanding for Industry Partnership is always a challenge.

Common Risk Factors may include: building up trust in the first 2 years, consistency of executive sponsorship (replacement of leaders), corporate Master's Agreement with the university, sponsorship for international student, and compliance restriction on particular industry sectors.

2-B. Design Capstone Project

For the design capstone project, the sponsor will usually define the objectives and the expected deliverables for the semester. Depending on the school/department execution process, the overall project execution effectiveness could be a major challenge.

Common Risk Factors:

- a) Delay Project Kick-off date, one might start the project as late as the 4th week of the 16 weeks semester. At the end of each semester, for the team poster presentation, certain project team might spend less than 10 weeks of actual engineering activities.
- b) Limited support of the university faculty – relied too much on the industry sponsor mentor. It is not common to see the objective and the deliverables are altered throughout the semester. Students are not capable to negotiate with the project sponsor or stakeholder.
- c) The Size of the project team, a large project teams (5-8 students) tend to have underperforming team members that result in an overall negative team culture [19,20,21]. Unfortunately, for some of the top public engineering schools, it may be a real challenge to identify 50+ industry sponsored Capstone Project to accommodate 300-400 graduating seniors.
- d) Team discipline of time management and communication is often not up to the industry standard [8,9,16,19]. Unproductive prep-work for the weekly meeting resulted in a zero deliverable (waste) on certain weeks of the semester. The amount of team commitment could further reduce down to 10 weeks of work or less.
- e) The business case of the capstone project might not be well-defined at the beginning. The director of the industry relations and the university faculty may not have the in-depth industrial experience to scope and identify the burning platform for the specific industry sponsors. Unfortunately, the stakeholder sponsor team often change their focus and expectation during the semester [9].
- f) Limited industry sponsor site-visit [13,19], based on the limited funding and proximity, it affects the overall client engagement level. For most of the data science capstone projects, the students rarely visit the sponsor facility and meet with the industry stakeholders in-person.
- g) Lack of project consulting training – for most cases [19,21], undergraduate engineering students do not often to learn the industrial psychological skills, like, team building, effective meeting, conflict management, time management, negotiation, and client engagement.

2-C. Benefits of Capstone Project

As mentioned earlier, industry partners value the universities as the ideal partners to outsource their latest research and development activities and improve their competitiveness in the market [3,4,5,6,7]. Whereas, the higher education institution may see the value-added source of grant to conduct their research. However, for a typical non-research U.S. senior design capstone

project, the industry funding amount is usually low [20,22], like \$5,000.00 or less per semester project. This may be one of the reasons why faculty is not too motivated to coach undergraduate senior design project.

For industry, it is common to charge client with \$20,000 per single management consultant for a week (not included airline ticket, rental car, hotel, and food) a decade ago. Obviously, any capstone project student would not be eligible to work 50 hours a week, nevertheless, it depends on what value that one could deliver to the industry sponsor ultimately.

Contrary, the industry sponsors utilize this partnership for talent acquisition of candidates to join their companies as the summer intern and the co-op that lead to the permanent employment role [7,14,17,18]. In some cases, the industry sponsors would like to partner with the top engineering schools to further improves their brand marketing and potentially obtain local economic development state government funds.

Common Risk Factors: In conventional engineering capstone design project course, instructors may not focus on “Business Impact” or “Value Proposition” as related to the actual value-added to the industry sponsors. The graduating senior students are assigned to complete the capstone projects as part of their engineering degree requirement. However, if one could emphasize more on the business impact, such as, reduce process variation by 20%, improve productivity by 15%, or yield \$200,000 net saving, it may motivate both the students and the instructors to deliver the true industrial values from the Senior Capstone Projects [6,10,11,12].

2-D. Roles and Responsibilities of People

One of the most critical success factors for the senior capstone project is the relationship among students, industry sponsors, director of industry relations, and faculty as shown in Figure 1. Most of the undergraduate students may not realize how many hours of work need to perform in supporting project team weekly. Most of their failure came from the poor communication within the team, and between the sponsors or the faculty mentor [6,8,15,16]. Students relied too much on their teammates – sometimes, due to the busy weeks of homework and exam, certain individuals did not have time to prepare for the sponsor weekly meeting. It is not surprised to see some students whom did not contribute any task for 3-4 weeks within the semester [19,20,21].

The degree of involvement with the faculty mentor is always limited. One could label the faculty as “on-paper mentor”, basically, the particular faculty is under the “passive mode” and waiting for the students to come and ask for help. In reality, it is uncommon to see the faculty mentor who will take the team to visit the sponsor facility regularly and/or attend any weekly meeting with the project sponsor team. Some faculty might only meet with their senior project team about 1-3 times in the entire semester.

Some engineering schools may create the role, the director of industry relations. The key responsibilities may include connecting industry sponsors and promoting activities, like career fair, industry guest workshop, make limited site-visit with students, project kick-off, and conduct final poster presentation. Nevertheless, the director of industry relations is not expected to participate or support the capstone design project in depth due to the extensive traveling to connect with existing and future industry sponsors.

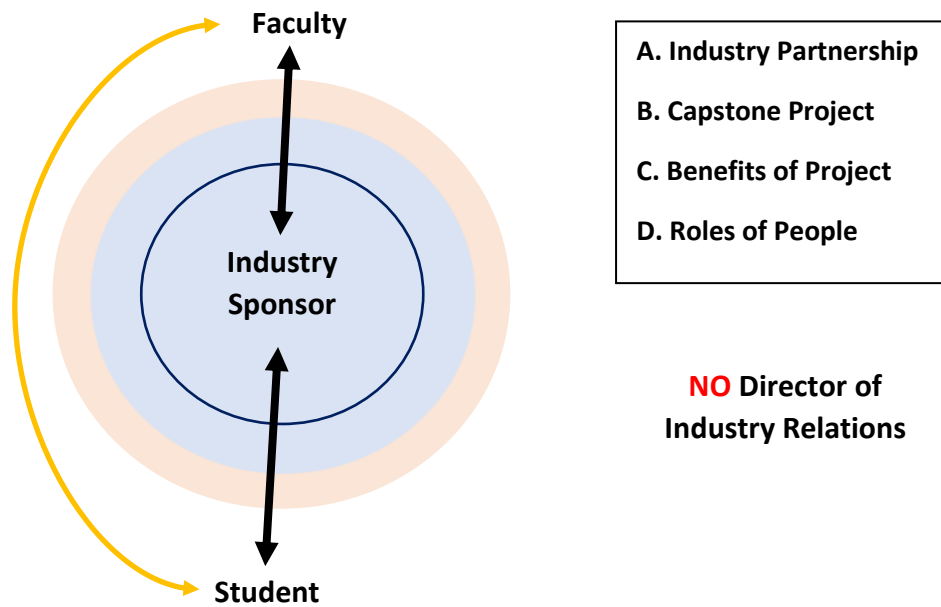
Basically, the graduating senior teams execute the projects mostly by themselves with minimal coaching – the author was astonished to learn directly from one of the top IE school's presentations (faculty) at the IISE Annual Conference [21]. To be fair, some faculty might have never worked in industry or did any consulting work in his/her career, they may not have the proper training or experience to collaborate and work directly with the industry leaders.

For the industry sponsors [13,14,15], they usually determine the project charter and the expected deliverables at the beginning of the semester. Unfortunately, without much interaction with the faculty mentor, some sponsors might even treat the student team as an unpaid, remote intern or co-op. Often, the sponsors could change the objective and deliverable in the middle of the semester [19,20]. Hence, it could lead to a disappointing lesson of the execution of the senior design capstone project.

3. Innovative PMP Project Model

As previously mentioned, the evaluation of the conventional engineering senior design capstone project is from the viewpoint of the 30 years of experience in global industrial practice. The author has no intention to compare 1-to-1 with the conventional engineering senior design capstone project, rather, there are very limited engineering schools that currently offer the Professional Master's Program throughout the regular semesters (Fall, Spring) at the graduate level.

The main purpose of this section is to introduce a new approach to identify the gaps and implement new practices for the conventional experiential capstone learning. In the past 3 years, the author has regularly communicated with major corporation executives and top engineering faculty through various industrial events, site visits, and global engineering conferences. It is intended to share this best practice with the new standard to bridge the gap between higher education institutions and industry practice.



**Fig. 2: Relationship Among Team for IE-
Professional Master's Program (PMP)
Capstone Project**

Figure 2 indicates the new Innovative model relationship. The Director of Industry Relations is no longer existed as compared to Figure 1. Given the limitation of certain director of industry relations global industrial experience, the industry faculty has become the Consulting Business Partner in a firm. The industry faculty will outreach and build the strategic partnership directly with the industry executive sponsors. The particular industry faculty has the ability with the necessary global industry experience to coach and negotiate with the client executives to scope and define the expected project deliverables before the regular semester begins in Fall and Spring.

The Innovative PMP is a transformative Engineering Operational Excellence (OpEx) Consulting Project Model as illustrated in Figure 3. This educational model integrates with advanced engineering knowledge and industry-based business challenge. The outcome of this PMP model has bridged the gap and enables sustained engagement between corporate sponsors and world-class academic institution.

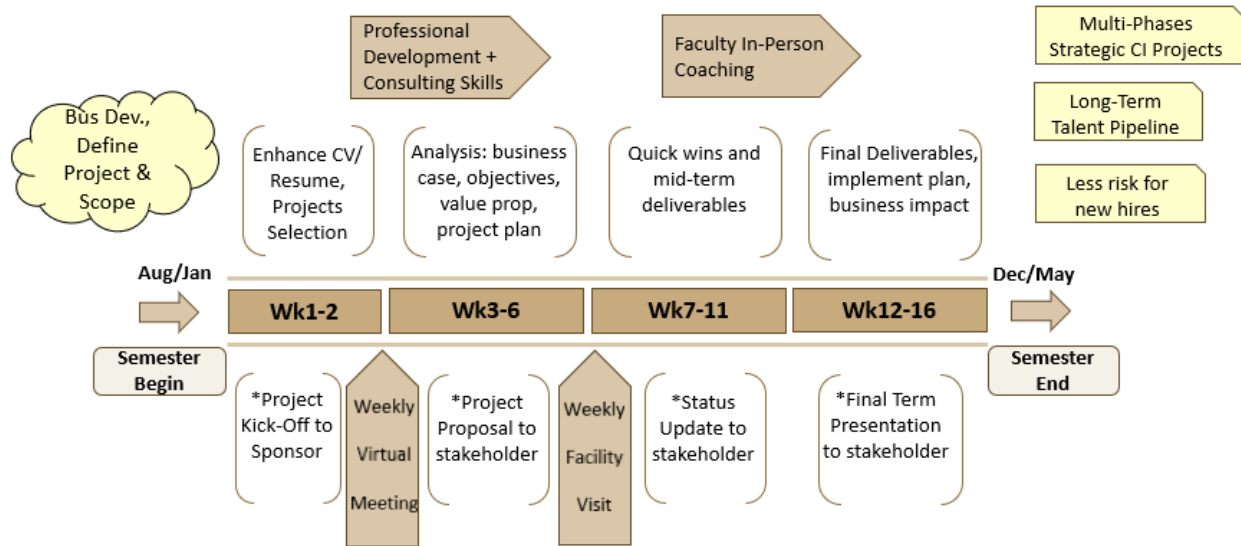


Fig. 3: Process Flow Map of the PMP OpEx Project Model

Figure 3 has demonstrated the process flow map of the PMP project model. The faculty director will explore and engage with numerous industry executive sponsors (domestic, international) throughout the year. Each PMP project is initially assigned and scoped at the beginning of the semester (August/January). Once the semester begins, the faculty director will take the PMP team to visit the client’s facility and evaluate their process issues and their burning platform. The key deliverable of the 5th week is to complete the business analysis, understand the business case, identify the value proposition, and determine the project plan, “Gantt Chart”). Additional consulting training will be covered in the classes for the first 5 weeks. Faculty and each PMP team will coordinate the weekly meeting with their industry sponsor (anytime between Monday and Friday with agenda and weekly minute). Moreover, students are required to meet with their faculty advisor (Sunday/weeknights), and student team will host their own team meetings (weekend/weekdays). Faculty will conduct a weekly PMP Master’s Class (classroom/virtual) to present the latest update and challenge on the specific PMP projects (students could learn and evaluate each team progress). Each PMP team is expected to present “Major Gate Review” to the executive sponsors in a monthly basis (prep-present with the faculty the night before). The PMP teams are anticipated to work 10-15 per weeks on top of their other advanced graduate courses (12 credit hours per semester). Lastly, each PMP team is expected to set up their own “WhatsApp” Team Chat, including the faculty advisor. Professional communication is expected to conduct around the clock, typical conversation runs from 8 am – midnight, each team member is responsible to reply within 12 hours window for his/her PMP team. Sometimes, PMP team will set up Teams Chat account with the client sponsors. The whole idea is to provide a real-time

response to the client team – industrial executives prefer instant responses and keep things moving [19,21], eliminate unnecessary waiting time.

3-A. Industry Partnership - key improvement on PMP

- a) Strategic Partnership with Senior Executive Sponsors – identify annual PMP projects, talent acquisition, opportunity for summer intern, co-op, and full-time job placement.
- b) Faculty revise PMP student resume and share them to the executive sponsors for team selection.
- c) Perform 4-week business analysis and proposal to confirm and identify business case and the value proposition of the project. (Minimize waste between Sponsors and PMP team)
- d) Frequent site-visits to build trust and engage with the sponsored team (Weekly/Bi-Weekly within 3.5 hours drive) – no one could learn the product, the process or the corporate culture remotely.
- e) If it is over 7+ hours round-trip, one will take the flight to visit the facility for 2-4 days in a semester.
- f) Faculty will train students with the “Prep-Present Review meeting” (complete within 15-17 minutes) to executive sponsors (Directors, Managing Directors, VPs, SVPs). Allow the executives to ask questions in the next 13-15 minutes. Most of the executive project presentation will complete in 30 minutes.
- g) 100% Faculty Coaching (business partner) and attend all sponsor weekly meetings – none could coach without understanding the client’s issues and their thoughts.

3-B. Design Capstone Project - key improvement on PMP

- a) Pre-define the Project and Scope (Faculty made the initial site visit and scope the project with the executive sponsor).
- b) Project Kick-off on 2nd week of the semester and focus on business impact/value prop.
- c) Offer OpEx Consulting Training to students in the first 5 weeks of the semester.
- d) Determine the Optimal PMP Team Size to be 2-3 students
- e) Utilize “WhatsApp” per each PMP Team, delivers a real-time response around the clock.
- f) Introduce Sunday meeting to review project status – reply to sponsors w/ questions on Monday. Create proactive communication with the sponsored team at least 2 times per week (Monday email and the destinated weekday meeting).

3-C. Benefits of Capstone Project – key Improvement on PMP

- a) Focus on value-added activities (i.e. business impact, \$\$) to industry sponsors
- b) PMP students work closely with the executive sponsor team on a regular basis to evaluate gaps and implement changes.
- c) PMP students could have spent two semesters with the same sponsor team, then join the same corporation as the summer intern and/or co-op for 3-8 months. It reduces the amount of onboarding training required for new hires.

- d) Establish a strategic partnership between major corporation and specific PMP team to offer the talent pipeline of top prospective project leaders/managers (most of the PMP students came with 2-9 years of industrial experience).
- e) Request for the 2-semester of PMP project donation of USD\$50,000 annually to cover travel expense, project cost, faculty coaching, and PMP outstanding awards. All PMP capstone projects focus on digital transformation, lean six sigma process improvement, and AI/ML applications. There is no cost related to any product prototype.

3-D. Roles and Responsibilities of People – key improvement on PMP

- a) Faculty advisor provides the expert coaching to the PMP industry sponsored team for their digital business transformation. Runs like an Engineering OpEx Consulting Group.
- b) Faculty advisor coaches and trains PMP students to be management consultants via a total of three semesters of PMP projects. Some top PMP students will be assigned with 2 projects in their 2nd and 3rd semester. A top PMP student could complete up to five semester-long industry projects (i.e. 3 different major corporations) in 3 semesters.
- c) Faculty advisor works directly with the industry executive sponsors to identify, recommend, and create new opportunities for summer internship and permanent CI roles for the top performing PMP students.

Note: There have been 20 major corporate partnerships established in the past 3 years. The total PMP student enrollment has grown over 50 people and completed 22 PMP Capstone Projects. There are two PMP marketing promotion videos have been developed with GE Aerospace and Eaton Corporation. It has been a successful job placement upon the MSIE-PMP graduates.

IE-PMP has partnered with leading companies like Tesla, American Airlines, Eaton, GE Aerospace, Thermo Fisher Scientific, Continental Tire, ZF, Caterpillar, Cummins, Canon Medical Research, Dana, Boeing, Intel, Amazon, Applied Materials, TSMC, HP, Bank of America, Mondelez International, and other.

Testimonies from the industrial leaders' quotes:

"...PMP program has been fantastic. The student's knowledge and professionalism have blended well with our organization, ..., continuing to improve our processes that exceed our customer expectation as well as our employees" <https://youtu.be/PtBsbJh-x-8> (Eaton-PMP video)

" ... it has been a great partnership and I am really excited to see what the future holds." <https://youtu.be/uu E-XEKITO> (GE Aerospace-PMP video)

4. Conclusions

There is always a challenge to implement the engineering knowledge into industry practice and real-life applications. In this paper, we have evaluated the overall effectiveness of the senior design project in the areas of Industry Partnership, Capstone Project, Benefits of Project, and Roles and Responsibilities of People. The PMP Capstone model has been introduced and compared to the senior design project model. The three-years outcome so far has indicated that it made a significant business impact to the industry sponsors.

The innovative PMP Capstone Program has been instrumental in merging academic rigor with industry application fostering an educational environment where students engage directly with real-world engineering challenges. This new strategic guidance has been pivotal in driving project success and leading diverse teams to achieve operational excellence.

This Engineering OpEx Consulting Model has bridged the gap between academic theory and industrial practice that benefit both higher education institutions and the industry at large. It is intended to share the best practice and create a new standard to enhance the experiential learning from the top U.S. engineering schools. The PMP Capstone program has provided the graduate students with invaluable hands-on experience and offers the major corporations access to fresh top talent and innovative solutions. This initiative is a testament to the vision of seamless integration between industrial engineering education and industry practice representing the zenith of the ongoing commitment to bridging these two vital spheres.

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