

Global Software Engineering Experience through International Capstone Project Exchanges

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ABSTRACT

Today it is very common for software systems to be built by teams located in more than one country. For example, a project team may be located in the US while the team lead resides in Sweden. How then should students be trained for this kind of work? Senior design or capstone projects offer students real-world hands-on experience but rarely while working internationally. One reason is that most instructors do not have international business contacts that allow them to find project sponsors in other countries. Another reason is the fear of having to invest a huge amount of time managing an international project. In this paper we present the general concepts related to “International Capstone Project Exchanges”, the basic model behind the exchanges (student teams are led by an industry sponsor residing in a different country) and several alternate models that have been used in practice. We will give examples from projects in the US, Germany, Sweden, Australia, and Colombia. We have extended the model beyond software projects to include engineering

projects as well as marketing, and journalism. We conclude with a description of an International Capstone Project Exchange website that we have developed to aid any university in establishing their own international project exchange.

CCS CONCEPTS

• **Software and its engineering** → **Software creation and management**; Collaboration in software development, Programming teams • **Social and professional topics** → **Professional topics** → **Computing education**; Computing education programs, Software engineering education

KEYWORDS

Capstone Project, Senior Design Project, Global Software Engineering, International Collaboration, Software Engineering Education, Industry-Sponsored Projects

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1 INTRODUCTION

In today’s global environment, the need to employ individuals with solid inter-cultural skills and the ability to work across multiple time zones while still efficiently executing a project is a very high priority. Traditional Senior Design/Capstone programs do a great job in preparing University students for a project-based work environment, but fall short in arming them with the skills

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needed for the global environment they will experience in their upcoming professional life. We created an International Capstone Project Exchange program to address this gap and share our experiences on the creation and running of this program. This program alleviates challenges posed by students being unable to live abroad for long periods of time, aids in the identification of partner companies and educational institutions, and optimizes the engagement process.

Our current International Capstone Project Exchange program engages multiple academic institutions and companies from around the world allowing multiple departments (Computer Science, Software Engineering, Electrical Engineering, Mechanical Engineering, Agricultural Engineering, Marketing, and Journalism) to engage in a highly efficient manner. We have setup an International Capstone Project Exchange website (www.ndsu.edu/cs/icpe) to pair universities wanting to join and do project exchanges.

In the remainder of this paper, we will explain the usefulness of this exchange platform. We do so by first explaining the history and rationale behind setting up international project exchanges in section 2. In section 3, we will explain alternative collaboration models in international capstone projects that have been used recently. We will also discuss individual advantages and drawbacks of these approaches. Section 4 will discuss how individual assessments can be done based on group projects. Section 5 addresses some issues associated with international project exchanges. Section 6 explains more details on the Project Exchange Platform before we conclude the paper in section 7.

2 INITIAL EXCHANGE OF INDUSTRY SPONSORED PROJECTS

2.1 History

At the Capstone Design Conference in 2010, two of the authors of this paper, Dr. Knudson from North Dakota State University (NDSU) and Dr. Kleiner from Hochschule Hannover, met informally for the first time. We quickly discovered that both of our universities offered regional capstone projects to final year undergraduate students, and we were both interested in offering industry sponsored international capstone projects. We both felt that having a lack of contacts in other countries was a barrier. During this meeting, we identified a solution - we could each find a local industry sponsor who could provide a project for one of the other's student teams. In this case NISC, in the US, and Inwerken in Germany were paired with Hochschule Hannover

and NDSU cross-nationally, respectively. We each introduced our industry contacts to our partner and their students. After that, all further contacts were done directly. No paperwork or approvals from university administration was required.

The following year, Dr. Sandahl from Linköping University in Sweden and Dr. Knudson from NDSU established a similar pairing. We have continued these international project exchanges at NDSU, Linköping University, and Hochschule Hannover now for seven years.

In 2014 Dr. Knudson from NDSU received an Australian Endeavour Executive Fellowship, which allowed him to visit several universities in Australia. The Australian government was interested in international collaborations between universities and industry and capstone project exchanges were in line with these interests. The resulting contacts have led to several universities in Australia being paired with universities in the US for project exchanges.

2.2 Basic Model

The basic model is illustrated by Figure 1, which might be used as an architectural blueprint for the desired functionality of the Project Exchange Platform.

We have found this model to be very flexible. For example, initially Linköping University paired Ericsson with NDSU. After a couple of successful projects Ericsson had to skip a year as a project sponsor. At that point Dr. Knudson contacted Linköping University once more and Dr. Sandahl found a different company to sponsor a project. In this manner, a sustainable international experience for students in every single year was easily achieved. It quickly became evident that once we had one international capstone project exchange it was easy to set up a second, third or more. Each university looked at their individual needs to determine how many international projects were right for them. (For example, at NDSU in computer science that number seems to be 3-4 out of 21. This allows for a good mix that can also include large multi-national companies, midsize, small and startup companies as well as local, regional and international options giving students a good variety of projects.)

The model has been so successful and well received by students at both Swinburne and Deakin that Deakin University is evaluating opportunities to send students to NDSU to meet the industry partners (clients) face to face for a short period (two weeks). This could be at initial stages of the capstone project - to understand the nature of the requirements and meet the client - or at final stages - as a formal handover procedure. We see this as a once in a lifetime opportunity for students to experience a different working culture and industry during their studies, providing valuable experience for students and enhancing their employability after graduation.

2.3 More Universities Added

Pursuant to the success of the first International Capstone programs and dissemination of the information to industrial partners, we have had several more companies as well as academic institutions join in as the benefit to the students and industry was very clear. To date over seventeen universities have



Figure 1: International Capstone Project Exchange

used the basic model or a variant and over a dozen companies have participated.

Australian universities have been actively participating in the international capstone project exchange program for several years. For example, Swinburne University of Technology joined the program in 2014 sharing capstone projects with NDSU. Over an 18 months period two projects were proposed to NDSU from Australian companies, and one NDSU sourced project was offered to Swinburne. All projects were successful and achieved the set outcomes. In an interesting turn of events, the Software Engineering team at Swinburne (including Dr. Avazpour) moved to Deakin University while the second project sourced by then Swinburne professors was in session at NDSU. The model proved very flexible in this case as well and we encountered no issues or obstacles in the students' progress as the then Swinburne (now Deakin) professors had kept their ties with the company and industry mentors and their move did not affect the remote nature of the collaboration.

Dr. Gingie at Western Sydney University of Australia has been involved in the capstone program since 2015 through the school of computing. While the initial engagement with Southern Georgia was successful, the partnerships fell-apart in the years 2016 and 2017, due to coordinating staff changes in the universities in the United States. However, at Western Sydney we are revitalizing the international capstone projects with Professor Kalafatis (Texas A&M), and Dr. Gupta (NCSU) in 2018. In these new partnerships, we expect to explore working with capstone programs where program structures differ (e.g. one semester vs. two semester based projects). Also, similar to the efforts at Swinburne and Deakin, at Western Sydney we are exploring the possibilities of having student exchange and collaboration models, between universities in northern and southern hemispheres.

The Texas A&M Qatar campus provided a low barrier of entry for testing the International Capstone Paradigm. In the past, students would visit each other's campus, but did not work on the same projects remotely. This was a missed opportunity that was quickly addressed by setting up initial cross-site projects. Note that these were HW-SW projects, i.e. spanned the gamut of development.

3 ALTERNATIVE METHODS

3.1 Joint Development/Distributed Teams

The model we use at Texas A&M, ITCU and TAMUQ is one of 4 person teams where 2 students reside locally and 2 abroad. At least two project ideas are provided to the teams, and the teams and their mentor pick the one that best fits their skillset. This model, which we are using at Texas A&M (for example paired with Institute of Technology Cluj-Napoca, Romania via National Instruments, as well as Texas A&M with TAMUQ), is used in the majority of projects. The benefit of this approach is that the students not only gain cultural interaction learning, but they are also exposed to time zone difference challenges as well as tools that can be used to interact with team members remotely.

Dr. Kleiner at Hochschule Hannover, Germany, and Grand Valley State University, US, have been using a model with joint student development teams. At the beginning of the semester students

submit their own project ideas and in a second round vote for their favorite project ideas. The ideas getting the most votes are selected and joint student teams consisting of two German and two US students are formed to work on the project. Project organization over the semester is pre-structured by the instructors with fixed sprint deadlines and deliverables.

This model has proven very successful as well, as students learn how to work on real international teams. They also experience the difficulties associated with that, such as time zone differences, lots of schedule conflicts, higher and lower student involvement. Team formation has also proven difficult for some teams as there is no face-to-face kickoff opportunity. Whereas earlier project teams tended to achieve very high quality results, we observed a higher number of organizational issues on the teams and higher mid-semester dropouts recently. Since absolute numbers of participants are small, it is too early to draw general conclusions from that now. A general drawback of this model is the lack of a real-world customer for the project ideas.

3.2 Subcontract a Portion of a Larger Project

It is quite common that a capstone project is a sub-part of a larger system. One scenario is that capstone projects build on previous capstone projects by adding more functionality or components such as a graphical user interface for non-expert end-users. This is feasible if the documentation and testing of the previous projects are accurate. We have linked up to three projects sequentially at Linköping. A related scenario is when the company is developing a product and delegate one or several components to capstone projects. One year, at Linköping University, we had two projects working in parallel on the same company project.

In both scenarios, companies need to make sure that necessary requirements are correctly understood by the students to make the projects compatible. As show in the section above, an international repository of projects might facilitate more parallel development. Alternatively, companies can setup competing projects around the world. This is especially valuable if the goal of the company is to explore different possible solutions and/or are more interested in getting the students' creative input to their products.

Steve Zahos from the Agricultural and Biological Engineering Department at the University of Illinois recently sought an international partner for their undergraduate capstone program. A meeting with the Dean of Engineering at Universidad del Norte (Uninorte) in Colombia at the Colloquium on International Engineering Education in November 2016, soon established a relationship between Illinois and Uninorte.

A project with a US grain storage bin company was obtained. Four Illinois engineering students were the lead team and a team of four mechanical engineering students at Uninorte acted as a subcontractor. Day to day communication with the client was done by Illinois. Weekly teleconferences with the Uninorte and Illinois teams were held. The teams did not travel to their partner campuses. The client wanted a design for housing a certain mechanism for transporting grain from a bin. The client provided

parts, drawings and mentoring. The Illinois team provided overall project management, component fabrication and prototyping. The Uninorte team provided detailed calculations and drawings to the Illinois team. Electronic presentations were made between teams and between Illinois and the client. Faculty mentors worked with their respective teams. The project was completed on time and under budget and provided the client a strong foundation to take the work done into their own engineering and product development process.

Factors which contributed to the success of the experience included: everyone spoke English very well, there was only a one hour time zone difference, and Uninorte has much experience in international collaborations. Lastly, the faculty involved at Uninorte obtained engineering degrees in the US and so were aware of capstone and how it works.

Our Capstone project at Uninorte, in Colombia, involves two main concepts that help students in these collaborative projects: the first element is the adoption of a project management methodology (such as that of the Project Management Institute) that includes scope management, budgeting, scheduling, stakeholders' management and communications. The second element is the development of the engineering design process that considers conceptual, basic, and detailed design phases with very specific deliverables in agreement with UIUC team and the client. The conceptual design phase develops multiple alternatives with the best alternative being determined according to multiple criteria such as cost, reliability and environmental impact. The basic design phase studies best alternatives and includes engineering drawings, calculations, bills of material, budgets and implementation schedules. The detailed engineering phase involves the full design of a main component using design tools acquired to that point. The deliverables of this phase include detailed engineering calculations, drawings (CAD), FEM analysis, simulation and prototyping.

We will continue the Uninorte (Hugo Caballero) and UIUC (Steve Zahos) collaboration in capstone projects with a Colombian manufacturer of agro-industrial machinery (Hugo Caballero) as client in Spring 2018. This company will propose some candidate projects of interest and the faculty mentors of Uninorte and UIUC will adopt the most suitable project. Both programs are accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org>, so this collaboration is an important element for providing students with an appreciation of engineering in a global context. In August 2017, Dr. Gorder and a capstone engineering design team from the Mechanical and Aerospace Engineering program at the University of Colorado Colorado Springs (UCCS) was paired with Dr. Detterfelt and a student formula competition team at Linköping University. In this model, we have the Linköping students serve as the international customers for the UCCS design team.

The Linköping formula student team was founded in 2010 and has competed internationally with 5 different vehicles, performing all of their design, build, and test work outside of school hours and without the assistance of school professors. As with any product development team, desired improvements to their current car were identified, but, due to the aggressive schedule necessary to

get a car ready for competition in a given program year, it was recognized that those improvements would have to wait for subsequent development years.

This year, the UCCS capstone design students are working as a contracted design team to the Linköping formula team to design enhancements that the Formula Student team would like to incorporate into next year's competition vehicle. The UCCS capstone design students worked with the Linköping formula students to develop an appropriate engineering design specification for two different projects: an improved adjustable pedal box, and an automated drag reduction system. This model provides a unique opportunity for both sets of students. The UCCS capstone students are afforded an opportunity to work for an international client, with the complications inherent in those interactions, and the Linköping students get a chance to work on the other side of the equation, defining and managing expectations in order to receive the desired outcome.

Mikael Roos at Blekinge Institute of Technology in Sweden has a team of three students doing web development for a customer in Fargo, ND USA. The Swedish team is a distributed team. All team members are located in different physical locations and communicate through chat and emails. They collaborate on the development using tools suited for distributed team work and development.

3.3 Exchange of Research Oriented Projects

This model has not been executed yet, but the exchange between UNSW and Stavros Kalafatis at Texas A&M has led to discussion of future areas of research (ex: IOT, sensor development) that would build upon the current University to University project co-development model. There are some academic areas where industry sponsored capstone projects are not common (e.g. biology). In these cases, it may be desirable to exchange professor-sponsored research projects. While most of the international projects co-developed so far have been at the undergraduate level, the connections with both the academic institutions as well as international companies have indicated that graduate level research projects could also be addressed.

3.4 Non-engineering Project Exchanges

We are investigating ways to expand the program beyond engineering. As a starting point, Dr. Seegebarth at TU Braunschweig (Department of Marketing) plans to use the basic model. Therefore, a partner in the US finds a company that is paired with a 4 person team of German graduate engineering students, who work on a topic in the field of international marketing. In particular, students work on a market research project for a US company, where they have to analyze consumer (buying) behavior in the US and Germany. With a company-specific research question in mind regarding to international consumer behavior and in close collaboration with the US partner, students are asked to carry out a survey. After collecting data from the relevant consumers, students use multivariate data analysis to extract meaningful information on consumer (purchase) behavior for US vs. German consumers or segment-specific behavior for relevant target groups from the data. Based on these findings

managerial implications for the US partner are derived to answer the initial research question. From an international marketing perspective, students therefore need to consider cultural differences regarding US consumers' awareness, motivation to buy and buying intention toward the specific brand/product under consideration compared to German consumers. A face-to-face kick-off (via Skype or equivalent) is planned to familiarize the student with the company and respective conditions regarding the topic they are working on. Frequent meetings are planned throughout the semester to ensure the support of the US exchange company and tracking the progress of the work. Finally, students will present their deliverables in a joint seminar.

4 CAPSTONE PROJECT ASSESSMENTS

Capstone project assessment can be quite challenging due a number of reasons. Firstly, the heavy group activity nature makes it important to have mechanisms in place to grade individual students in a group setting. Secondly, certain projects would involve students from varying disciplines needing to meet differing learning outcomes. In this situation, it is imperative that assessment-instruments are equipped to evaluate both the quality and quantity of contributions of individuals. In addition, the perception of the success of the outcome of the project varies depending on whom (students, sponsors, coordinating academics, and mentors) you ask. Therefore, it is imperative to have the all viewpoints taken into consideration in the grading process.

Due to above mentioned complexities associated with capstone project assessment, Dr. Ginige at Western Sydney University, has developed and tested an individual marks calculation tool. The tool allows individual marks to be calculated with input from the student peers, sponsoring organization, the supervising academics and input from other academics closely associated with the project, such as the partner academics from the partner university. Currently, the tool is being implemented as an online system. In the future, the online system could be enhanced for general use of any capstone program coordinator and linked with the International Capstone Project Exchange portal developed by NDSU.

5 ISSUES

Navigating the IP ownership barriers is one of the challenges that Texas A&M and others of us have been dealing with, especially with countries that are under IP and technology restriction regulations. Higher level agreements (i.e. at the University level) seem like the preferred path to address these issues, otherwise individual professors are not able to work with each other. Industry sponsor challenges are similar, especially when the company is headquartered in the nation that has restrictions imposed on it. In the case where the company is based in the US and has an international branch, the issues of information flow have been to a large degree ironed out and thus the process is easier.

One area we are having some initial issues with is pairing a university that has mandatory funding requirements (e.g. all sponsors are required to pay \$10,000 USD for a project). This is

much more common in the US and with ME in particular. More work needs to be done to make this kind of exchange work easier. Shifted academic schedules as well as differing Senior project milestones pose a challenge that needs to be discussed up front especially with respect to deliverables and timelines. In the experience of Texas A&M with TAMUQ (for example), these early misalignments were easily addressed over 2 meetings and clear identification of local team mentors who ensured that deliverables were tracked and students had local support as needed. All 3 projects executed in the past 2 years have been successful, with one winning #1 spot in a senior project competition in Doha, Qatar.

6 HOW TO JOIN THE INTERNATIONAL CAPSTONE PROJECT EXCHANGE

We have had great success with this program and hope to continue to grow it so that students around the world can gain international project experience.

6.1 How the Exchange Works

Universities can request to join the International Capstone Project Exchange at www.ndsu.edu/cs/icpe. Once the university is registered, the faculty facilitator can request to be paired with a university in another country that is working with students in the same or a complementary discipline. That university will find a company to sponsor a project for your students, and you will find a company to sponsor a project for their students. The exchanges, however, are not required to run at the same time. Project timelines are based on each university's academic calendar. The exchange is open to any discipline. Current projects are in computer science, mechanical engineering, ag and bio-engineering, international marketing, and journalism.

7 CONCLUSIONS

When students today enter the workforce they are likely to encounter the need to work in multi-national teams. Working on a capstone team led by a mentor/sponsor in a different country provides the experience they will need and that employers are looking for. The international capstone project exchange model is an easy way for universities to establish the relationships needed to provide this kind of experience. A website has been set up to aid in pairing interested universities. It provides easy access to help in finding a partner in a different country interested in project exchanges. There are several models of how exactly the pairings/exchanges can be done ranging from finding local sponsors for independent projects to subcontracting parts of a project to joint development teams.

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