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Uncovering Strategies to Improve Student Engagement and Enhance the Engineering Education Curriculum

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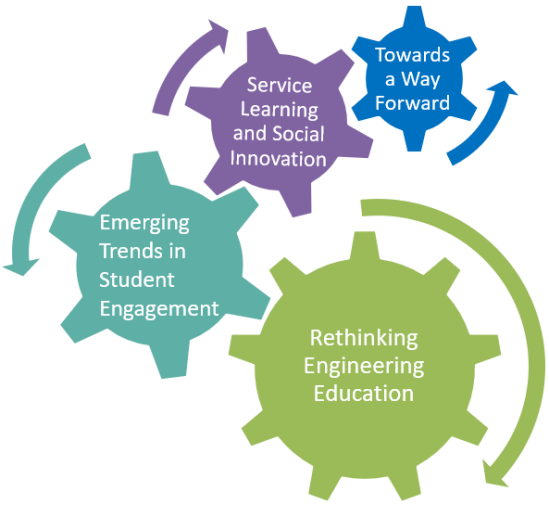
Uncovering Strategies to Improve Student Engagement and Enhance the Curriculum of Engineering Education

Abstract

In February of 2019, the authors convened a workshop to explore ways to improve student engagement in engineering education. The two-day workshop assembled an uncommon range of stakeholders including professional engineers, engineering faculty, psychologists, anthropologists, pedagogy and educational scientists, students, curriculum developers, entrepreneurial evangelists, members of the diplomatic community and representatives of industry. Collectively we sought to share existing approaches to improving student engagement in order to discern what works and what does not. Uncovering strategies to improve student engagement has meant examining and creating a comprehensive roadmap for including innovative ideas and best practices in engineering curriculum enhancements.

The opportunity for this workshop was created by a confluence of needs, resources, and interdisciplinary interests. Integrating previous experiences with service learning and social innovation learning opportunities, our interests matched NSF IUSE's exploration and development (E&D) implementation framework. The workshop, funded by NSF, implemented and reflected the steps of design thinking as increasing the engagement of students is a classic human-centered opportunity. This opportunity prioritizes the engagement of the targeted stakeholders, rather than experts who are often at a distance from the problems they seek to understand. This workshop took advantage of the academic discovery process through a series of brainstorming sessions and presentations to: (i) understand the nature of the problem around increasing student learning and engagement, and (ii) identify specific intervention strategies on how to integrate service learning and social innovation into an existing curriculum.



The main outcomes of the workshop centered on four themes. The first theme was *Rethinking Engineering Education* that emphasizes the experiences of workshop participants on the transformations that have taken place in the last decade in engineering education. The efforts along the tracks of the changing direction were the focus of the second theme, *Emerging Frontiers and Trends in Student Engagement Strategies*. The industry and non-academic participants at the workshop offered opportunities for potential social or community enhancing solutions or needs. The third theme, *Mechanisms of Integrating Service Learning and Social Innovation,* built on the trends to improve engagement by focusing on how education science can articulate steps toward using community needs to meet experiential learning goals and needs. The fourth theme of the workshop, *Towards a Way Forward*, focused on closing the loop to synthesize the highlights and lessons learned from the Workshop.

Some of the significant crosscutting highlights of the sessions include identifying the opportunities and strategies for school-wide training of students in social innovation, harnessing the value of developing intervention programs that are deeply integrated in a scale that accommodates diverse student participants, and developing programs that have interdisciplinary scopes with room for inclusivity. It is also of importance to note that there are culture gaps in the learning pedagogy of today's students such that it is of significance to connect the education of the students to the local community and for K-12 education system to transition to project-based learning.

1. Introduction

The premise of convening a workshop to highlight the strategies to improve student engagement by enhancing the curriculum of engineering education draws on Linus Pauling's suggestion, that, "To have a good idea you must first have lots of ideas." [1]. While innovative ideas offer the promise of challenging the status quo, the processes of generating them also tend to be complex because of the preliminary set of divergent thoughts and ideas. Nonetheless, it is important to have a diverse group of people involved in the process of identifying the best strategies [2]. The use of workshops to distil the optimal strategies for success is well-documented particularly in terms of their long-term effectiveness in curriculum planning and design [3], [4]. Motivated by the tenets of design thinking, the workshop aimed to avoid how initiatives falter because of ignoring the connection between needs and outcomes, and the omission of eliciting prototypes to solicit feedback be it in course design [5], social innovation integration [6]–[8], service learning [9], or entrepreneurship [4], [10], [11]. The objective of the workshop was to examine the implementation of an exploration and design (E&D) project on new interventions or strategies and provide guidance on ways to address potential challenges to curriculum redesign toward the adoption of service learning and social innovation in an engineering curriculum. In other words, the frame of inquiry of the workshop can be summarized by a design question: how might we improve student engagement in engineering education by the adoption of service learning and social innovation learning opportunities?

It is imperative to understand the differences across the varieties of existing approaches to increase student engagement in the curriculum of engineering education. This understanding highlights what works and what does not. Thus, convening a two-day workshop with an uncommon assembly of stakeholders helped to create a comprehensive roadmap for including innovative ideas and best practices in curriculum enhancements designed to increase the engagement of engineering students. Instrumental to this objective was the novelty of integrating service learning and social innovation activities into the undergraduate engineering curriculum. The event helped identify numerous strategies for an E&D implementation framework. Catalyzed by the opportunity for human-centered exploration, the workshop was built on the fundamental steps of design thinking particularly in stakeholder engagement. This opportunity prioritized the engagement of a range of stakeholders, rather than experts who are often at a distance from the problems we seek to understand. This meeting took advantage of a discovery process through a series of brainstorming sessions and presentations to: (i) understand the nature of the problem around increasing student learning and engagement, and (ii) identify specific intervention strategies on how to integrate service learning and social innovation into an existing curriculum.

The seminar helped the participants to expand their awareness of the different strategies that exist in improving student engagement from different viewpoints. First, the discussions crystalized the philosophy of education aptly captured as "education with impact and preparing students for a life of impact" with emphasis on improving human conditions. Second, a critical discussion challenged some of the fundamental, long-held assumptions of higher education in the past. For example, the platform of learning is now multidimensional with opportunities such as P2PU, 42 coding, Khan Academy, Kumon and others. Third, there was a profound recognition that the primary mission of universities is to prepare students for the industry, but that mission is not always cognizant of the multiplicity and wide range of industries, the gig economy, the number of distinct jobs a student might have over their career – this currently averages to between 9 and 12, when in the past it was merely between 1 and 2. Fourth, the participants valued the elements of working in tandem including enhancing mindsets about believing and thinking, developing skillsets about learning and applying knowledge. By mindsets, the key ingredients identified include creative inquiry-led approach, design thinking, systems thinking, global citizenship, and ethical decision making.

There was unanimous agreement that more engagement can only be achieved by bringing social innovation into the classroom through projects that ask students to work on real problems. This is consistent with

Bloom's Taxonomy [12]. Some of the emerging constructs or prescriptions include what is now termed, "Fruits of Innovation," *i.e.,* what are the students tasked with creating – knowledge, social movement, technological solutions, or a combination of these? Regardless of the modality, there was consensus on the requirement for learning to take place in creative spaces where learners could come together, identify unmet needs and create new solutions. The issue of creating such innovative hubs can carving out open, creative spaces across campuses could be solved with the formation of partnerships with private and nonprofit ecosystems as gateways.

Lastly, the workshop shows that the agenda to offer support for the learner requires answers to two interdependent questions related to (i) how do we support students in finding and navigating these opportunities, and (ii) how do we blur the boundaries between inside and outside classroom? These questions magnify the need for the role of learning opportunities that would get students out of their comfort zones and pursue their passions. Perhaps the opportunity for fellowships that would complement examinations with open-ended questions could offer avenues for the students to actualize their creative elements.

2. Organization of the Workshop

The two-day workshop had academic and non-academic participants from different universities and the industry as shown in Table A1 in the Appendix. The workshop centered on four themes as illustrated in Figure 1. The first order of presentations and discussions centered on *Rethinking Engineering Education* by emphasizing the experiences of workshop participants on the transformations that have taken place in the last decade in engineering education. In the second theme, *Emerging Frontiers and Trends in Student Engagement Strategies,* the changing direction in the pedagogy of engineering education dominated the talks with the industry and non-academic participants at the workshop offering opportunities for potential social or community enhancing solutions. The third theme, *Mechanisms of Integrating Service Learning and Social Innovation,* built on the trends to improve engagement by focusing on how education science can articulate steps toward using community needs to meet experiential learning goals and needs. The fourth theme of the workshop, *Towards a Way Forward*, focused on closing the loop to synthesize the highlights and lessons learned from the Workshop. The following sections detail the discussions and the emerging constructs from each theme.

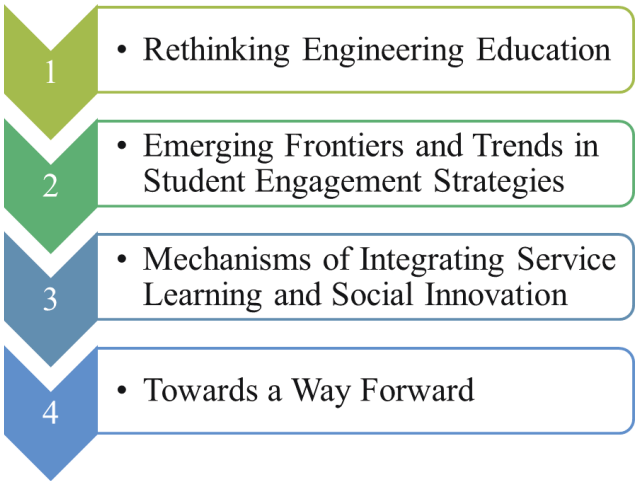


Figure 1: Workshop Themes

3. Rethinking Engineering Education

This theme, also the title of the panel, created a platform for workshop participants to share experiences with some of the transformations that have taken place in the last decade in engineering education. Some of the highlighted approaches to include project-based learning (PBL) [13]–[15], technology-enhanced delivery [16]–[18], or curriculum restructuring [19]. Some of the characteristics observed with PBL include the theoretical (or Case Studies) dependence that students **discuss** in order to deepen their assimilation [19]–[22]; and the knowledge deficit with regards to the increasing focus on entrepreneurship and social innovation in engineering education [11], [23].

To exemplify some of the critical shifts in engineering education, three case studies were presented: (i) the Vertically Integrated Project (VIP) platform at Georgia Institute of Technology, (ii) the YES and CAMP-YES program at the University of Central Florida, and (iii) the integration of bioengineering into the Kern Engineering Entrepreneurship Network (KEEN) at Lehigh University.

3.1 The Vertically Integrated Project (VIP)

The workshop attendees learned how the goal of the Vertically Integrated Projects (VIP) at Georgia Institute of Technology is to involve everyone on campus on the innovation exploratory journey where the notion of innovation is interpreted as "inspiration" + "execution". The success of the program are due elements of fragmentation by time, mission and discipline:

- By time: The time fragmentation is due to the semesters thereby putting students in different years at different stages. This guarantees that the VIP is run in tandem with the Engineering Projects in Community Service (EPICS). The VIP freshmen-senior design projects exists in multiple programs in the university.
- By mission: The mission is the alignment of the program with faculty and staff interests in participating – VIP made it worthwhile for faculty to participate.
- By Discipline: The program is inclusive because it attracts everyone particular on the thought processes, the budget lines, and its value-adding activities to the culture of the university.

The projects in the program may take at least 4 years to complete with the option that allows students to opt in and out. The freedom to participate in the program are such that project teams made only for faculty could have their activities embed into their research and innovation agendas. With team sizes of 10-20 undergraduate students and 1-4 graduate students, the program has been scaled to include more than 70 teams with over one thousand undergraduates enrolled across all disciplines.

3.2 YES and CAMP-YES Program

The Young Entrepreneur & Scholar (YES) Program and Career Advancement Program (CAMP-YES) at the University of Central Florida were presented in a manner that offered the lens of diversity and inclusion because 46% of the students are minority with approximately 44% having no student debts. Excerpts and student testimonials reflect the efforts on diversity and inclusion. For example, students claimed that the CAMP-YES scholarship allowed them to work less while dedicating more time to school. Funded by NSF's S-STEM division, the CAMP-YES program aims to prepare academically talented, financially-needy STEM students to enter workforce after they graduate or create a start-up. The program also provides a mentor, faculty or industry representative, respectively on sought experience to support the students. The program has graduated more than 140 students to date with 92% graduating with a STEM degree, and having a STEM job after graduation as at 2019. The appealing aspect of the program is that it is not just about the financial support, it is also about how the program integrates accessibility and social support.

3.3 Bioengineering Integrated with KEEN

This program, at Lehigh University, runs in association with the Kern Engineering Entrepreneurship Network (KEEN) funded by the Kern Family Foundations. KEEN's Engineering Unleashed programs aim to increase engagement in Bioengineering at Lehigh through entrepreneurship. The opportunities for engagement through the KEEN network include: (i) promoting curiosity, (ii) making connections, and (iii) creating value. The program has grown from 12 faculty members in 2015 to 75 in 2018. The core elements of the program include: (i) the identification of where skillsets and mindsets interact; (ii) incorporating into the curriculum opportunities for course overlaps in a way to create connections from the early stages of the curriculum. Examples of critical integration indicators include:

- Identifying where students were struggling with applied fluid dynamics in their junior year;
- Identifying early projects that can introduce and bridge the topic in software level class of a smaller fluid type project (evaluate a heart valve) – leading to connections to classes of regulatory, advanced materials, fluid and physiology.
- The program element also includes the Creative Inquiry Courses and Projects (CINQ) which are multi-year, global projects based on the desire to make a difference right from the beginning but requires significant amount of thinking and creativity;
- There is the Summer Mountaintop Experience Project that promotes student innovation and self-driven projects. The university has systems in place to get tracking on projects including the Capstones. This shares similarity with the nanotechnology fellows program at GW [24], [25].

These programs led to the elimination of "teaching in silos," and the assessment of success was based on feedback from the industry on student impact. Figure 2 shows the answers to the thematic questions.

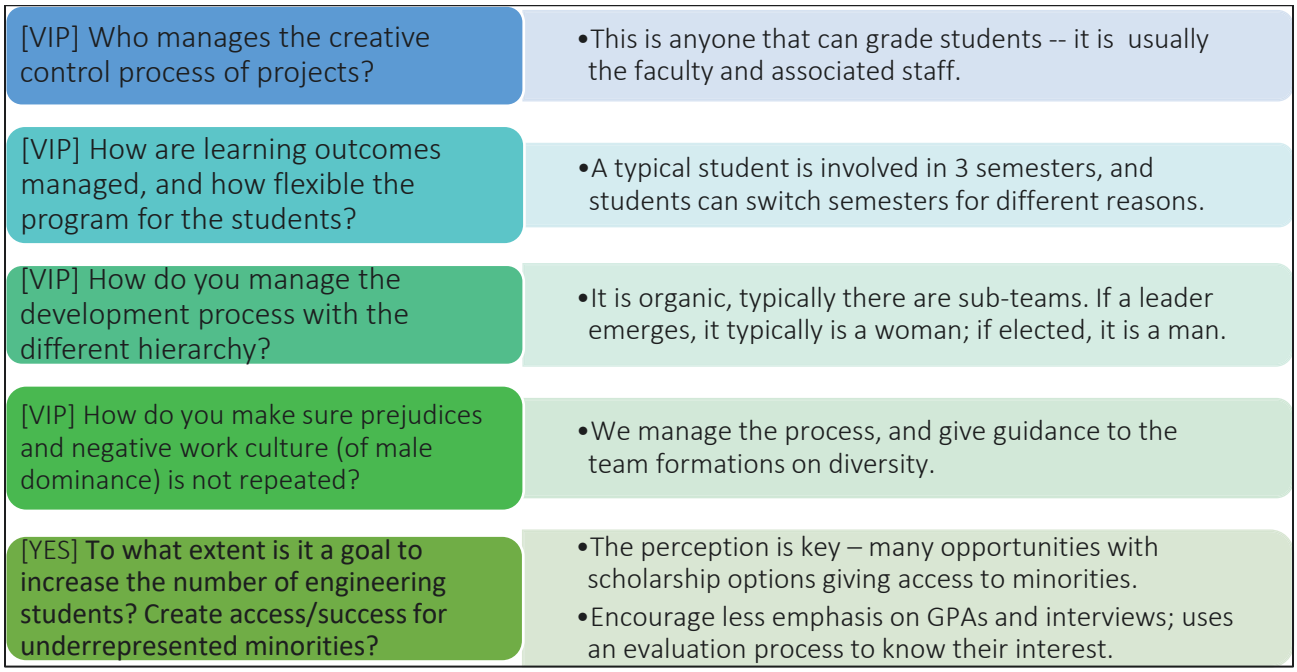


Figure 2: Management concerns and solutions of the VIP and YES programs

In conclusion, some of factors that resonated from this panel include the emphasis on scale of the intervention programs, the depth of integration, the need for not just having diversity in student

participation, but also having programs that are inclusive [26]. The inclusion factor underscores the interdisciplinary nature of the programs that are deemed to be successful.

4. Emerging Frontiers and Trends in Student Engagement Strategies

The discussions in the segment on frontiers and trends focused on the role of academic innovations in interdisciplinary studies and included non-academic stakeholders active in diplomacy. Their involvement shed light on the opportunities for potential programmatic changes that include human technology collaborations and social or community-focused solutions.

A discussion about the Human-Technology Collaborations (HTC) program at GW's Graduate School of Education and Human Development offered several important ideas on program incubation. Created in 2016 with solid foundations in the culture of collaboration, the HTC requires the participation of three schools across the university. HTC program elements include data science, engineering, psychology, cognitive neuroscience, medical informatics, and education. The curriculum was designed to entail 6 credits of foundation courses, 6 credits of interdisciplinary courses, 12 credits of methodologies and a total of 24 electives. The foundations courses target mindsets, skillsets, environment and experiences required to propagate a culture of collaboration. In a model fashioned as a think tank, sub-groups on technology collaboration and social machines (or computations for social problems) were created. In the context of the collaborative courses, the theme of Science of Team Science, or the study of how teams of students work together, was initiated with specific key lessons including the challenges of interdisciplinary work and the herculean processes of institutionalizing interdisciplinary education. In summary, the culture of curiosity and discovery created proved to be a vehicle to resolve the inherent challenges and provided a substrate for the germination of collaborative explorations moving forward.

In continuation of the panel discussing HTC, the culture of collaboration was found to underscore the drive for change. For example, for over a decade, the emphasis on Richard Leakey's provoking question: "can you do something for the people outside the camp?" precedes how the mindset is conditioned on the knowledge and realization that the human society is like a pyramid. Using the analogy of a water purification process that took a decade to evolve, the specific elements are based on harnessing nature for the purification of the organic and inorganic components of water. The increase in support from project partners enlarged the scope of the project slowly over time right from a vision to motivate the people though the development of the solutions. This primary concept espoused a definition for "interdisciplinary" work as one with a diversity of people with emphasis on the letter "T" person – where the top part of the "T" represents "breadth" and the vertical part represents specific "depth".

The non-academic perspective to innovation was provided by the Counselor of Science and Innovation of the Swedish Embassy in DC who has a science and engineering background and is well-vested in organizing academics for start-ups by mimicking other successful programs across Europe such as in Switzerland, Germany, and Denmark. The discussion drew parallels and comparisons between the E.U. and the U.S. innovation ecosystems and on what the E.U. could learn from the U.S. about improving diversity. The value of the Horizon Program of the Swedish Embassy in the U.S. was to assess how to transform individual teaching which is egocentric into something more interdisciplinary. The Horizon Program also aims to encourage collaboration rather than organizing niche operations. The discussant illustrated how Stanford is very focused on interdisciplinary education with bottom-up centers, collaborations; and an emphasis on the surrounding society, both private and public. However, it was also noted that there is a huge cultural gap between locations such as Silicon Valley and Washington D.C., a gap that was recently pronounced as the CEO of Facebook was questioned by members of the U.S. Congress. Addressing this culture gap is part of the current challenge.

In examining the future of education, it is important to understand how universities will engage and motivate students of the future. Currently, young students use mass online media for immediate knowledge and skills, such as solving the Rubrics Cube with the help of YouTube videos (which has reportedly lowered the solving time to 37 seconds!). How will the future of education appeal to this new generation of learners? The "T" shape philosophy or the balance between breadth and depth was echoed again as especially important in this context. Climate change was identified as the biggest threat to man and while the U.S. is deemed better suited to produce solutions because of the focus on education, Sweden has the advantage of research, ease of mobility, and global recruitment, finding the best professors to hire from across the world.

Key Points in the Question and Answer Session

The salient issues that ensued in the question and answer for this panel are presented in Figure 3 below.

One of the approaches to enhancing interdisciplinary work is to have faculty in dual roles. One of the problems with that is that institutional review board (IRB) discourages junior faculty to pursue dual roles. What is your take on that?

- Though the discussant was not into interdisciplinary work prior to tenure, it was stated that it would be essential to focus on future guidelines for recruitment that accommodate interdisciplinary work -- the old bylaws will have to change.

Why does cluster hire not work?

- It poses logistical and political problems in solving gaps in teaching, and thus rarely works.

Could the industrial PhD programs in Sweden be practiced in the U.S.?

- Industrial PhD in Sweden is a faculty position, and normally PhD students do 80% research, 20% teaching. However, industrial PhD students do not teach but rather work for their company. It is 3 times more expensive to hire a consultant than have an industrial PhD student because innovation companies get the best minds with mobility between industry, education, private, and public sectors.
- The notion of "burst the Stanford bubble" shows how the Silicon Valley and Stanford are starting to understand the implications of their exclusion and inclusion ecosystem -- efforts should not be about imitating the Silicon Valley, but rather about understanding what works.
- The Silicon Valley may have a culture of gender exclusionary ecosystems limiting female enterpreneurs from accessing venture capitalists.

What is the role of immigration policy?

- Immigration may be a deterrent due to the rise of nationalism in Europe.
- The challenge also includes how to integrate immigrants into social systems.

Figure 3: Important FAQs from the panel.

A strong point was raised on how the liberal arts education appears to be increasingly diminished over the years suggesting that the future of education is increasingly relying more on interdisciplinary work and STEM education. Nonetheless, it was posited that (i) liberal arts should be a life-long mission; and (ii) moving away from liberal arts would be disconcerting. A salient point on the role of developing nations as necessary opportunities for innovation further illustrates the interdisciplinary challenge – developing nations can leapfrog over many of their challenges when a holistic interdisciplinary approach is taken to addressing problems. It was argued that the entire ecosystem of "frugal innovation" – innovation driven by necessity – ought to be driven by the benefits to the society.

In conclusion, this panel reiterated the previous panel's emphasis on the significance of interdisciplinary programs while also highlighting the culture gaps that exist in the learning pedagogy of today's students.

5. Mechanisms of Integrating Service Learning and Social Innovation

This segment of the workshop was aimed at identifying the trends to improve engagement with a focus on how education science can articulate steps toward addressing community needs while meeting experiential learning goals and needs. In the context of this workshop, the essential ingredients of experiential learning will help students' access deeper cognitive skills and excite student interest in learning, be it through the flipped classroom [27], or turning real world, practical experiences into avenues for learning [28], [29]. This theme examined the evaluations of the standard curriculum layouts and sheds lights on prospective restructuring alternatives that will allow the infusion of service learning and practicum opportunities.

A George Washington University student provided an overview of gender and minority issues in higher education, emphasizing that despite the improvement in gender and minority percentages over time, low counts at the graduate and PhD levels persist. Two key problems in STEM education were identified as responsible for this continued challenge: the first is the increasing demand from the economy for students with strong preparations in STEM, and the second is the desire for gender equity in STEM. The proposed solution is on how an inclusive STEM high-school program could be designed to increase participation of not only female students but also under-represented minorities in STEM with more STEM courses and more required college preparation coursework. The narrow pathway to the STEM fields should be expanded. In addition, it was noted that admission policies should be targeted at students' interests in order to achieve a diverse student body and record positive outcomes for all groups. The pilot program described by the participant was recognized as innovative and successful because the school selection process was focused on impacts. For example, impacts during high school should emphasize (i) what students know, (ii) their interest in STEM, and (iii) the process learning dynamically over time based on emerging experiences.

Closely related to the emphasis on students' interests is the focus on what the students can do. For example, to what extents are the students able to build creatively, collaborate with peers, and what are the depths of their critical thinking and communication skills? These examples are prerequisites of metrics to demonstrate academic achievement and are sufficient to prove preparedness for post-secondary success. Combining these metrics leads to the question on what students might become, with answers ranging from self-identity as STEM-capable, become college savvy with aspirations for STEM fields, feel accountable to school community and mission, and value individual differences. Another example was provided that illustrates how a student in an agricultural high school in Chicago had her dreams evolving into wanting to become a Vet, and how she learned the skills that would help in realizing that dream. The intriguing aspect of the example was how the student came to find her passion. The student's experience at working with horses gave her some of the preparation. Other elements that contributed to the student's success include: (i) college class felt like home, (ii) the support network, (iii) every project has a business plan associated with it for the students to complete, and (iv) no demographic majority.

Another participant provided a contrasting picture questioning what the experience of the student above might have been had that student attended an institution like GW or an institution that is void of the components of the local environment the student was accustomed to? In response to this rhetorical question, the participant offered the core ingredients to keep students in the STEM pipeline: (i) The process should not merely be about reproducing the high school experience, but should be about the trajectory of progress, (ii) the desire to be in school, and (iii) how the formations of the student's goals is nurtured by the student's passions. In discussing the roadmap to STEM education, the participant highlighted how GW students are very engaged in the education process because they are often invited as "customers" or "clients" or course evaluators. For example, their involvement as *Learning Assistants* (LAs) accords them the opportunity to work alongside the instructor in class, they facilitate "sense making", and they lead learning/studying processes

The last participant to speak on this panel highlighted the problem with the pipeline of students as they transition from school to the workspace to include the need to (i) get hires up to speed faster, (ii) increase satisfaction, and reduce (iii) reduce turnover, which currently hovers at around 20-54% in 2 years. The major concern is how the industry realizes that "we throw them in the deep end, and they sink or swim". Based on the notion that most people want to do a good job, it is however, evident that if you pit a good performer against a bad system, the system will most of the time make the good performer less desirable. In describing the problem space, there is the challenge surrounding what was thought particularly on the problems in transitioning to and translating academic knowledge into practice. It was found that many did not have the exposure to how to play the political game, integrating the newcomer into collaborative systems which are often complex and adaptive, culminating in new hires coming into different subcultures and norms that are mostly unwritten.

Key Points in the Question and Answer Session

Regarding the transition to workplace challenges, the question of whether work groups chose the hires was answered with "it depends". In fact, another participant noted that it is the same at the universities where there are no written guidelines or policies to guide new recruits. The ambiguity of whether sometimes the culture of states and individuals may impact work ethics or expectations shows that culture indeed does play an important role, but different countries view relationships differently. For example, if working with a multinational team, how can your work influence cross cultural ties? The answer to this is for the organization to improve the cultural awareness and resources to help people succeed. To a large extent, community involvement is also critical especially where health impacts are involved. A participant noted that Latin communities have higher health impact interventions because of their community networks.

In summary, it was detailed that it is important (i) to connect around the community and support network, (ii) to learn the culture, a responsibility of both organization and employee, (iii) to go above and beyond expectations, (iv) for worker retreats to celebrate diversity and bridge connections, and (v) for the K-12 education system to transition to project-based education.

6. Synthesis of Opportunities for Professional Development

The crosscutting theme across the panels highlights how relationship building was a primary driver on the on-boarding process to promote productive work, knowledge about the company or organization, and integrating and engaging with existing workers. The observation that work groups were the primary context for on boarding, and not the organization because of requisite instructions, insights, and opportunity for membership. As sources of new learning, coworker engagement is a critical first step preceding managerial involvement. The success factors for new hires are as follows:

- Non-work relationships: Does someone in the group provide regular, ongoing directions and instructions?
- Collaboration: Does the group invite new hire to lunch/work after social activities? Is there a buddy group?
- Beyond the call of duty: Did they have a meaningful project from the beginning?

The key factors of success and activity of work group include the correlation between success and positive work group activity, and the relationship affected by (i) quality of leaning and performance; and (ii) level of satisfaction, engagement, commitment, and relation. The overarching takeaways include the knowledge that work is embedded in social, political and informal contexts; knowing that social, political and informal contexts are primary to learning and performance; and understanding that culture must support the organizational responsibility for effective onboarding to help people learn and grow.

7. Towards a Way Forward

The fourth theme of the workshop, *Towards a Way Forward*, focused on closing the loop to synthesize the highlights and lessons learned from the workshop. This session also included four student presentations on how their experiences in a trial course, *Social Impact Design Thinking (SIDT)*, in the host engineering school impacted their engagement in learning and the interdisciplinary knowledge and mindset gained.

Another way forward was opined by the founder of a European gaming company, Grendel Games. Grendel Games was born out of his fascination for games. The vision of the company is to develop "seriously entertaining" games that contribute to positive change in people and the world. The company has forged ways to improve the gaming industry over and above mere use for entertainment, but also for education and engagement in health care and energy sectors in four synergies.

At Grendel Games, the design process entails collaborating with domestic and international, academic knowledge partners on research and validation of effectiveness of proposed games. These are often predicated on Innovation and the internet of things including unique angles for high entertainment value. In this context, the value behind the game design is that playing is not just for children, but for everyone as a vehicle to understanding and appreciation conditioned on the notion that learning takes place through fun. In other words, "playing is a natural form of education." In addition, Grendel Games casts off the outdated idea of students playing games on consoles. Now that games can be accessed via smartphones and the smartphone user spends 5 times more time on their device than on consoles, the opportunity for creating social value is increased. The Grendel Games participant illustrated how the game, "Candy Crush" was designed for older women and it turned out to be an extremely successful game that even became a popular Facebook app.

7.1 What can we learn from this and future applications?

It is important to note that games and gamification define rules that are important to challenge the players. For example, the game, "Monopoly" was intended to show the bankruptcy implications of mortgages. However, it was incorporated widely to introduce the topic and eventually became a 50-50 luck strategic game. Game elements include: *dynamics* (rewards, rank, progression, altruism) and *mechanics* (points, level, and challenges). It is imperative that a game should be easy to play and hard to master – this is where the game, "Tetris" has been successful. Other gaming ecosystems include:

- *Design loop:* Pokemon Go - Core loop of game activities where repetition is key;
- *Rehabilitation:* (i) Computerized Assisted Rehabilitation Environment (CAREN) Walter Reed Hospital; (ii) Songs of Elstryn – oath of the gryphon: Gryphon Rider – this was developed for child rehabilitation support with brain damage through physiotherapy sessions. The team worked with 400 children and national health organization to develop and make accessible and includes 160 hours of physio therapy; (iii) Surgery training game. Data shows simulators are very important, but doctors / students do not engage with them because of challenges with operation: (i) Inverse of movement; (ii) Bi-dexterity; (iii) 2 dimensionality. In addition, the existing simulation technology very expensive and cumbersome with new systems utilizing Wii/Nintendo functions, designing the game with appropriate dimensions and skill and low-cost.

Another example is Saving Energy where games are employed to save energy and water by monitoring water usage and identifying the peak consumption periods. The water company wants to be part of the social dialogue because the company is only visible if you have no water or when there's a leak. This example led game developers to work with water, energy and computer companies. The framework for this energy saving game is presented in Figure 4. The figure shows how gamification is a pathway to education – A player receives real information of water use, i.e., virtual level of water is connected to physical

consumption of water in the neighborhood. The game has been tested/piloted in 2 neighborhoods with excellent and overwhelming results. Five months after the pilot, the community was still saving water consumption as usage reduced by 25%. The second pilot with 40,000 people is being considered.

Figure 4: Games leading to education.

8. The Road Ahead

The workshop was concluded with a peek at the road ahead. Significant observation was on how collaboration could emerge for innovation grants such as NSF's IUSE $300,000 development grant to establish model and short-term and long-term plans. A menu of potential options include a project with a research objective on the Food, Energy, and Water (FEW) nexus with emphasis on conservation and preservation [30]. This is a global problem that could spur engagement of students in the search for solutions. The engagement of undergraduate students to build a model and to include K-12 students for the necessary STEM skills prior to entrance to college. The workshop also considered exploring synergies with the VIP program for small-scale funding. The impact metric would be to expand knowledge of how to educate conservation and preservation for college and K-12 for engineering education.

Classroom activities could also be extended to allow students apply/extend classwork to extracurricular and interdisciplinary tasks. This may require partnership with different organizations and DC community to figure out relevant projects. The process will also involve an assessment to analyze the skills and knowledge needed to address project, determine the necessary knowledge partners, and help with student participation and leader transitions. For example, the process could utilize GW's Innovation Center and other campus centers and projects that are presently engaging students. It was also suggested that reverse engineering week could be initiated where project teams go out to identify sociological/culture/technical issues and learn to understand and solve them. A last proposal option was to get the VIP equivalent at GW such that the platform is set up to incorporate existing GWIC projects with involvement of faculty. The entire fabric of this exploration would be to focus on innovation as a social good. GW recognizes that social good is a bonus as it may not be the primary criteria in a research university.

9. Conclusion

The workshop uncovered four major themes.

1. *Rethinking Engineering Education: Education for a Life of Impact*. Participants reflected on the changes that have taken place in the last decade in engineering education particularly on appraising the growing interdisciplinary fields of engineering.
2. *Interdisciplinary Collaborations: Approaches and Frontiers:* On this theme, the participants identified the opportunities to improve engagement of the students in their education. This theme also highlighted the *Mechanisms of Integrating Service Learning and Social Innovation* with a focus on how education

science can articulate steps toward using community needs to meet experiential learning goals and needs.

3. *Towards a Way Forward*: This theme focused on *building pipelines and skills* with emphasis on closing the loop to synthesize the highlights and lessons learned from the Workshop. The discussions on the theme also featured student presentations on how their experiences including engagement in learning, interdisciplinary knowledge gained, and overall course experience have been impacted.
4. *Gamification:* The attendees listened to a renowned educational game developer, Grendel Games, from the Netherlands, on the use of games to increase student engagement.

The workshop ended with key considerations about the Road Ahead. In summary, it was evident that there are many and often dissimilar approaches to increasing students' engagement in learning. Nonetheless, there was a consensus that there is tremendous value in integrating dynamic or active learning opportunities that prioritize interdisciplinary education and diversity and inclusion, either through gamification or service learning opportunities. Creating open creative spaces and tackling engagement through curriculum redesign could lead to school-wide training of students in social innovation. We anticipate that the lessons from this workshop would be integrated into a competitive proposal that could offer the benefit of more and cogent opportunities for training and professional development of many undergraduate students at GW.

The authors appreciate the contributions of the reviewers one of whom requested for our next goal. In response, a subset of the author team is currently working on a funded NSF: IUSE-EHR project titled, "Service-Learning Projects to Improve Engineering Students' Civic Engagement and Capacity for Innovation" in a research-based teaching program that engages students in an interdisciplinary engineering service-learning model focused on civic engagement. The project is conditioned on one of the outcomes of this workshop on how civic engagement can enhance engineering education especially as the students learn new skills, such as human-centered design and problem solving with empathy. The intervention being implemented in this project includes two one-credit seminar courses that will allow students to learn and apply problem-solving based on principles of systems thinking, human-centered design, and empathy.

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Table A1: Workshop attendees and participants

	Name	Affiliation	Title
1	Abby Ilumoka	NSF	Program Director
2	Angel Bisamaza	SEAS Affiliate	Event Coordinator
3	Annamaria Konya Tannon	SEAS, GW	Chief Evangelist GWIC, Host
4	Benjamin S. Hsiao	Stony Brook University	Distinguished Professor of Chemistry,
5	Bhagi Narahari	SEAS, GW	Associate Dean, Undergraduate Education
6	Dan Kunitz	OIE, I-Corps, GW	Innovation and Entrepreneurship
7	David Lee	SEAS, GW	Professor of Practice
8	Dor Hirsh Bar Gai	EMSE, GW	Ph.D. Student
9	Edward Coyle	Georgia Tech	Chair, Integration of Research and Education
10	Ekundayo Shittu	EMSE, GW	Associate Professor, Host
11	Ellie Fini	ASU	Program Director
12	Erica Wortham	SEAS, GW	Event Coordinator
13	Henric Jonson	Innovation Council, Swedish Embassy	Program Manager
14	Kevin Morgan	Wash. DC Economic Partnership	Program Manager
15	Khanjan Meta	Leigh University	Vice Provost for Creative Inquiry
16	Konstantin Mitic	SEAS, GW	Student presenter
17	Lisa Massi	ASEE	Experiential Learning Division Chair, UCF
18	Michael Feder	AAAS	Director Invention Ambassador Program
19	Paige Nagy	EMSE, GW	Student presenter
20	Rene van Dorp	EMSE, GW	Professor
21	Russell Korte	GSEHD, GW	Associate Professor, Human & Org. Learning
22	Ryan Watkins	GSEHD, GW	Professor
23	Sandra Little	SEAS, GW	Support Coordinator
24	Saniya LeBlanc	SEAS, GW	Associate Professor, Host
25	Sarah Shavin	SEAS, GW	Student presenter
26	Sharon Lynch	GSEHD, GW	Professor of Curriculum and Pedagogy
27	Shreya Patel	EMSE, GW	Student presenter
28	Steve Brunetto	Refugee crutch	Student presenter
29	Susan Perry	Lehigh University	Program Coordinator at Lehigh
30	Tiffany Sikorski	GSEHD, GW	Assistant Professor of Curriculum and Pedagogy
31	Tim Laning	Grendel Games	Special Guest, Speaker