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Developing an International Undergraduate Research Community in College Engineering Programs

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Introduction

Engineering programs in the United States are faced with the problem of decreasing retention rates[1,2,3] that lie in the range of 40-60%. It is known that the United States requires trained engineers, and it has also been demonstrated that gaining a university education is linked to achieving financial success[1].

Based upon research, it is known that high attrition rates in engineering programs are partly due to the programs being theory-focused and lacking a practical, hands-on component that enables students to understand the visualize the relevance of their classroom knowledge[4,5,6,7]. Additionally, the introduction of new, state-of-the-art technology into the learning process can also enhance the educational experience for students.

In this light, this paper briefly describes a hands-on, industry-affiliated, interdisciplinary undergraduate research project involving the use of state-of-the-art technology in an international environment, completed by a junior year undergraduate student in a small, undergraduate, primarily teaching-focused public school that does not have access to significant funding avenues to support research, under the joint mentorship of local and international collaborators. Additionally, a large percentage of students at the authors' university are from economically disadvantaged backgrounds and are first – generation college students that have little exposure to the possibilities open to them in college and thereafter. The research was performed in the laboratory of a prestigious international university, adding a strong international collaboration component to the project. The purpose of describing the project is to expose academics in similar institutions to the scope and level of difficulty of a representative undergraduate engineering research project, and to demonstrate how the process employed in accruing funds for completing an internationally focused undergraduate research project in which the US faculty provided mentorship remotely can be navigated successfully. The results of the research have been published in peer-reviewed journals and academic conferences. The paper concludes by presenting the student's perspective of this research experience, and recommends a process, which is currently in the process of being implemented, in which hands-on research opportunities involving an international collaboration can be formally introduced in a systematic manner into the undergraduate curriculum and discusses the benefits of doing so both to the student as well as to the academic community.

Project Overview

Structural health monitoring (SHM) is emerging as a vital tool to help engineers improve the safety, maintainability, and reliability of critical structures and assists infrastructure owners with timely information for the continued safe and economic operation of their structure. The ten week long undergraduate student –focused research investigation was performed over one summer and determined the effect of specimen out-of-plane movement on the accuracy of strain measurement made applying 2D and 3D measurement approaches using representative, state-of-the-art digital image correlation (DIC) – based tools ARAMIS[8] and iMETRUM[9]. DIC techniques can be used in structural health monitoring by measuring structural strains and correlating them to structural damage. This study was motivated by initially undetected damage at low strains in connections of a real-world bridge (the Storstrom Bridge in Denmark), whose detection would have prevented its propagation, resulting in lower repair costs. This study built upon an initial investigation conducted by the collaborating US and Danish partners that concluded that out-of-plane specimen movement results in noise in DIC-based strain measurements[10,11,12]. In the current investigation, the effect of specimen out-of-plane displacement on the accuracy of strain measurements implementing the 2D[13,14] and 3D measurement techniques using both the aforementioned tools was determined over a range of strain values and specimen out-of-plane displacements. The minimum resolutions of the four DIC-based measurement techniques (2D ARAMIS, 3D ARAMIS, 2D iMETRUM, and 3D iMETRUM) in measuring strains under the effect of specimen out-of-plane displacements were determined and their accuracies compared. Based upon the results of this study, recommendations were made regarding whether it is practical to use these tools in the SHM of real steel bridges within the bounds of out-of-plane displacements that they typically undergo and strains that they generally develop during the course of their service life. The results are in the process of being published (some of them have been published[13,14]).

To start with, the student constructed a specimen made of high-density polyethylene (HDPE), which comprised of a beam cantilevered from a vertical support and consisted of 3 plates[13,14]. This cantilevered beam specimen can be seen in Figures 1 and 2, and is the horizontal grey plate protruding from the vertical column in Figure 2. The main plate was sandwiched between two secondary plates, the three plates being held together using nine high resistance bolts. The secondary plates were welded to a larger vertical plate, which was then mounted to the vertical support (grey vertical column in Figure 2). HDPE was used for the main plate due to its flexibility, since the experiment involved subjecting the main plate to an out-of-plane displacement. Consequently, the specimen needed to be loaded to higher strain values than those in previous investigations by the same research group in which stiff steel connections were studied without the presence of out-of-plane specimen movement, since the out-of-plane specimen displacement in the current study could reduce the accuracy of the DIC technique, possibly resulting in noise and inaccurate readings at very low strains.

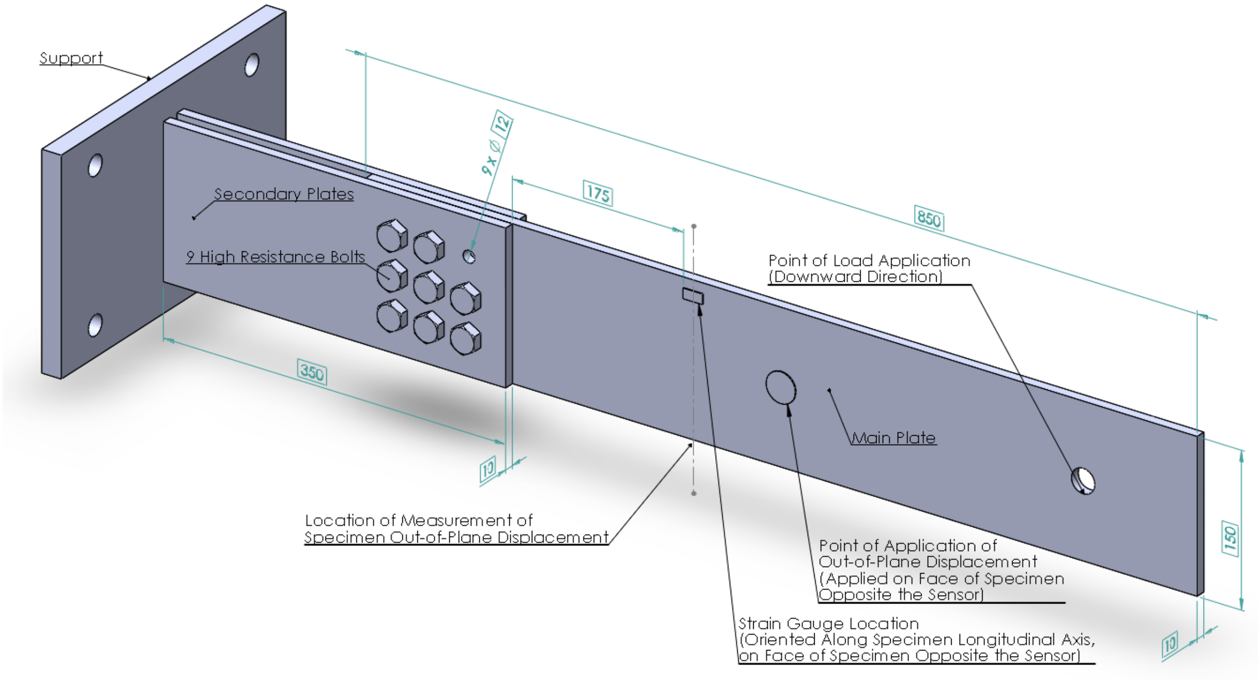

Fig. 1 Drawing of the Specimen (Same Side as Sensor)

Fig. 2 The specimen with the support to prevent buckling (above), with the apparatus to apply the displacement

From the very beginning of the project, the student was forced to confront and tackle unexpected problems and develop innovative solutions to them. For example, during the first test, the flexible HDPE plate nearly buckled under low values of load by twisting out of its own plane (flexural torsional buckling). This was interesting to the student: having studied this concept in the classroom, it was exciting to see this first-hand in a real specimen. Exposure to such classroom concepts in a hands-on environment such as that afforded by this project was beneficial to the student's learning experience. The student independently developed an innovative solution to overcome this problem: to prevent the flexible HDPE main plate (beam) from buckling laterally, it was braced using the system shown in Figure 2. The bracing system was placed vertically above the grey colored main plate, and was also supported from the same vertical column that supported the HDPE main plate. This demonstrated to the student the implementation and design of a bracing system to prevent the collapse of a beam due to buckling. Civil and Mechanical Engineering students learn about bracing systems in their design courses (for example, in an undergraduate course on Steel Design for Civil Engineering students), and observing buckling in real-life helped cement these classroom concepts.

Subsequently, it was learned that the equipment in the laboratory that was initially supposed to be used to apply the out-of-plane displacement to the plate was not available for use. The entire study was dependent upon the out-of-plane displacement being applied to the specimen. Once again, the student was required to think creatively and develop an innovative solution to this new problem. The student developed a convenient method to apply out-of-plane displacement to the specimen by constructing a tool using simple objects that were available in the laboratory. The tool comprised a simple threaded rod, with two nuts installed to allow for the precise movement of the beam, as shown in Figures 3 and 4[13,14]. On turning the threaded rod clockwise in a manner identical to tightening it, the rod pushed directly onto the beam, creating an out of plane displacement of the beam. Using the threaded rod, displacements were successfully applied to an accuracy that lay within ±0.01 mm. A digital caliper was used to measure the displacement. This exposed the student to a practical application of a digital caliper, an instrument that the student had learned about in the classroom, and had briefly used in the "Mechanical Engineering Experimentation" laboratory course offered as a part of the Mechanical Engineering curriculum. Once again, being compelled to develop an innovative solution to a hands-on engineering problem enabled the student to access a reservoir of classroom knowledge and select an appropriate set of tool to solve a practical problem.

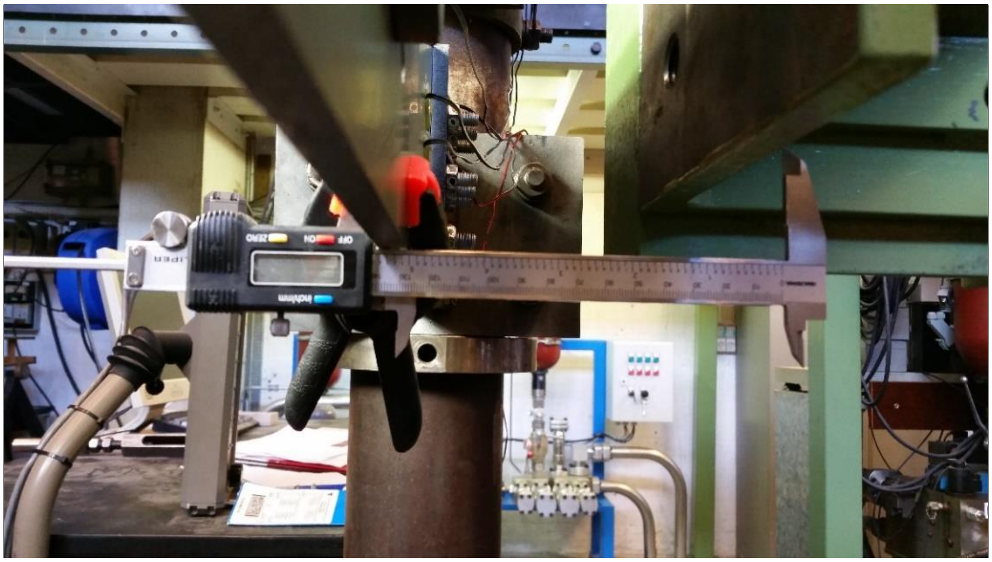

Fig. 3 The caliper to measure the displacements

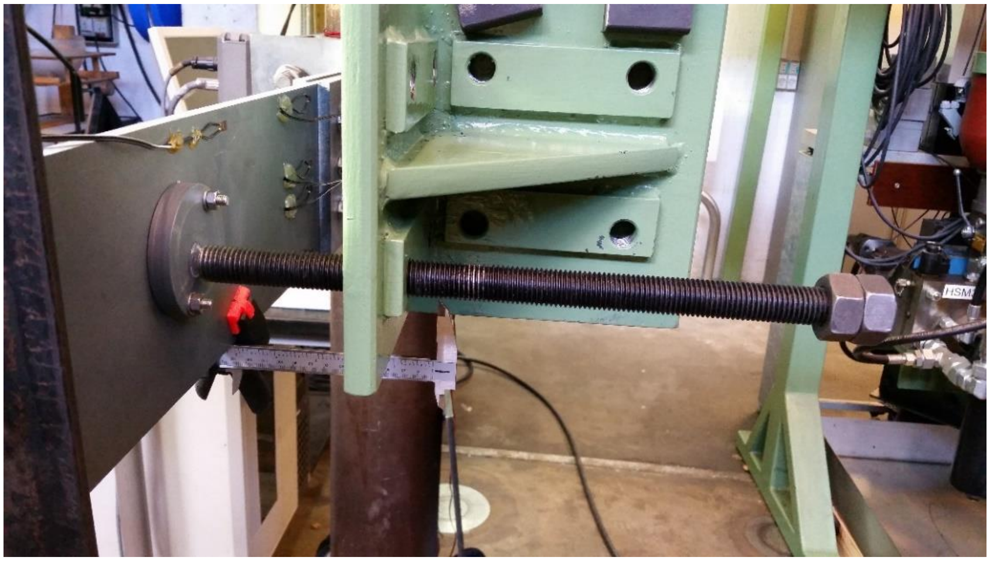

Fig. 4 The threaded rod that applied the displacements by turning clockwise

Following this, the student learned how to calibrate the load cell that was used to apply the load to the specimen. A standard load cell calibration process was used, but the execution of this process was new to the student, who only knew about it from a theoretical perspective. Actually performing the calibration in a hands-on environment cemented the student's theoretical understanding of the process. Additionally, with the faculty mentor's support, the student selected the range of loads that were applied to the specimen during the test. Since the project involved the performance of several tests using the same specimen, it was crucial that the specimen did not yield. Hence, the yield stress of the material was needed. In order to obtain representative values of the stress-strain constitutive relationship of HDPE, the student contacted a company that performed materials tests on HDPE and obtained the values that were used in the current experiment[15]. This process helped the student define crucial components of the overall model of an engineering system: the material and load models. In the classroom, the material models and values of loads that are applied to the systems and structures being analyzed are typically given to students in textbook and exam problems. Being required to define these models exposed the student to a critical step of the engineering process that is not always emphasized in the classroom: defining the engineering system which will subsequently be analyzed.

Specimen strains were measured using the two different DIC-based tools, as well as traditional strain gauges as a reference. This was another interesting aspect of the project for the student since it required the student to independently attach the strain gauge to the specimen and calibrate it as well. Since the output of the strain gauge was in mV and not the standard units of strain (ε) (length/length), the strain gauges needed to be calibrated. The strain gauge that was used was a traditional electrical resistance strain gauge, in a Wheatstone bridge configuration. The process of understanding the calibration process for the strain gauge exposed the student to a deeper understanding of the working of a strain gauge, an instrument that is extensively used in a standard laboratory course in both Mechanical and Civil Engineering curricula. Additionally, the student was typically accustomed to the laboratory assistant or professor's help during laboratory courses. Being alone in a foreign country without help at hand forced the student to independently apply the laboratory knowledge gained via the curriculum.

As in many of the situations described above, the lack of immediately available assistance was a strong motivating factor to the student to push the bounds and tap into his own resourcefulness and potential. This was an uncomfortable, yet rewarding experience. Additionally, the student was required to determine the optimum location on the specimen at which the strain gauge needed to be attached. If the strain gauge was placed at the cantilever's support, it would be challenging to study the effect of the out-of-plane displacement of the beam on strain measurement, because the displacement at the support point is very low. The end of the beam being displaced laterally would have to move a distance that would be too large in order to create a displacement at the support that would be appropriate for this experiment, thereby leading to the possibility of damaging the HDPE beam.

Conversely, as the distance from the supported end of the cantilever increased, the magnitude of axial strains being measured in the plane of the beam decreased, since the point of measurement moved closer to the location at which the load was applied (free end). If the location of the strain gauge was too close to the free end, much larger loads would need to be applied to the free end in order to achieve the entire range of strains being measured in this experiment, once again leading to possible damage of the HDPE or even exceeding the capacity of the load cell. Hence, the final position of the strain gauge was such that it reached a balance between the aforementioned parameters: it was possible to achieve the range of strains desired for this experiment over the range of out-of-plane beam displacements over which the experiment was conducted, without damaging the specimen. By going through this process, the student was once again exposed to a crucial component of the engineering process discussed earlier: defining the engineering model. The classroom experience is usually focused on solving pre-defined problems. This is an essential component of the learning process, but is still incomplete since engineering involves first defining the problem (or engineering system) and then applying a solution process.

Finally, after setting up the apparatus, the student performed the experiment and measured the specimen strain at the location of the strain gauge using both the 2D and 3D DIC-based tools: ARAMIS and IMETRUM. This involved learning how to set-up the tools, how to calibrate a 3D volume for the 3D DIC tests, how to apply an appropriate speckle pattern on the specimen which is required for the DIC process to be implemented, and how to select the optimum combination of parameters (such as lens focal length, distance between camera and sensor, lighting, shutter speed, and duration between successive load increments) to get the best results. This information was unknown to the student as well as the supporting faculty and was obtained by performing a parametric study involving varying the different parameters that influence the accuracy of the results. This process educated the student in the art of performing a parametric study which involves identifying all the parameters that effect the investigation, then tactfully varying each one of the investigation parameters at a time, and finally evaluating the effect of this variation on the results, thereby assessing the effect of this parameter on the accuracy of the results. Additionally, this exposed the student to the use of state-of-the-art DIC-based tools to make strain measurements. This was a very challenging aspect of the investigation, since these were both highly complex and sophisticated tools. The student had no prior exposure to these tools and successfully mastering their application independently resulted in him gaining a boost in confidence and self-belief in his hands-on abilities, as well as his ability to grasp and apply new and unfamiliar technologies. These are essential ingredients that an engineer requires to possess, and engaging in a project of this nature trained the student to acquire them.

In order to obtain good results and master the experimental procedure, the student had to perform numerous tests, which very often involved repeating the identical process over and over again. This exposed the student to another aspect of research: that it can also involve a relatively tedious, mundane and repetitive component that has to be performed successfully in order to get results. However, on completion of the project and obtaining excellent results, the student felt great satisfaction in having gone through the whole process, despite it being occasionally frustrating.

Finally, the student adopted a leadership role in compiling the results into scholarly publications. The student learned about the publication process that involves a rigorous peer-review, the different types of publication outlets (peer – reviewed conference proceedings and peer-reviewed journal publications), and the proper way to write a scientific publication that presents original work. The student also presented the project results at two conferences, one a national conference[13] and the other an international conference[14]. The process of developing the presentation and then presenting the work to a group or academics trained the student to speak in front of a large group of professionals and present his ideas in a coherent and easily understandable manner, and also to provide satisfactory responses to any questions that curious listeners had. This was an invaluable experience for the student and will be beneficial to him whether he chooses to be an academic or to work in the industry after graduation.

The funds for this project were obtained via two sources: 1) The Summer Student Research Award, and 2) The College Administration. The funding was required to pay for the student's airfare to Denmark, his accommodation, food, and conveyance, and other miscellaneous living expenses. The total cost of the project was $7500. Of this, $3000 were supported by the Student Summer Research Award, and the remainder was provided by the College Administration.

The student was recruited by the faculty mentor in the US. The faculty mentor had taught the student in his sophomore year in the course titled "Statics: Basic Mechanics 1", which is an introductory and mandatory core course for Civil and Mechanical Engineering students. The faculty mentor selected the student for this project because he was an active participant in this course and secured an "A" grade. Since this was an introductory pilot study, a formal recruitment process was not implemented. However, the approach of selecting high performing and motivated students from sophomore and junior level classes is a reasonable strategy that can be applied in a formal undergraduate research program based upon the success of this pilot study. The US faculty mentor had an ongoing research collaboration with the international collaborators. This is an important ingredient needed in order to be successful in obtaining the involvement of the international collaborators from prestigious research universities in the project.

The faculty mentor in the US communicated with the student remotely using Skype. Remote mentorship significantly reduced the cost of the project. The success of this pilot project using a cost-saving remote mentorship strategy can be implemented subsequently in a formal undergraduate research program. This is especially useful in smaller teaching focused schools that do not have a large amount of money to spend of research. Since the project was done over summer, the faculty mentor had time available and focused on mentoring and supporting the student in successfully completing this international project. Additionally, onsite mentorship was provided by the international collaborators. However, the common theme was to encourage the student to independently define the course of the project (as far as possible), and develop creative solutions to new problems that arose daily. This assisted the student in gaining confidence in his engineering judgement, and also understanding the fundamental nature of engineering projects, whether in academia or in industry: not all problems are clearly defined from the start, and not all solutions give guaranteed results. Obtaining the optimum solution requires patience and often involves a process of trial and error and involves several failures before the solution is arrived at.

In order to secure the Summer Student Research Award, the student developed a grant proposal with the assistance of one of the authors of this paper. The award was a competitive award. The process of developing a grant proposal was a novel and unique experience for the student. The student learned about the rudiments of proposal writing, which involved describing what the proposed project was about, the motivation behind the investigation, the novelty and significance of the research, intellectual merit of the study, the scientific procedure that would be followed in obtaining the results, and the impact of the research. This exercise will be of benefit to him as a professional in the future. This is typically not a mandatory component of an undergraduate curriculum and engaging in this exercise taught the student about the business side of engineering, and how to sell an idea in order to successfully attract funding. These are useful skills for an engineering professional, whether in academia or in the business world. Additionally, being successful in attracting the funds gave the student confidence in his proposal writing skills.

As mentioned, the second source of funding was the College Administration. This was obtained by meeting with the Dean of the College, to whom the idea of the project and its benefits in the context of: 1) improving the student educational experience, 2) assisting junior faculty in research in a primarily undergraduate teaching focused school, and 3) using the results of this pilot exercise as a basis for attracting external funding in order to develop a systematic, undergraduate, international research program engaging students in hands-on, practical, industry – affiliated projects that have been recommended by researchers in the field of engineering education as an approach to increase retention in engineering programs by demonstrating the relevance of their classroom theory in the real-world of engineering.

The success of the pilot “International Collaborative Research Project” described above has inspired the authors to embark upon the next stage (currently ongoing) of their vision: to leverage the results of the pilot study described above and take it to the next level by developing a proposal to obtain external funding from the National Science Foundation in order to create a formal structure in the engineering school at the authors’ university to provide undergraduate students the opportunity to engage in international collaborative research. The similar approach, structure, and planning employed to successfully execute the pilot project will be translated to successfully developing the international undergraduate research program, if the proposal which is in the process of being written is funded. The success of the pilot project and the peer-reviewed publications co-authored with the student researcher that resulted from it will add validity and substance to the authors' proposal and increase the likelihood of it being funded. The authors briefly describe key aspects of the "Request for Proposals" (RFP) here in order to provide the engineering education community with the information regarding the NSF funding program that supports the development of an international undergraduate research program. This information will be useful to educators in the future that are interested in developing a similar program.

Synopsis of the International Research Experiences for Students (IRES) program[16]: International collaboration in engineering is essential in today's globalized world. The International Research Experiences for Students (IRES) program provides support for U.S. students to conduct high-quality research overseas in collaboration with foreign investigators, exposing U.S. students to the international research community at a critical early stage in their careers. Projects must involve U.S. students conducting research at foreign sites with appropriate foreign expert mentorship. Projects are organized and proposed by U.S. institutions and U.S.-based PI's. Students are also recruited by US PI's. A key feature of IRES is that the primary research mentorship in-country must come from the researchers at the foreign host institution. Each student must have an individual research project for which he/she is responsible. However, the IRES proposals must have a unifying research theme that enables a "cohort" experience for participating students. (In this case: structural health monitoring). Support is supplied for projects of three years' duration, and is expected to support three separate student cohorts during those three years. A typical IRES project supports four or more students per year for a summer-length research experience abroad, not shorter than four weeks. Projects involving larger numbers of students and covering a longer duration are preferred. US PI's are not expected to remain on-site and actively engaged with the U.S. students throughout the period abroad.

Results obtained from a successful execution of a pilot project designed to fulfil criteria that are desired by the IRES RFP can be used to support an application for external funding from this program in order to develop a formal, system-wide undergraduate international research program in engineering. Also, completing a pilot project gives one a better idea of the logistics involved in organizing an international student research project. Some key aspects of the pilot project are:

Research Environment: The research environment should be a supportive one, both in terms of providing student participants with state-of-the-art equipment and infrastructure, and also providing them with high-quality mentorship. Additionally, the research project should ideally be incorporated into an ongoing research collaboration between the US institution and the foreign host. The successfully completed pilot project discussed above fit these criteria since labs at the host international university were equipped with state-of-the-art DIC tools such as ARAMIS and iMETRUM. The research environment there was excellent for work in this area and comprised several international PhD and Post-doctoral students also working in the DIC area. The international mentors and collaborators work in this area, are heading research groups, and offered excellent guidance to the guest US student.

Logistics and cost: Organizing the pilot project clarifies the path to obtaining suitable accommodation, health insurance, travel arrangements, food costs, visas and conveyance for participating students. A good accommodation option that is also safe would involve renting an entire “Airbnb”[17] housing accommodation in close proximity to the university. In the case of the authors’ pilot project, conveyance in the host international site involved a month train pass which could be conveniently renewed. US citizens did not require a visa. Additionally, the IRES program requires foreign host mentorship and does not require US faculty to be present on the international site. The pilot project was performed in this manner, resulting in cost savings and also demonstrating that quality results can be obtained by satisfying the requirements of the IRES program.

The total cost of the pilot project was approximately $7500, and supported one student over a nine week duration. Typically, the IRES program funds projects requesting about $250000. Having being able to successfully complete the pilot project and get excellent results for $7500 provided the authors with a good estimate of the cost that would be incurred in an overseas project for one student over one summer in a representative safe and technologically advanced university located in a foreign country. The IRES program requires at least four students to be part of a cohort each summer for three consecutive summers. As mentioned earlier, larger groups of students working on projects covering a longer duration are preferred. Since a nine week project for one student over summer cost approximately $7500 to produce good results, a 12 week project involving about five students would cost about (1.33*5*7500) = $49875 or approximately $50000. Over a three year period, that results in a budget of about $150000. This provides the opportunity for the program to include a larger cohort, of say 7 students, resulting in a total budget of about $210000 over three years. Since the program typically funds projects asking for about $200000 - $250000, an estimated total cost of about $210000 falls well into the program budget and gives the proposers some flexibility in designing the structure of the project.

Professional development: The pilot project should be designed with a vision to promote the professional development of the student participants. In the case of the authors’ pilot project, the successful implementation of the pilot project has resulted in a collaboration between the US student and the “iMETRUM” company, which supplied the DIC equipment to the lab. iMETRUM provides PhD funding and their representative was impressed with the US student’s work and is interested in the possibility of the US student completing a PhD at the host international university’s laboratory, funded by iMETRUM and focused in the area of product development to improve their product. Additionally, the international mentors were impressed with the US student’s ability, drive, and excellent results. They are still in contact and working on future graduate school possibilities. The US student is very enthusiastic about pursuing his PhD studies and is following up with iMETRUM in order to obtain funding to do his PhD at the host international site. The US student was a first generation college student (as is the case for a large percentage of students at the authors’ university), and was unexposed to the avenues open to him. By participating in this project, a path has opened for him to pursue his long-term goal, which is to become a professor.

Student Feedback

This section contains written feedback from the student-researcher that performed the research project described in this paper. Certain aspects of this feedback stand out, and could serve as useful information for other engineering departments in institutions such as the authors’

institution: predominantly undergraduate teaching-focused schools that serve the needs of financially underprivileged students from the local community:
1) An exposure to hands-on work can serve to motivate undergraduate students to persist in engineering and also pursue graduate school in engineering.
2) Including a project either performed entirely in a foreign country, or in part, can contribute significantly to a student's growth, exposure and development.
3) Hands-on research projects performed independently overseas can significantly contribute toward developing leadership skills, possibly more so than a research project performed locally.

The student researcher's comments are quoted below as a first-person account:

"As a member of a rural community surrounded by cornfields, traveling was not a priority. Most of my friends growing up never left the state of Indiana. Having grown up not traveling regularly and not particularly liking the idea of traveling, being asked to go out of the country alone with limited communication with my friends and family was terrifying. Growing up, attending college was not important to my peers in the region in which I was raised. To add to that, an engineering major was considered to be the hardest major to pursue and to most of my peers, just doing engineering made me unique. Based upon my background as described above, by engaging in an engineering-focused project in a foreign country was going far beyond the limits of what was normal within our community. It made me wonder about what I had gotten myself into.

Despite the apprehensions that I had prior to starting the project, on its completion I was very glad that I had this amazing opportunity. It made me grow in many ways. My classroom knowledge was put to the test and engaging in this project demonstrated to me the value of the material covered in the classroom. When you are sitting in the class room and you are going over these "hypothetical" situations, but when it's time to apply it to the real world, it's like you are a deer in headlights. As I was meeting with my mentor in this unfamiliar land and got to sit and start the process of problem solving on how I was going to get what I needed done, I realized that this wasn't much different than what I was learning in the classroom. One of the important things that I learned was that textbook problems had an exact solution process and answer, but working on an engineering research project did not. After developing an initial path of action, the solution process method was obtained via a trial and error approach in order to figure out the optimum approach to solving the problem.

This exercise gave me a great appreciation for what I had already learned, and has also given me an appreciation for the vast amount of material that I can potentially learn in the future. The value of this research experience was demonstrated in that its completion helped me move ahead of my peers that had not engaged in a research project of this nature. As we were learning new concepts in class, I now already had a background knowledge and hands-on experience with the subjects. This research project was a learning experience that I would remember for the rest of my life.

In addition to the above academic benefits, this project gave me a new perspective on what I wanted to do after college. Previously I only wanted to get into the work force and work in a fairly standard industry job for the rest of my life. This experience changed that. I now have something that I am very passionate about within the engineering field and would like to spend my professional life pushing the limits within this field. This project was a highly motivational experience and its completion has resulted in my deciding that I want to pursue a PhD degree in this field. Furthermore, I am now open to the idea of traveling and actually enjoy it. I now want to work toward enabling me to eventually enter into a professional environment in which I can share my experience with future engineering students.

On returning to the United States, it was my experience that even my peers felt a surge of refreshing interest in what they were studying, based upon my sharing my experience with them. The new knowledge that I acquired made me a leader in my class. My classmates would regularly approached me for assistance and this helped me connect with them. This has given me the confidence that I am capable of achieving my goals. Also, experiencing regular setbacks during the course of the project gave me the confidence not to question each step of a solution process to the extent that I didn't act, but to be willing to try potentially reasonable solution approaches and have the confidence to make modifications if they do not entirely succeed. This experience also gave me the humility along with the confidence to ask questions, even if I feared being ashamed of asking a particular question.

In hindsight, I am truly grateful that this project was performed in a foreign country. If it was done locally in the United States, I might not have pushed myself to the extent that I did overseas as I was alone and out of my comfort zone. Being forced to think independently in a foreign country where not everyone spoke my language resulted in my learning a lot and gave me confidence in my abilities, which working in a familiar environment would most likely not have done. Visiting another country, making new friends there, and being exposed to different ways of thinking has given me a new outlook on life. This project has opened my eyes to the possibility of performing research overseas and potentially impacting and helping people on a global level.

I strongly encourage undergraduate students entering into an engineering discipline to not only do hands-on research, but to do it internationally. In my perspective, the "takeaways" from doing research internationally are priceless and the people you meet are invaluable to you. I would like to thank all those who made this possible."

Conclusions

Engineering programs in the US face the issue of increasing attrition rates at the undergraduate level. One of the reasons for this is that the programs are focused on theory. While a clear grasp of the theoretical fundamentals is essential in order to become a good engineer, research shows that introducing more hands-on work and practical projects involving the use of state-of-the-art technology into the learning experience can assist in increasing undergraduate retention.

In this context, this paper described a hands-on, industry affiliated project performed by an undergraduate student hailing from a teaching-focused institution in a laboratory located in a prestigious foreign university. The successful completion of the project demonstrates how funds were acquired in order to make an international project of this nature possible. A unique aspect of this project was that it was performed in collaboration with and in the laboratory of a prestigious research-focused international university, and provided a first-generation college student from the US in a primarily teaching – focused institution not fully equipped in terms of funds or resources to perform significant research, to perform high-quality research that was published in peer-reviewed outlets. The intent of this paper is to provide institutions such as these with the motivation and overall framework to engage in similar endeavors in order to provide their students with a quality learning experience involving both classroom learning as well as hands-on research.

The paper concludes by describing the next stage (currently ongoing) in the authors' vision, where the authors are attempting to use the success of this project as a basis for developing a formalized international undergraduate engineering research program in their school by soliciting external funding from a program specifically tailor-made for this purpose. This information would be useful to other engineering educators interested in doing similar work.

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