This column addresses aspects of lifelong learning for current students, alumni, and faculty. Examples of student and faculty activities that involve industrial practice and engagement as well as continuing education are welcome. These topics may not always lend themselves to the traditional scholarly format with formal assessment and extensive literature review but may be more editorial in nature. Submit papers through journals.flvc.org/cee, include lifelong learning in the title, and specify lifelong learning as the article type.

THE IMPORTANCE OF INDUSTRIAL/ACADEMIC SPONSORSHIP OF INDUSTRIAL INTERNSHIPS -

A CASE STUDY ON DIGITAL INTERNSHIPS TO FACILITATE DUAL DOMAIN SKILLS IN THE STEM FIELD

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INTRODUCTION

The importance and positive impact of "in field" internships at the associate, bachelors, and graduate level are well known.[1-3] The accessibility of such opportunities is challenged by the vast numbers of community colleges, colleges, and universities in STEM versus the availability of such internships. According to the National Science Foundation (NSF), US institutions graduate over 800,000 students in a STEM field at the associate, bachelor's, master's, and doctorate/professional levels annually.[4] We searched sources to obtain reasonable estimates of the number of internships, co-ops, and other forms of in-field experience available to students during their STEM degrees. For example, the National Association of Colleges and Employers (NACE) gave an estimate of 300,000 annual internships across the US in all disciplines.[5] It seems clear that a small percentage of students have access to such experiences and yet a smaller percentage in STEM. The National Survey of College Internships estimated that some ~20% of college students took an internship, with STEM being among the most challenging to find for students.[6]

A group of academic and industrial colleagues with an interest in improving the accessibility of this experience has worked with The American Institute of Chemical Engineers (AIChE) to launch an organization called The Institute for Learning and Innovation (ILI) https://www.aiche.org/ili/about, to improve overall academic and industrial engagement in areas such as internships. We present our findings on a two-year journey to cultivate such relationships in a specific area: dual domain expertise between STEM and computer/data science. We believe that the lessons learned here make the program scalable with these communities and possibly for other areas of STEM.

BACKGROUND

A significant gap that is appearing in STEM fields is that most graduates lack skills and attributes of "data scientists,"[7] which are increasingly important in STEM R&D. This gap is prevalent in academia, industry/commercial, and government settings. Often, an attempted mitigation strategy relies on collaboration between parties, a hub and spoke approach with centers of expertise (like an Information Technology or a modeling department) working closely with the more traditional STEM field (chemistry, chemical engineering, or materials science). In our experience, this mitigation strategy is not the most effective strategy to fill this gap because a langauge barrier often exists between traditional STEM researchers and those with an expertise only in the emerging area (e.g., data science). This barrier leads to inefficiencies in R&D because extra time is needed to build a mutual understanding of the traditional domain (by the data scientist) and the power of data science (by the traditional expert). This leaves employers and employees with a desire to maintain the two sets of expertise within their organizations as a means for more efficient solutions. Such dual-domain expertise where a single person combines, through curricula and experiential learning, the traditional STEM field with the emerging capabilities of data scientists makes for a powerful combination for now and the future of innovation.

This gap is challenging to solve for several reasons. Three examples are: (1) current curriculum at the associate, bachelors, and graduate level within most fields in STEM are overloaded already with little room for adjustment, (2) students may be reticent to pay for additional degrees or credentialing outside of their current domain knowledge with educational costs escalating,[8] and (3) companies and industries cannot train for the new combinations of skill bases needed in the short term, and often cannot rely on the standard hub and spoke models (creating multiple capabilities to service parts of dual domain needs) because of cost in the long term.

The common skillset of a data scientist includes Computer Science (coding and programming); Math & Statistics; and business or domain knowledge as the main areas of skill to define an expert. Universities have responded by creating Data Science or Data Analytics degrees. We have seen the Master of Science in Data Analytics offered by many universities. More than 100 universities offer a Master of Science in data science today.[9] Benefits of additional education in this area are often weighed against the cost of the degree, as well as the fact that curriculum is not homogeneous and often not customizable. Additionally, non-Computer Science (CS) domain knowledge is not gained during the degree but is based on previous studies and relies on the student to build the intellectual bridge between the previous degree and their newly acquired skill set. Other responses for dual domain knowledge are dual degrees in Computer Science and a more traditional STEM degree like a physical science or engineering. These degrees avoid some of the cost issues but challenge the student in developing the practical skills needed in both domains to get a job in the fields of study. Both of these solutions are sub-optimal because they either lack significant depth in one of the two domain/skill areas or they do not show the practical connection between the two with real examples that will be valuable for the individual as they move into their career.

The authors, and others [10], believe that this type of dual domain knowledge, the augmented needs of the students, and the challenges associated with the change in the basic STEM curriculum require new forms of education to augment the existing curriculum. Data Science and Analytics are becoming prevalent in other areas and will continue to push on already burdened academic and industrial education and training systems. We suggest that adoption and expansion of low-cost, complementary forms of education are necessary. Several example of these alternate forms of education include: micro-credentials to augment students' knowledge;[11] amended curricula within academic institutions; and new forms of engagement, including internships. Internships, apprenticeships, and co-ops are some of the most cost-effective ways for industry and academia to collaborate at shaping the educational experience of the future workforce and build long-term skills in environments that will shape the careers of the students. STEM-based internships, co-ops, and apprenticeships are ubiquitous in high GDP economies in places including China, Germany, and Japan.[12-14] There are good lessons from these geographies and others on the importance of such interactions with students, faculty, the university system, industry, and society.

DIGITIAL INTERNSHIPS – CASE STUDY

Our team began a two-recruiting season journey to test the concept of "digital internships" at industrial companies. For the scope of this paper, we describe "digital internships" as internships that are focused on Research and Development projects within the realm of analytics or data science skills applied to physical science or materials applications. The journey was pursued with assistance from AIChE, a technical association with some 60,000 global members. AIChE has launched the ILI to support chemical engineers throughout their careers. ILI provides education and skills to further their progress at every level, in industry and academia, through (1) career discovery and services, (2) education and training, (3) certificates and credentials, and (4) "practice+," which includes internships and opportunities to learn by application.[15]

We used focus groups gathered at ILI to begin a digital internship program during the COVID-19 pandemic in 2021 – 2022. (Figure 1) ILI worked to connect companies with a pool of high-caliber students with chemical engineering, materials science, and data analytics backgrounds for an industrial internship. We intentionally attempted to assess certain variables (by no means exhaustive) to obtain a qualitative understanding of our ability to conduct robust and productive internships. First, we assessed our ability to attract students at the Doctorate or Bachelor degree level. This was especially important at the PhD level where students work year round and are often fully funded. Second, we had students from both Chemical Engineering and Computer Science to determine their interest and delivery in industrial chemical and materials R&D. Third, each of the students was given pre-training coursework customized by AIChE to orient the student for maximum effectiveness (Table 1) moving into industrial R&D. All students were expected to complete the whole of the coursework even if they had previous experience in a specific area. Lastly, 100% virtual versus in-person assignments were utilized due to pandemic circumstances.

In the first pilot trial, we had 20 interns across three different companies. The division of labor was clear. AIChE's ILI provided: (1) a pool of highly qualified PhD and undergraduate interns, (2) training per Table 1, and (3) a virtual community of companies/universities. The company would provide: (1) the selection of interns (from AIChE or self-recruitment), (2) project charters and oversight, and (3) financial compensation for the interns. Additionally, data was collected from students and the host company at the end of the internship to gauge internship effectiveness.

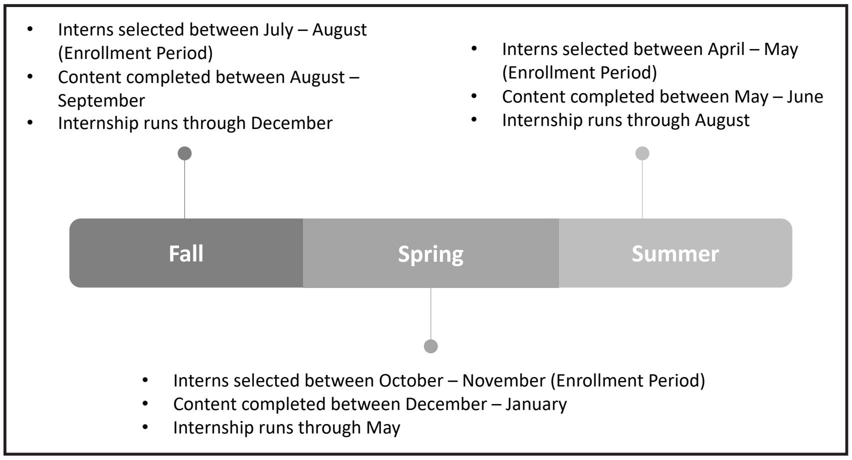

Figure 1. *ILI cohorts for digital internships.*

TABLE 1
Training Modules Customized for the Internships by AIChE

Learning Theme	Activities / Titles
1. Pre-assignment – Designed for Digital 2. Professional Etiquette	1. Designed for Digital (30 min) 2. It's True! You Don't Get a Second Change to Make a First Impression (1 hr) 3. Complete Pre-Self-Evaluation (30 min)
1. Ethics 2. Python Programming	1. A "Virtuous" Approach to Ethics in Engineering (1 hr) 2. Introduction to Python for Chemical Engineers (1 hr)
1. Virtual Networking 2. Python Programming	1. Virtual Networking (1 hr) 2. Python for Chemical Engineers: Getting Started (1 hr)
1. Project Management 2. Data Visualization	1, Fundamentals of Applied Project Management (1 hr) 2. Applied Statistics – Exploratory Data Analysis (1 hr)
1. Critical Thinking 2. Data Analysis with Python	1. Critically Thinking about Critical Thinking (1 hr) 2. Scientific Computing for Chemical Engineers in Python (reading)
1. Completed Work 2. Data Extraction with SQL	1. Completed Staff Work (1 hr) 2. Data Science for Chemical Engineers (reading)
1. Diversity & Inclusion 2. Fundamentals of Process Control	1. AIChE's Improving Gender, Diversity, & Inclusion (1.5 hr) 2. Process Control Considerations in Process Design (1 hr)
1. Process Safety 2. Fundamentals of Statistical Programming	1. Introduction to Process Safety (1.5 hr) 2. Applied Statistics in Research & Development (12 hr)
1. Engineering Leadership Development 2. Introduction to Applied Machine Learning	1. AIChE's Engineering Leadership Development (12 hr) 2. Introduction to Deep Learning: Part 1 (reading)

Experience at Dow

Within Dow R&D, there is a small but growing contingent of Data Scientists and Dual Domain (Chemical Engineering & Data Science) experts as outlined in the Background. However, the need outpaces the demand when it comes to available projects versus the total number of skilled individuals to execute the projects. The value of the internship experience is that capacity can be added to accelerate projects beyond what we're capable of with our current staffing level. Our mentor group helped shape and guide projects to maximize the time the intern cohort spent doing technical development to see the true value of how their skills can be utilized in industry. Some of the technologies explored by the intern cohort and their application to Dow challenges are:

- Development of Models for Thermodynamic Packages
- Development of an Optimization Package for Reactor Network Design
- Comparison of Property Prediction Using Standardization of Data Schemes for Representation of Formulated Systems
- Automation of Image Analysis
- Graph Neural Networks for Formulation Prediction
- Simulation of Tensile Testing of Elastomers using Machine Learning

This list above represents needs in Manufacturing, Process R&D, Formulation Development, Analytical Science, and other areas and shows the breadth of need for our industry as we strive to increase our efficiency and innovation delivery.

Dow's initial cohort was four students in 2021 (Cohort 1). In Cohort 1, the interaction was 100% virtual and all students were at the PhD level and their time was paid by Dow. This was significant as all our students as well as the vast majority of all PhD students in the nation are fully funded by the university or fellowship and are not often granted such a long time away from their PhD program to pursue outside paid opportunities. Thus, success of this program required good coordination with PhD professors at the respective universities to ensure that the internship was valuable to both the student and the company, and that the internship did not disrupt the student/intern's university research progress.

The engagement was facilitated by specially configured laptop devices designed to integrate with the Dow team. For Cohort 1, the students were assigned separate projects with a common theme: the use of machine learning to facilitate chemical formulation for specific industries.

All students took the AIChE specified coursework. This coursework took on the order of 40 hours to complete. Students were assigned to work with a specific R&D team within Dow and a primary Dow contact person from that team. They met daily for 30 minutes to talk about the next steps on assignments. In addition, they attended group meetings monthly and presented their progress. Lastly, there was a broader presentation to interested Dow parties at the midpoint and the completion of their assignment. In the final presentation, students were asked to give feedback on what would be an improvement mechanism to make the assignment more impactful. Assignments ranged between 3-4 months.

All students provided feedback on their experience. A summary of the experience questions of Cohort 1 is shown in Table 2. Since at the time of this writing the detailed score data were no longer available, we report that average scores were between 4.5 – 5.0 in each category, which indicates a good experience.

In addition to the survey questions, students were given the opportunity to provide their own comments. Example comments were:

Positive Comments

My team was full of passionate, knowledgeable members with diverse backgrounds and experiences. I had access to great technologies, like the Tachyon5 HPC, which considerably enabled my work.

Access to seminars and presentations by teams in and out of Dow was enjoyable.

Negative Comments

Technology security measures heavily restricted my and my co-interns abilities to rapidly use the tools we wanted to.

My biggest dislike about the assignment is working remotely. The group has meetings every day and I always received help and feedback on time. However, the communication is not as efficient and it would be great to experience the working environment on-site and meet more people.

The value of this program was obvious to Dow and we expanded our 2022 Cohort 2 to 15 interns. Cohort 2 slightly expanded the domain expertise as well where we had interns who were obtaining PhD's in mathematics and mechanical engineering but with overlap to chemical engineering or chemistry programs at their universities. The 2022 Cohort call was posted on the major job boards and dow.com and received 85 applicants. Of the candiate pool, 43% were women which is above the 29% PhD level availability in U.S. institutions for Chemical & Petroleum Engineering graduates in 2021.[16] This diverse slate of candidates was interviewed by a diverse pool of interviewers, resulting in a final intern cohort of 15 interns with 40% women and 60% men. The universities included: the University of Chicago;

#	Statement
TABLE 2 **Post Assignment Feedback Questionnaire for Digital Interns – Cohort I**	
1	My project was thoroughly explained to me within the first week of arrival.
2	My supervisor provided me with the proper amount of direction and guidance throughout my assignment.
3	My supervisor was available for questions/concerns about the company as well as those related to my project.
4	My supervisor identified and supported utilization of resources/mentors both within and outside my immediate work group.
5	My supervisor made an effort to check on my progress and was responsive to my needs.
6	My department had a good orientation for a new employee (including safety, building tours, introductions, etc.) that was in addition to general "Welcome to Dow" orientation.
7	My assignment utilized my background in training.
8	My project workload kept me busy the majority of the time.
9	I found my individual projects to be challenging.
10	I found my overall assignment to be a valuable experience in preparing me for my career.
Scoring Key: 1 = Strongly Disagree; 2 = Disagree; 3 = Neither Agree or Disagree; 4 = Agree; 5 = Strongly Agree	

Georgia Institute of Technology; University of Illinois; University of California, Berkeley; Michigan State University; University of Michigan; Texas A&M, and more. Additionally, in 2022, we allowed the interns to choose either virtual or on-site in one of our large research sites (Midland, Michigan; Lake Jackson, Texas; or Collegeville, Pennsylvania) and sponsored an all-intern meeting in Midland prior to the end of the internship. These minor changes, enabled by our moving away from the pandemic, allowed us to bring additional Dow functions – supply chain, manufacturing, commercial – together with the intern cohort to better show them the overall opportunity space of the company. All students had separate projects and themes ranging from hybrid modeling (physics-based modeling combined with optimization modeling), process optimization modeling in platforms like AIMMS (AIMMS.com), elastomeric network modeling, integration of machine learning and formulation modeling, advancing chemical and polymer descriptive techniques like SMILES (Simplified Molecular Input Line Entry System), etc. Due to changes in program leadership and management-Cohort 2 was not surveyed as they were in Cohort 1, but instead given informal exit interviews. All voiced positivity in their experience in terms of learning, project challenge, and collaboration with other interns and their Dow partners. The students were most impressed with the full, on-site visit to Midland, Michigan to meet Dow leaders and personally interact with each other and their mentors/coaches. The internship program showed immediate dividends for Dow's hiring as seven interns in total (three women, four men) have accepted full-time positions in Dow starting in 2023. Plans for 2023 are to expand to 40+ interns.

Feedback from Merck KGaA, Darmstadt, Germany

In the case of EMD Electronics (US legal entity for Merck KGaA, Darmstadt, Germany Electronics Business Sector), the initial cohort consisted of nine undergraduate interns. Each intern was assigned to a manufacturing plant located in various regions of the U.S. The interns were aligned to a lead data scientist and also a local manufacturing liaison. In this pilot, the talent need was for chemical engineering majors with data science expertise and co-location of universities closer to the manufacturing plant region (Pennsylvania, New Jersey, South Carolina, California, and Texas).

One of the key challenges for the implementation of Industry 4.0 in manufacturing plants is the combinatorial capabilities of engineering and basic data science. The EMD Electronics business is focused on systematically automating each manufacturing plant, which drives the need for greater data science capability in manufacturing engineering. As described above, this is not necessarily a combined capability that is being developed in a traditional engineering degree. For this reason, the ILI internships were seen as a way to build these skills based on the industry need rather than standard academic degree programs. In 2021, the EMD cohort had nine students and after completion they were surveyed about their experience with the AIChE/ILI training curriculum. The feedback was very positive especially for the professional skills modules. There was some desire to expand the training in Python™ and lower the amount of information in the area of Analytics. This feedback highlights the need to tailor the technical training through ILI to the specific needs of a student or cohort while showing the importance for maintaining the professional skills training (Figure 1) often overlooked in typical university curricula.

One additional need was to identify talent closer to each manufacturing plant, giving the student and company the opportunity to establish a longer term employment once the student graduates. For this region, the initial cohort was selected to be between their third and fourth year of undergraduate study. Several of the interns were then offered and joined full time once they completed their degree in 2022. The intern program addressed the following company needs: (1) recruiting regional talent with chemical engineering and data science skills, (2) building a pipeline of talent for the company, and (3) providing the students to work remotely even after the summer internship was completed. With the success of this pilot in EMD Electronics, the program is now being expanded in 2023 to include the Life Science and Healthcare businesses in the US. The three businesses of Merck KGaA, Darmstadt, Germany span 26 states so this pilot and approach is seen as an important approach to recruiting technical talent in the key area of chemical manufacturing plant automation and analytics.

Digital Internship – Case Study – Summary

The combined experiences of the Dow and EMD Electronics (Merck KGaA, Darmstadt, Germany) interns and employees highight that these emerging skill areas can be quite varied depending on the focus area of the company and the internship program can be an effective way to build "on the job" expertise and mutual success. As traditional domain focused companies (e.g., chemicals, materials, etc.) evolve their R&D practices to incorporate more of the emerging digital capabilities and skills, internships allow them to evaluate which subset of these capabilities are most vital. Additionally, it shows potential candidate employees (students, interns) how their skills can be effectively applied in the field towards important and valuable research efforts. This is a win-win for both industry and academia as they fine tune hiring and training practices, respectively, to meet the needs of a digital future.

DIFFERENT TYPES OF INTERNSHIPS

There are several different ways to conduct internships.

Compensation

From a compensation standpoint, there are paid and unpaid internships. We suggest direct paid internships (versus school credit, etc.) as we feel that this is the relationship that employers will ultimately have when permanent employment occurs. The program decribed herein was paid by the company.

Virtual versus In Person

We believe that both can and must work. When choosing the program or project, consideration should be made for ease of networking within the host company using tools like Microsoft Teams® or CISCO Chat™. We have observed that applications like these are critical in both in person and virtual internships. Contact consistency, with a defined mentor or coach, through daily meetings, weekly summaries and reviews, and monthly presentations are critical in addition to other work-based interactions. In essence, a formal and frequent contact schedule laid over a flexible networking and collaboration approach was found to be vital for a good experience between the intern and the mentor.

Even if a focus is placed on virtual for most/all of the program, opportunities must be provided for in-person engagement with their cohort, project teams, and others in the hosting company. There is no replacement for in-person interactions to help get a true feel for the culture of the company, which is a vital decision criterion as people choose their long-term path. In the 2022 Dow program, all interns gathered for several days at Dow's headquarters in Midland, Michigan to present on their work, meet a variety of leaders, and tour the facilities. This was viewed as a very positive and valuable experience for the cohort. Travel was fully company paid.

Group Projects versus Individual Projects

Our experience suggests that individual, written goals coupled with either individual work or group intern work create positive results. One must keep in mind that the intern cannot have truly individual work. Because of the time frame involved, they must contribute by learning about the goals, previous work, obstacles, and accelerators of the host company. Nevertheless, we have tried both group work and individual work in both the virtual and in-person environments, and both produce good results from our experience.

Intellectual Property

During the program, the intern projects were typically part of larger efforts of the company that extend beyond just the length of the internship. As such, intellectual property considerations (either as patent applications or trade secrets) extend well beyond that which is in control of the intern and careful consideration must be taken when considering what the intern can publish after their internship. The company can find ways to grant release of non-proprietary information to augment the student's dissertation and should identify short and long-term opportunities for co-publishing manuscripts. If a student's contributions lead to a patent application, then the company is obligated to ensure that proper inventorship is granted.

<u>No Pre-training versus Pretraining</u>

Our previous experience with interns outside of these digital pilots led us to partner with AIChE to develop the coursework detailed in this paper. Our observations are that all degree levels that have not had a prior employment experience in STEM benefit from an introduction to baseline technical material that is relevant in their space, and a "soft" skills tutorial with tips, hints, and "must do", and "don't do" for interns allows them to begin the assignment with the right information. A defined and consistent training curriculum also avoids the need to train at the company internally, provides a low-cost methodology to obtain the training background, and ensures that students are dedicated to the program as they cannot begin without this. At scale, the estimated cost for the AIChE training was less than 1% of the overall cost of the internship.

RECAP

Internships are a critical part of any advancement in robust, private sector-government-academic STEM collaboration. When critical needs in evolving skills emerge, ongoing STEM internships offer a low-cost way of both identifying those gaps and filling those needs. Our digital internship program is growing, and our goal is to use it as an example to engage the government and non-government organizations to help build towards the vision of internships for all STEM students within the US.

CALL TO ACTION

Internships are an integral part of the education experience in STEM. We believe that a well-balanced internship should be available for all 800,000 graduates of STEM in the US as an essential part of getting their degree. We advocate for a policy that would drive one mandatory internship for all 800,000 annual STEM graduates in the US at community college, college, and university levels. This would require a massive shift in priorities of academia and industry to focus on the talent profile of students. We estimate that a 3 – 4-month internship for all of these students could be accomplished at a full cost of $20,000 per student or $16B in total. In total, $16B is a significant investment for the country to make, but the financial burden on any one company would be commensurate with their size and revenue (larger companies should be able to accept more interns). Further, a program like the one described herein can allow companies to test their need and readiness for these digital capabilities through a defined, short-term commitment as compared to hiring a full-time employee. Further, on an individual basis, this cost is relatively small compared to the gains in experience, employability of the students, and the diversity of interaction that it stimulates in the STEM area. We suggest that a focus be placed on these dual-domain digital internships as a way to begin this journey.

Academia

Academia would benefit greatly from these STEM internships as it would help shape curricula to ensure students are being educated towards the long term needs of the STEM fields. The US academic community struggles with the ability to engage the private sector, and building collaborations via programs like this can help to improve relationships in areas of mutual interest (between a company and university, for example). These internships would form a consistent and permanent tie to the private sector and a welcome change to companies showing up to interview after 2 – 4 years of a student's time in university with sometimes sporadic interaction at the university/community college setting. Additionally, these internships would help facilitate deep relationships between students and potential employers assisting both in making the best decisions for hiring and career path. Establishing this permanent connection can also lead to other university funding (e.g., R&D funding, etc.), enhanced participation and guidance of industry on curriculum development, and a continuous feedback loop on the quality of students entering the workplace.

Industry

Industry must be a major driving force in making this happen. It is an industry whose skills need to change frequently and they must respond with private training like that offered by AIChE and others (Google® certifications, Coursera courses, in-house training, etc.) or by engaging the private and public universities, colleges, and community colleges. Industry and academia can engage and lobby for federal/state agencies to pay half for qualifying internships. Engagement of the governmental agencies can offset the cost for academia and industry while positioning the US as an innovator and leader in STEM. This would significantly change the cost profile for internships and allow companies to engage throughout the United States in STEM internships.

Government

The government in the United States at the federal and state levels funds state-supported academia but has struggled for years to make binding ties to the private sector. Long-range investment programs like NASA, NSF, DARPA, SBIR, etc. can point to many successes and describe how platforms helped to change industry patterns and technology by funding academia. The funding relationship between the federal and state governments to academia is clear. Public colleges educate 68 percent of all students in the US, and in 2013 they received an average of 21 percent of their funding from state funds and 16 percent of their funding from the federal government.[17] However, the relationships between federal, state, academic institutions, and the private sector are elusive. Ubiquitous STEM internships could improve this relationship and demonstrate a positive impact in a variety of areas.

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